

CLEAN AIR CATALYST

Opportunities to Reduce Air Pollution from Industries in the Indore Municipal Corporation Area

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Table of Contents

1. Introduction	4
2. Brief on Industrial Source	6
2.1 Primary survey	8
2.1.1 First phase	8
2.1.2 Second phase	10
2.2 Baseline of emissions in IMC area in 2019-2020	10
3. Recommendations	15
3.1 Recommendation 1: Replacement of the ordinary burner with the swirl burner in reheating furnace	15
3.2 Recommendation 2: Reduction of steam pressure in boilers	16
3.3 Recommendation 3: Automatic blowdown control in boiler	17
3.4 Recommendation 4: Controlling excess air to an optimum level	17
3.5 Recommendation 5: Transitioning from coal-based baby boiler/TFH to electrified boiler	19
3.6 Recommendation 6.1: Efficient operation of the existing APCDs	20
3.7 Recommendation 6.2: Installation of flue gas desulfurization	20
3.8 Recommendation-7: Transitioning from coal to natural gas: A transitional energy shift	21
4. Way Forward	29
4.1 Energy benchmarking	30
4.2 Pilot and technology demonstration platform	30
4.3 Energy audit program	30
4.4 Energy saving targets	31
4.5 Financial and technical support to reduce emissions	31
4.6 Creating awareness and training on EE, energy monitoring, and efficient operation of APCDs	32
4.7 Key stakeholder engagements	32
4.8 Benefits of Udyam Registration	33
4.9 Schemes for MSMEs across India	33
4.9.1 Schemes on credit and financial assistance	33
4.9.2 Schemes for skill development training	35
4.9.3 Schemes for infrastructure development	35
4.9.4 Schemes for technology upgradation	35
4.10 Gender-responsive approach	36
5. Conclusion	37

Table of Figures

Figure 1: Overview of solutions narrowing process	5
Figure 2: Location of air polluting industries in IMC area (Data source: MPPCB)	6
Figure 3: Industrial cluster-wise distribution of air polluting industries	7
Figure 4: Product-wise distribution of industries surveyed	8
Figure 5: Distribution of operational industries in the survey, based on fuel-to-energy conversion device	9
Figure 6: Distribution of operational industries in the survey, based on fuel consumption (Furnace Oil (FO), Piped Natural Gas (PNG), Low density oil (LDO)	9
Figure 7: Industrial cluster and product-wise estimated PM _{2.5} emission	10
Figure 8: Industrial cluster and product-wise estimated PM ₁₀ emission	11
Figure 9: Industrial cluster and product-wise estimated SO ₂ emission	12
Figure 10: Industrial cluster and product-wise estimated NO ₂ emission	13
Figure 11: Industrial cluster and product-wise estimated CO emission	14
Figure 12: Summary of utility and technology-specific recommendations for energy and air pollution reduction	15
Figure 13: Recommendations-wise PM _{2.5} emission in Indore from 168 air polluting industries	27
Figure 14: Industrial cluster-wise PM _{2.5} reduction through various recommendations	28
Figure 15: Potential paths for the future	29

Table of Tables

Table 1: Size-wise distribution of air polluting industries located in different industrial clusters	7
Table 2: Fuel-wise calorific value	23
Table 3: Summary of recommendations	24
Table 4: Recommendation-specific PM _{2.5} emissions in Indore's industrial cluster	28

1. INTRODUCTION

The Clean Air Catalyst (CAC) seeks to design and advance clean air actions that address the underlying drivers of pollution and deliver clean air along with the co-benefits of climate, health, equity, and gender.

The CAC is being implemented as a pilot in three cities – Jakarta, Indonesia, Indore, India, and Nairobi, Kenya – and partners with local teams and stakeholders to implement clean air actions. As part of the source awareness process in each pilot, the first step is to collect data so that the sources of air pollution, which are the most compelling to address, are identified. This is followed by the solutions process in which a root cause analysis is conducted. A longlist of clean air actions that address the root causes of air pollution is prepared. These actions are grouped into three broad categories – public transportation, waste burning, and industry. Three actions that are most impactful and implementable (based on political feasibility and a “cross-cut” analysis of the impacts on climate, gender, equity, and health) are then shortlisted. As part of gender diagnostics, data and information is analyzed to understand the gendered impact of air pollution, while identifying any disparities or inequalities that may exist. Of the three shortlisted actions, one or two are selected as the focus of a Solution strategy paper that outlines the clean air actions that the CAC will work to implement with the support of a coalition of relevant stakeholders. The remaining shortlisted actions are detailed in Solution Strategy Papers that outline recommended actions that other parties can choose to implement.

Working in three different cities has necessitated the CAC to adapt its approach to the context of each pilot while continuing to remain committed to its fundamental goal. Its work builds on the progress that other actors have made in addressing air pollution and offers new and intersectional perspectives to the air quality, climate, and gender spaces. The CAC hopes to encourage continued action in the pilot cities while simultaneously inspiring other cities to utilize its approach.

In each pilot, the CAC works closely with stakeholders to understand and complement existing ideas and initiatives and remain in close touch with the political and economic realities of implementing clean air actions.

The CAC approaches clean air action in a way that addresses the root causes of air pollution. Clean air action refers to an identified change that stakeholders in a community can make, to transition from the status quo to a state that will result in reduced emissions or reduced exposure to pollution. The change does not have a specific definition. It could range from a regulatory fine on driving a vehicle with an outdated exhaust system to a change in building codes that improves passive cooling in buildings, reduces the need for energy-intensive air conditioning, and limits the need for coal-powered peaker plants in a community. A clearly articulated justification for how the intervention intends to lead to emissions reduction or reduced exposure is the necessary criteria for a clean air action. The indicator measures the intent and potential impact of an action. In case an action is not implemented within the project duration, it does not get disqualified as an indicator.

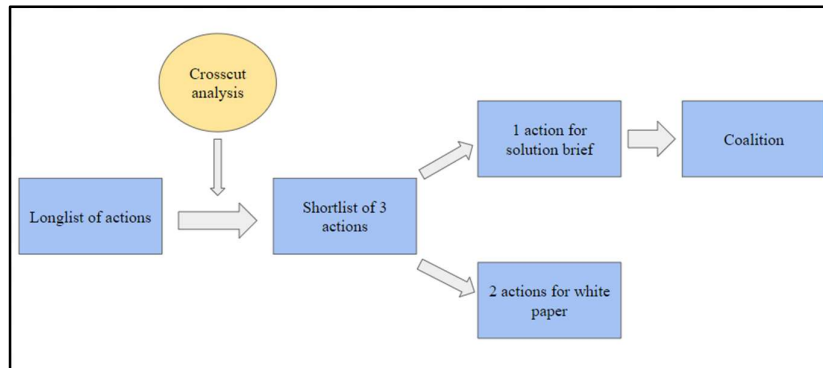


Figure 1: Overview of solutions narrowing process

The three clean air solutions sectors shortlisted for Indore are transport, industry, and waste burning. Transport is the focus of the coalition and the Solution Brief, while industry and waste burning are the focus of Solution Strategy Papers. This Solution Strategy Paper describes the root causes of air pollution in the industrial sector located in the Indore Municipal Corporation (IMC) and the mitigation strategies. It comprises three parts:

1. Identifying root causes
2. Developing solutions at the city and ward levels
3. Outlining ground-level implementation and impact

The Solution Strategy Paper proposes a roadmap to implement the actions recommendations for the industrial sector. Selected excerpts and/or derivative products of the Solution Strategy Paper will be disseminated among stakeholders in order to build awareness of the solutions and as part of the engagement and advocacy strategy.

2. BRIEF ON INDUSTRIAL SOURCE

According to the CAC's estimations based on the Indore Emission Inventory, the industrial sector is one of the major air pollution contributors (11% of the total particulate matter 2.5 (PM 2.5) emissions). The two major source of industrial emissions are the combustion of fuels in boilers for the production of thermal energy and thermic fuel heaters (TFH) used for manufacturing and processing products. Indore is home to several industries, including those that manufacture plastic goods, pharmaceutical products, drugs, leather goods, stainless steel kitchenware, and iron goods as well as milk processing plants, vegetable oil refineries, and real estate development for commercial, residential, and industrial areas and warehousing businesses (MPPCB Indore, 2010, 2018). Coal, wood, furnace oil, piped natural gas (PNG), and agricultural residue are the commonly used fuels in these industries.

The Indore regional office of the Madhya Pradesh Pollution Control Board (MPPCB) has identified a total of 168 air polluting industries operating in various areas of the city. Of these, 75% are located in Sanwer Road (Figures 2 and 3). Based on the total investment criteria, these polluting industries are divided into three categories, namely small (<₹10 crore) , medium (<₹50 crore), and large (>₹50 crore). There are 146 small industries , 21 medium industries, and 1 large industry. Table 1 presents a map of the polluting industries in the IMC area.

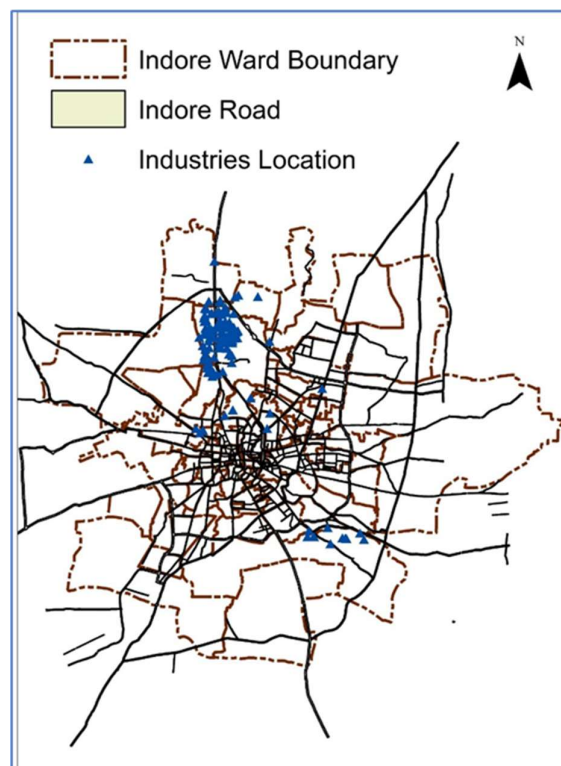


Figure 2: Location of air polluting industries in IMC area (Data source: MPPCB)

Table 1: Size-wise distribution of air polluting industries located in different industrial clusters (Data source: MPPCB)

Industrial Area	Small	Medium	Large	Total
Sanwer Road	113	13		126
Mangaliya Road	4	5		9
Palda	6		1	7
Pardeshipura	5			5
Pologround	4	1		5
Laxmibai Nagar	4			4
Bhagrirath Pura	1	1		2
Kumhedi	2			2
Lasudia Mori	2			2
Others	5	1		6
Total	146	21	1	168

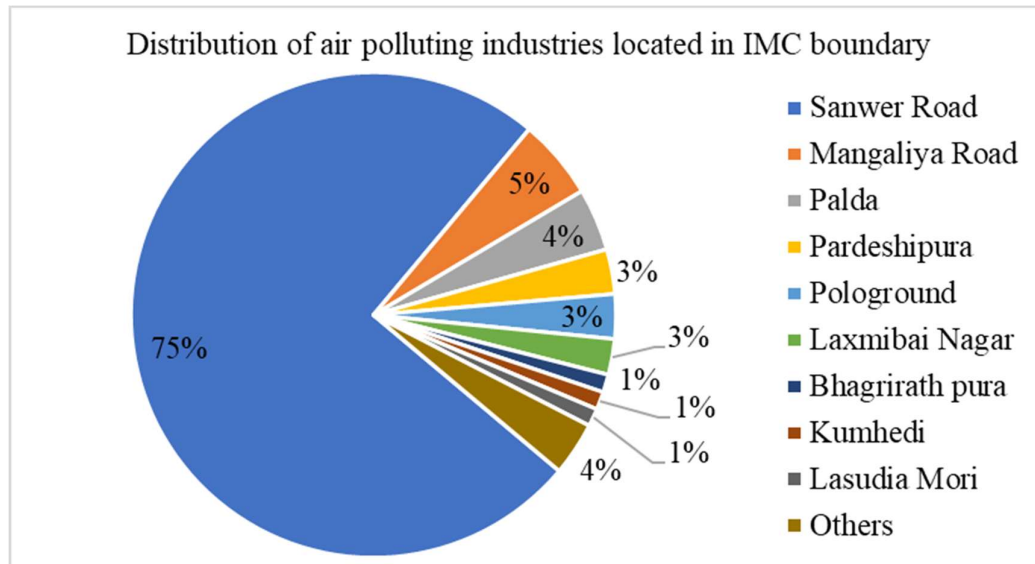


Figure 3: Industrial cluster-wise distribution of air polluting industries (Data source: MPPCB)

2.1 Primary survey

A primary survey was conducted in two phases. In the **first phase**, the baseline of air pollution emissions was calculated. In the **second phase**, sector-specific data related to mitigation solutions was collected and an implementation plan for reducing air pollution emissions was developed.

2.1.1 First phase

In September 2022, a primary survey of 44 industries was conducted to understand the type of fuel consumption and production, type of products, working hours, and availability of Air Pollution Control Devices (APCD). These would help verify the MPPCB data. The research tool was a questionnaire that was used to collect data on specific activities from industry representatives. The data that was collected included the type of fuel used, APCDs utilized, number of employees, number of female employees, stack height, working hours, and other relevant factors. Of the industries surveyed, 39 were functional and 5 had closed down. Approximately 50% of the industries surveyed in IMC were found to be part of either the pharmaceutical, medical, or metal sectors (Figure 4). In addition to these sectors, other manufacturing industries, such as food products, rubber, chemical production, and plastic manufacturing, were also found to contribute significantly to the consumption of fossil fuels in IMC.

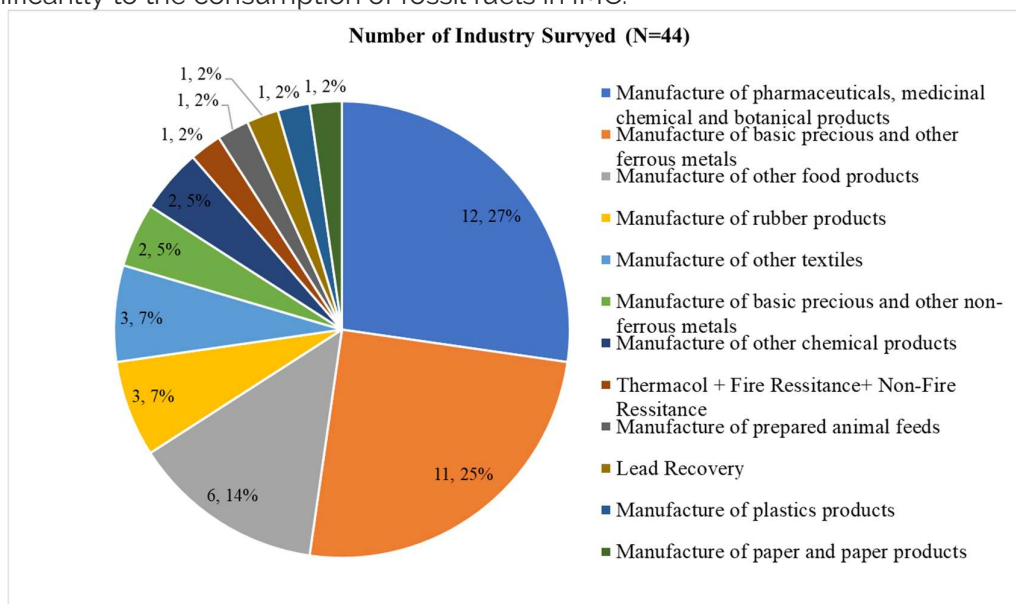


Figure 4: Product-wise distribution of industries surveyed

Types of fuel and fuel-to-energy conversion units in the IMC area

Figures 5 and 6 present the types of energy conversion units and fuels used in the IMC area, as per the primary survey. Various heating equipment is used in these industries, depending on the manufacturing processes, such as boilers, thermic fluid heaters, and furnaces (Figure 5). Industries are typically dependent on fossil fuels. The survey found that approximately 50% of the industries use boilers while 30% rely on a furnace. Coal was found to be the most used fossil fuel across industries. Metal industries are known for their high consumption of fossil fuels. About 75% of these were found to be using coal-based furnaces (Figure 6).

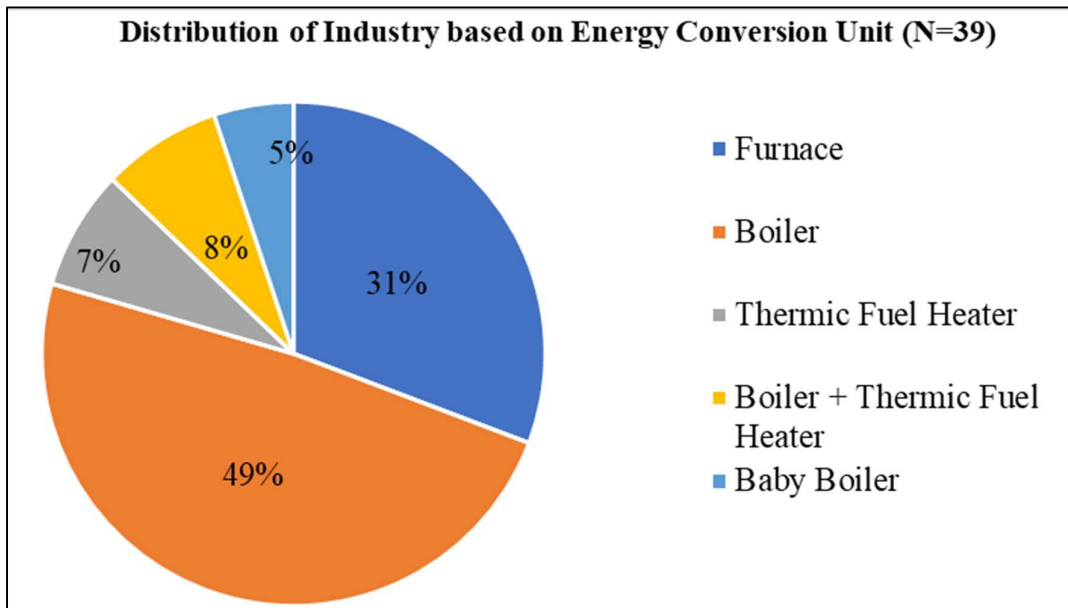


Figure 5: Distribution of operational industries in the survey, based on fuel-to-energy conversion device

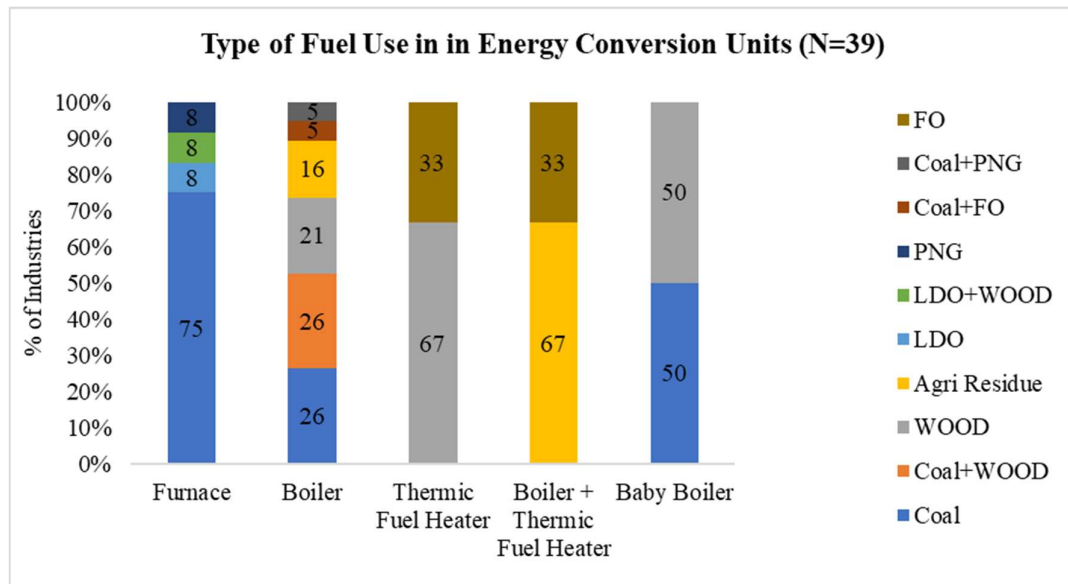


Figure 6: Distribution of operational industries in the survey, based on fuel consumption (Furnace Oil (FO), Piped Natural Gas (PNG), Low density oil (LDO))

In the first phase of the primary survey, significant insights were gained on the workforce. In the pharmaceutical and medicinal products sector, which encompasses 11 industries, an average of 82% of the workforce comprise men, contrasting sharply with 18% women. Conversely, in industries such as metal casting and rubber product manufacturing, there is a noticeable gender imbalance in favor of men, with women representing only a minimal proportion of the workforce. However, there is a stark contrast in sectors including textile manufacturing and paper product manufacturing, where constitute 100% of the workforce. These findings throw light on the diverse gender dynamics in the manufacturing industry, highlighting both disparities as well as instances of more equitable representation. A detailed gender impact assessment for the sector cannot be made because gender-segregated data on any other parameters could not obtained in the survey.

2.1.2 Second phase

As part of the second phase, a primary survey for a solution design was conducted, in which 35 industries from different sectors were identified to obtain the process parameters (type of heating instrument, operating conditions, etc.). The objective was to understand the sector-specific challenges in air pollution reduction, the solutions, and the potential for reduction. However, attempts to reach out to the industry through several channels as well as outreach efforts failed. No data could be obtained on account of the reluctance of the industry. Therefore, the estimates presented in this report are based on the data provided by MPPCB and the primary survey conducted in the first phase.

2.2 Baseline of emissions in IMC area in 2019-2020

Based on the survey and data provided by the MPPCB, industries were segregated on the basis of area and type of product manufactured. Further, estimations were made of emissions of particulate matter (aerodynamic size $< 2.5\mu\text{m}$) ($\text{PM}_{2.5}$), particulate matter (aerodynamic size $< 10\mu\text{m}$) (PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO) from these industries. Also, the industries were categorized on the basis of the type of products manufactured, using the National Industrial Code (NIC), followed by estimations of the pollutant emissions.

Figure 7 presents the industrial cluster and product-wise distribution of $\text{PM}_{2.5}$ emissions. As per the estimates made in this survey, the total $\text{PM}_{2.5}$ emissions is 492 metric tons per year (MT/yr). Of this, 77% is from the Sanwer Road industrial area, followed by Manglia Road (14%), Palda (3.8%), Shinath and Laxmi Bainagar (1.3% each), and other areas (2%).

As can be seen in Figure 7, the highest product-wise $\text{PM}_{2.5}$ emissions are from food product manufacturing industries (23%), followed by basic metal (20%), oil and fat manufacturing industries (15%), and the remainder is from other industries.

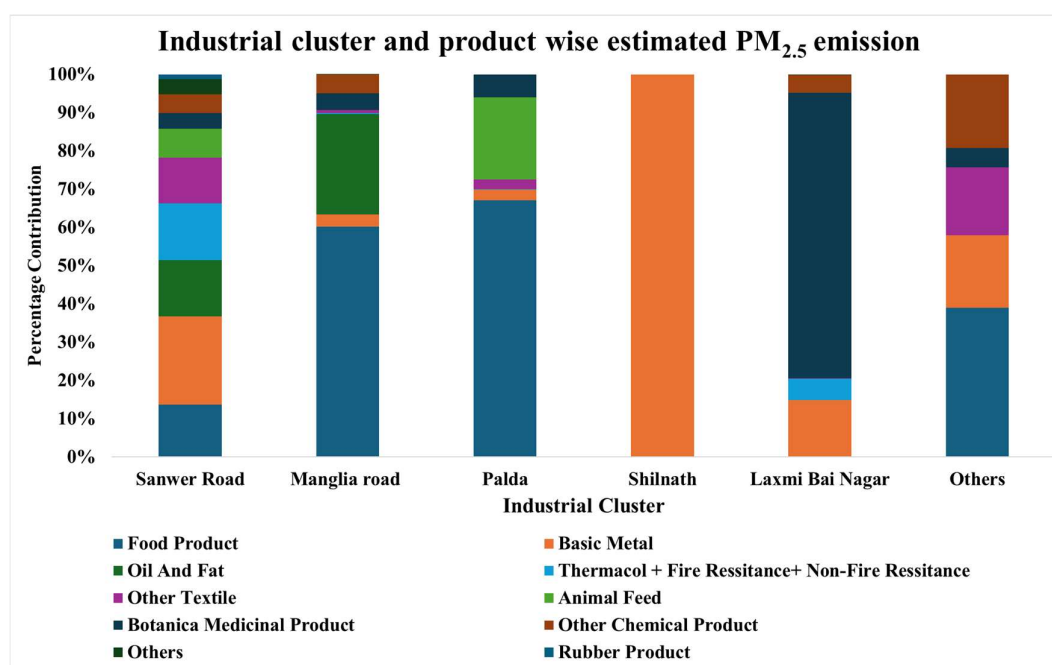


Figure 7: Industrial cluster and product-wise estimated $\text{PM}_{2.5}$ emission

Figure 8 presents the industrial cluster and product-wise distribution of PM₁₀ emission. As per the estimation, the total PM₁₀ emissions are 980 MT/yr. Of this, 80% is from the Sanwer road industrial area, followed by Manglia Road (12%), Palda, Shilnath and Laxmi Bai Nagar (2% each), and the remainder from other industries.

Product-wise, the highest PM₁₀ emission (Figure 8) is from oil and fat manufacturing industries (22%), followed by food products (19%), basic metal (19%), thermocol and fire and non-fire resistance (11%), and the remainder is from other industries.

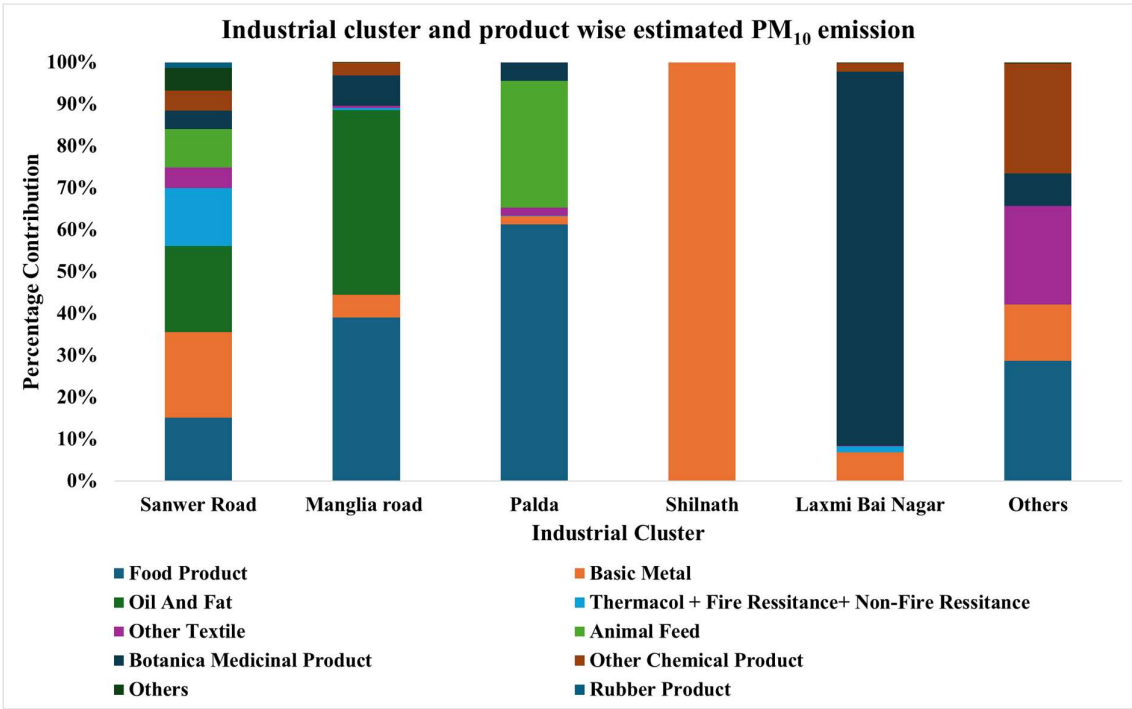


Figure 8: Industrial cluster and product-wise estimated PM₁₀ emission

Figure 9 presents the industrial cluster and product-wise distribution of SO₂ emissions. As per the estimation, the total SO₂ emissions are 2,630 MT/yr, of which 41% is from the Manglia Road industrial area, followed by others (37%), and Sanwer Road (21%). SO₂ emissions are high due to the unavailability of advanced APCD for SO₂ removal.

The product-wise SO₂ emissions (Figure 9) are the highest from oil and fat manufacturing industries (46%), followed by botanic medicinal products (36%), basic metal (7%), food product industries (4%), and the remainder is from other industries.

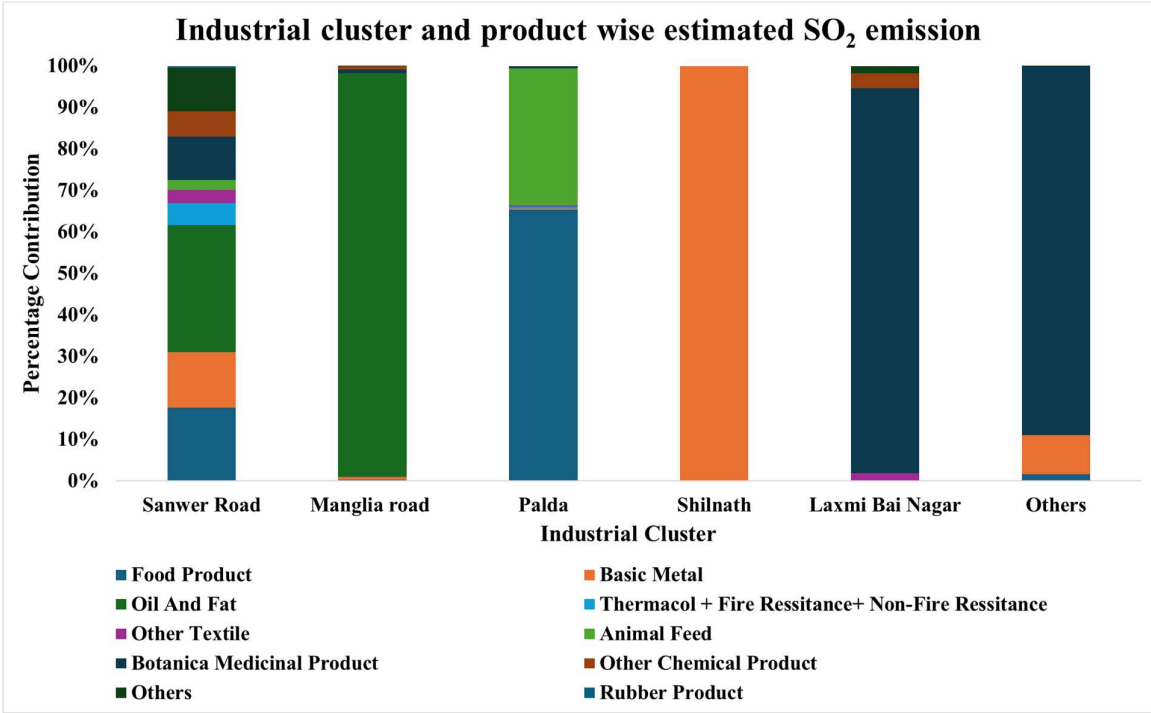


Figure 9: Industrial cluster and product-wise estimated SO₂ emission

Figure 10 presents the industrial cluster and product-wise distribution of NO₂ emissions. As per the estimation, the total NO₂ emissions are 789 MT/yr. Of this, 63% is from the Manglia Road industrial area, followed by Sanwer Road (28%), and the rest from other areas.

The product-wise NO₂ emissions (Figure 10) are the highest from oil and fat manufacturing industries (71%), followed by food product industries (7%), and the remainder is from other industries.

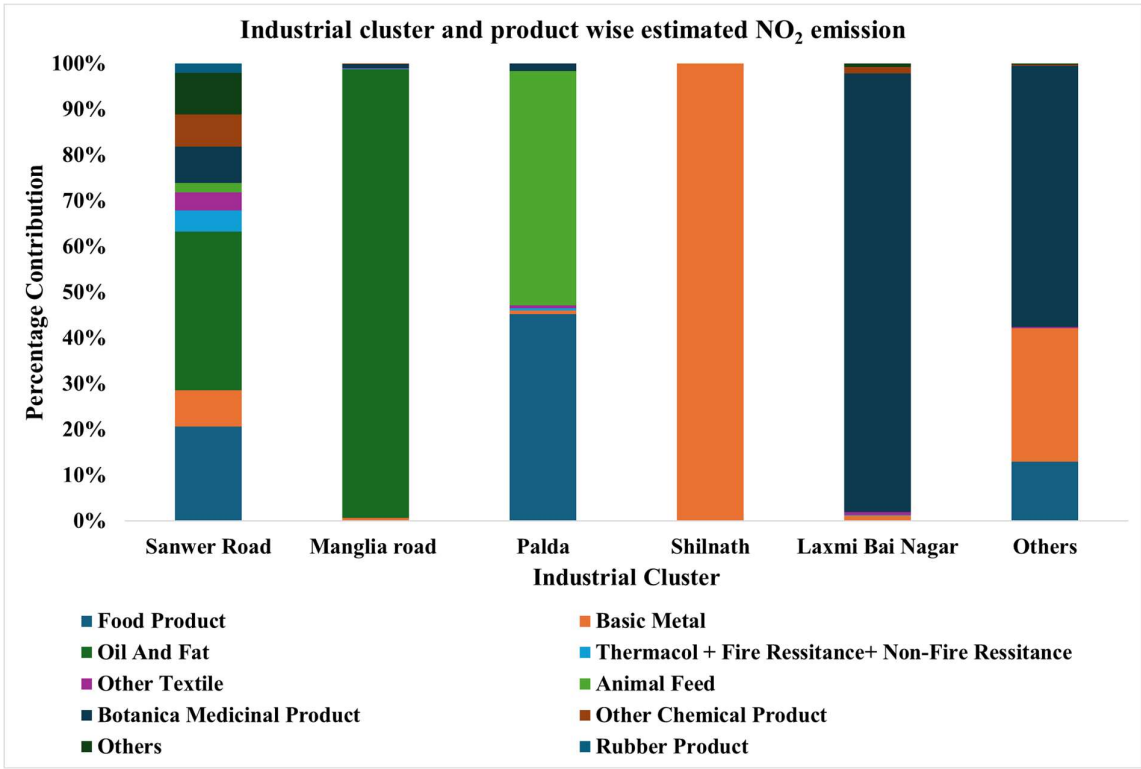


Figure 10: Industrial cluster and product-wise estimated NO₂ emission

Figure 11 presents industrial cluster and product-wise distribution of CO emissions. As per the estimation, the total CO emissions are 8529 MT/yr. Of this, 72% is from other industrial areas, followed by Sanwer (20%), and the remaining from Manglia Road, Palda, Shinath, and Laxmi Bainagar. The highest emissions from other industrial areas are caused by a significant amount of PNG use.

The product-wise CO emissions are presented in Figure 11, with the highest emissions from botanic medical products (75%), followed by basic metal products (5%), food product industries (5%), and the rest from other industries.

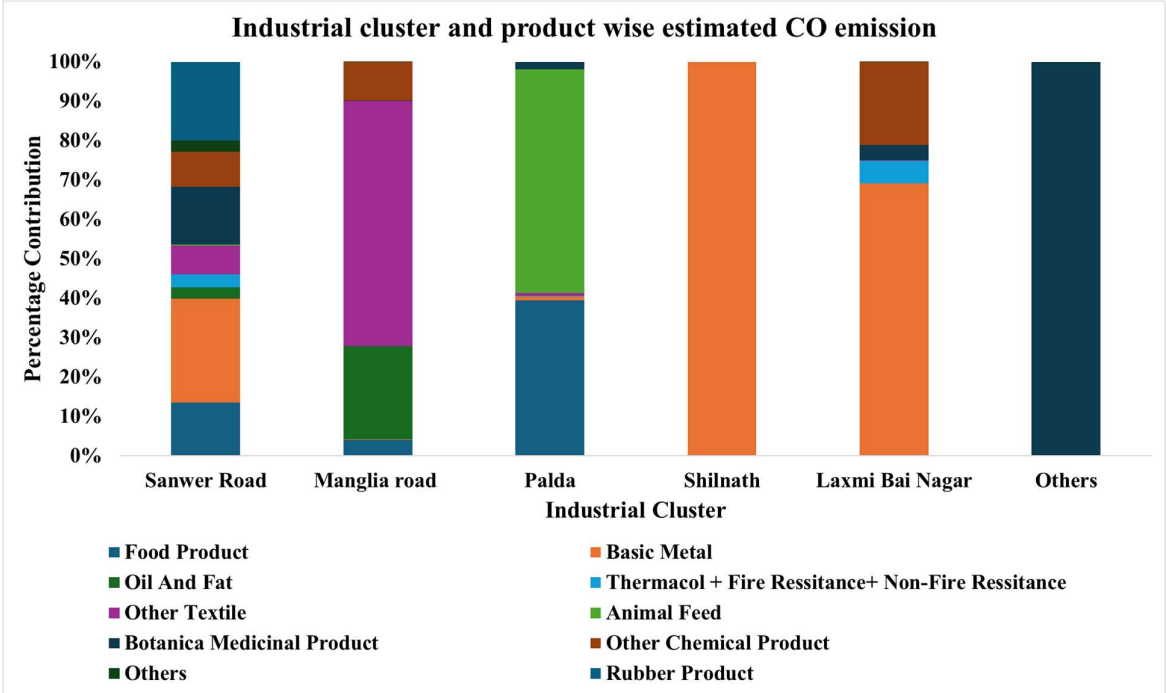


Figure 11: Industrial cluster and product-wise estimated CO emission

3. RECOMMENDATIONS

Several recommendations to reduce air pollution in the IMC industrial area have been formulated on the basis of MPPCB data, the emission inventory, and the first phase of primary surveys. These recommendations have broad applicability and are not specific to any industrial sectors. These are designed to address various aspects of reheating furnaces, boilers, baby boilers, TFH, and APCDs. A summary of utility and technology-specific recommendations for energy and air pollution reduction is presented in Figure 12.

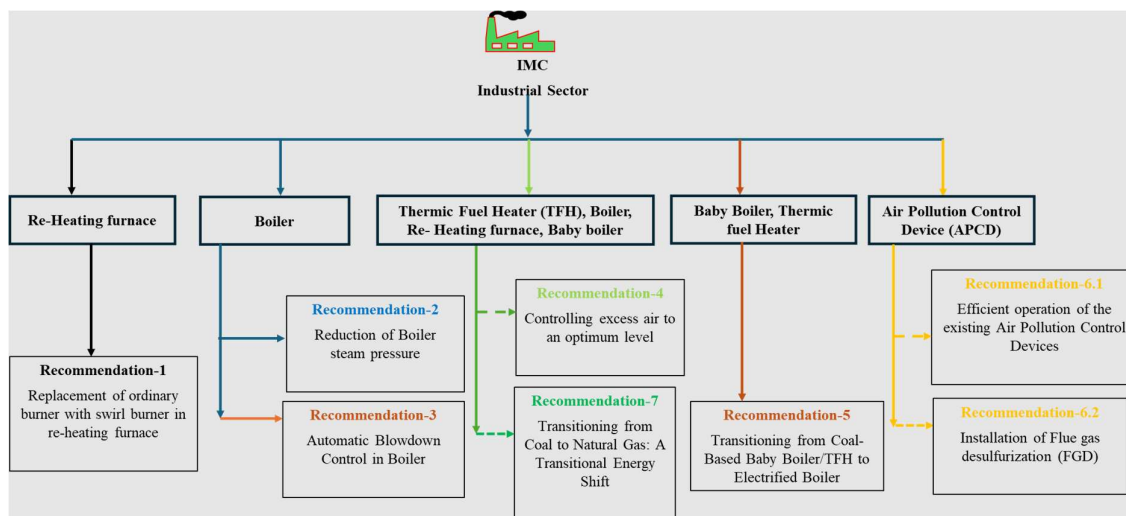


Figure 12: Summary of utility and technology-specific recommendations for energy and air pollution reduction

3.1 Recommendation 1: Replacement of the ordinary burner with the swirl burner in reheating furnace

Reheating furnaces are integral to various industrial operations, particularly in the steel and metal industries. The primary function of a reheating furnace is to reheat steel billets, slabs, or ingots to a specific temperature for further processing, such as rolling or forging. Traditionally, these furnaces have been equipped with ordinary burners, which emit a straight flame into the furnace chamber. A promising upgrade of traditional burner systems is the adoption of swirl burners.

Swirl burners are a modern solution designed to enhance the combustion process and, consequently, the overall efficiency of reheating furnaces. Unlike ordinary burners, swirl burners introduce a swirling motion to the combustion air and fuel mixture before ignition (Efficiency & Limited, 2015). This swirling action creates a more stable and efficient flame, offering the following advantages (Bureau of Energy Efficiency (BEE), 2015):

- Fuel compatibility and saving
- Improved combustion efficiency
- Enhanced heat transfer
- Reduced NO₂ emissions
- Greater flame stability

Considerations for implementation

While the advantages of using swirl burners in reheating furnaces are evident, the transition from ordinary burners requires careful planning and consideration, including the following:

- **Retrofitting:** Replacing existing burners with swirl burners might require modifications to the furnace structure and burner assemblies. This may involve additional costs and downtime during installation.
- **Operational training:** Operators and maintenance personnel may need to be trained to handle the new burner technology effectively. Proper training ensures the safe and efficient operation of the system.
- **Maintenance and monitoring:** Regular maintenance and monitoring of swirl burners are crucial to ensure their continued performance. Monitoring systems can help detect issues early and prevent downtime.

The replacement of ordinary burners with swirl burners in reheating furnaces represents a significant step toward improving efficiency, reducing emissions, and enhancing the overall performance of industrial processes. While the transition may involve initial investments and adjustments, the long-term benefits in terms of energy savings, reduced environmental impact, and product quality improvement make it a worthwhile endeavor. As industries continue to prioritize sustainability and operational excellence, swirl burners offer a promising solution for achieving these goals in the realm of reheating furnaces.

3.2 Recommendation 2: Reduction of steam pressure in boilers

Boilers are vital components in various industrial and commercial applications, providing steam for heating, power generation, and industrial processes. The efficient operation of the boiler is essential for optimizing energy consumption and maintaining process reliability (Bureau of Energy Efficiency (BEE), 2015). One of the strategies to improve boiler efficiency is through a reduction of steam pressure. The benefits of reducing steam pressure in boilers include the following (Bureau of Energy Efficiency (BEE), 2015):

- Energy savings and economic benefits
- Reduced heat losses
- Improved efficiency
- Extended life of equipment
- Enhanced safety
- Environmental benefits
- Cost reduction
- Better process control

There are additional considerations when reducing boiler steam pressure, which include the following:

- **Process requirements:** Before reducing steam pressure, it is essential to evaluate the specific process requirements to ensure that lower pressure will not adversely affect production, quality, or safety.
- **Steam distribution:** Changes in steam pressure may require adjustments to the distribution system, including the sizing of pipes and control valves, to maintain proper steam delivery.

- **Equipment compatibility:** Ensure that all equipment connected to the steam system can operate safely and efficiently at reduced steam pressure. Modifications or replacements may be necessary.

3.3 Recommendation 3: Automatic blowdown control in boiler

Blowdown control is an essential aspect of boiler management. The concentration of solids in a system is regulated through a method known as blowdown. During this process, a specific quantity of water is expelled, which is automatically replenished with feed water. This ensures that the ideal level of total dissolved solids (TDS) in the boiler water is maintained. Blowdown is essential for safeguarding the heat exchanger surfaces within the boiler. It is worth noting that the improper execution of blowdown can result in substantial heat loss. Automatic blowdown control systems are, therefore, key in maintaining boiler water quality, optimizing energy efficiency (EE), and reducing water and chemical consumption. The benefits of the automatic blowdown control in a boiler **include the following** (Bureau of Energy Efficiency (BEE), 2015):

- Economic benefits
- Energy efficiency (EE)
- Water conservation
- Chemical savings
- Extended life of boiler

Automatic blowdown control is a crucial element of an efficient and sustainable boiler operation. By continuously monitoring water quality and automating blowdown processes, industries can reduce energy consumption, conserve water, save on chemicals, and extend the life of their boiler systems.

3.4 Recommendation 4: Controlling excess air to an optimum level

Inefficient operation can result in excessive energy consumption and increase in greenhouse gas (GHG) emissions. A common source of inefficiency is the presence of excess air in the combustion process.

What is excess air?

Excess air in boilers, TFH, and furnaces refers to the amount of air supplied to the combustion process beyond what is theoretically required for complete combustion of fuel. While some level of excess air is necessary for safety and to ensure complete combustion, excessive levels can lead to various inefficiencies, such as increased fuel consumption, reduced thermal efficiency, and elevated emissions of pollutants, especially NO₂ and CO.

Fuel	kg of air required /kg of fuel	Recommended excess air (% by weight (wt))	Reference
Coal	10.8	(15-20) %	(Bureau of Energy Efficiency (BEE), 2015)
Wood	5.8	(20-25) %	
Furnace Oil	13.9	(20-30) %	
Natural gas	10*	(5-7) %	

*For Natural Gas (NG) the ratio is m³ of air required /m³ of fuel

Methods to control the excess air

Portable oxygen analyzers and draft gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction of up to 20% is feasible (Bureau of Energy Efficiency (BEE), 2015).

The most common method to control excess air is by using the continuous oxygen analyzer with a local readout mounted draft gauge with which the operator can adjust air flow, thus reducing excess air by 10-15%. If the analyzer has a remote-controlled pneumatic damper positioner, the readouts can be accessed in the control room, thus enabling the operator to remotely control several firing systems simultaneously. The benefits of controlling excess air to an optimum level **include the following** (Bureau of Energy Efficiency (BEE), 2015):

- Economic benefits
- Improved EE
- Cost savings
- Lower emissions
- Extended life of equipment
- Enhanced safety
- Improved combustion stability
- Reduced heat loss

Controlling excess air in boilers, TFH, and furnaces are vital energy saving measures, with significant environmental and economic benefits. Implementing advanced combustion control systems, regular maintenance, and other techniques, such as preheated air, flue gas recirculation, and oxygen trim control, can lead to substantial improvements in efficiency. By reducing excess air levels, industries can save on fuel costs, decrease emissions, and contribute to a more sustainable and eco-friendly future. Small and medium-sized enterprises (SMEs) have the option to manually manage excess air, which could be a cost-effective alternative to installing a fully automated excess air control system.

3.5 Recommendation 5: Transitioning from coal-based boiler/TFH to electrified boiler

In the ongoing global effort to reduce GHG emissions and combat climate change, transitioning from coal-based boilers/TFH to electricity has emerged as a compelling strategy for industries. This shift represents a pivotal step towards achieving cleaner, more sustainable energy production. The benefits of transitioning from coal-based boiler/TFH to electrified boiler include the following (Bureau of Energy Efficiency (BEE), 2015):

- Environmental benefits
- Energy efficiency (EE)
- Renewable energy integration
- Reduced maintenance and emissions control
- Improved efficiency

Transition process

Feasibility assessment: The first step in transitioning from coal to electrified boilers/TFH is to conduct a feasibility assessment. This assessment evaluates the existing boiler system, electricity infrastructure, and potential energy sources to determine the viability of electrification.

Infrastructure upgrades: To shift to electrified boilers/TFH, industries may need to upgrade their electrical infrastructure, including transformers, wiring, and distribution systems, to accommodate the increased electrical load.

Boiler selection: Industries must choose an electrified boiler/TFH that suits the specific requirements of the industry. The factors to consider include capacity, efficiency, and compatibility with the existing setup.

Integration of renewable energy: If possible, integrate renewable energy sources into the electrified boiler system to reduce emissions further and enhance sustainability. This may involve installing solar panels, wind turbines, or other renewable energy generation facilities.

Training and transition plan: Train personnel on the operation and maintenance (O&M) of electrified boilers/TFH. Develop a transition plan that minimizes downtime during the switch from coal to electricity. The training/transition plan should identify opportunities to empower more women with necessary skills for green jobs. The plan should ensure ways to expand women's participation in green jobs through increasing awareness, creating educational opportunities, and enabling fair hiring processes and supportive workplace cultures

The transition from coal-based boiler/TFH to electrified boilers/TFH is a pivotal step toward achieving sustainability and reducing the environmental impact of industrial operations. While this shift requires an initial investment in infrastructure and technology, the long-term benefits in terms of reduced emissions, EE, and operational cost savings make it a compelling choice. By embracing electrification, industries can contribute to a cleaner and more sustainable future while also reaping economic rewards.

3.6 Recommendation 6.1: Efficient operation of the existing APCDs

Several small and medium-sized industries in the IMC area rely on bag filters as their primary APCDs. However, it has been observed that these APCDs operate at less than their designed efficiency, as is evident from the release of black smog due to O&M issues (Department of Environment and Natural Resources, 2008). While preparing the emissions inventory as part of this Solution Strategy Paper, the APCD efficiency was kept lower for the bag filter and electrostatic precipitator (ESP). PM_{2.5} removal efficiency of 95% was used for the emission inventory calculation (the bag filter's PM_{2.5} removal efficiency is 95 to 99.9% and ESP efficiency is 90 to 99.9%) (Department of Environment and Natural Resources, 2008). Recommendation 6 is designed to assess pollution reduction if the APCD, especially the bag filter, is being operated at design efficiency (Department of Environment and Natural Resources, 2008). The improved O&M practices of the bag filter and electrostatic precipitator are listed in Annexure 1.

3.7 Recommendation 6.2: Installation of flue gas desulfurization

SO₂ stands out as a primary pollutant discharged during the combustion of fuels containing sulfur, such as coal, petcoke, furnace oil, and LDO/HSD. A majority of the industries in the IMC area employ bag filters or electrostatic precipitators (ESP), with only a limited number utilizing wet scrubbers. In these smaller industries, wet scrubbers are primarily employed for particulate matter removal due to a lack of sufficient expertise in operating these for SO₂ removal.

The absence and suboptimal utilization of available APCDs for SO₂ removal heightens the risk of elevated SO₂ emissions into the atmosphere, a concern that is expected to become increasingly significant in the future for the secondary particulate matter. To address this issue, it is recommended that highly efficient flue gas desulfurization (FGD) systems be implemented for SO₂ removal. These systems boast a removal efficiency of 90% (EPA-452/F-03-034, 2003). In 2017, the Central Pollution Control Board (CPCB) mandated the installation of FGD in captive power plants. Three types of FGDs are predominately installed in India (Central Pollution Control Board, 2023):

- Dry sorbent injection
- Wet limestone-based
- Seawater-based

Dry sorbent scrubbing systems, also known as dry injection or spray drying systems, facilitate the reaction of SO₂ with limestone in flue gas before reaching dust control systems.

In contrast, wet desulfurization scrubber systems, which is the most widely adopted technology for large-scale flue gas treatment, utilize a cost-effective alkaline scrubbing reagent (limestone) to generate stable gypsum, ensuring high SO₂ removal efficiency. A seawater-based process can achieve a 70-95% reduction in SO₂ using alkaline sea water, particularly applicable when SO₂ emission standards are less stringent. The initial cost of the seawater-based process is lower than that of the wet limestone-gypsum FGD process due to the former's uncomplicated equipment configuration.

Various wet scrubber designs, such as spray towers, venturists, plate towers, and packed beds, are employed in FGD. Due to operational concerns, such as scale buildup and plugging, industries often opt for simpler scrubbers, such as spray towers. However, these towers necessitate a higher liquid-to-gas ratio for equivalent SO₂ removal as compared with other absorber designs.

Limestone and sodium hydroxide serve as alkaline scrubbing reagents. Limestone slurry is commonly used in the scrubbers of large coal/oil-fired boilers in power plants due to its cost effectiveness as compared with caustic soda. Caustic soda, although an option, requires the disposal of the spent sodium sulfite/bisulfite solution, especially in cases where downstream utilization in industries such as pulp and paper mills is absent.

Less frequently used techniques include scrubbing with sodium sulfite solution and gas-phase oxidation, followed by reaction with ammonia. Given its abundant availability, limestone is predominantly used in FGD systems leading to the production of calcium sulfate di-hydrate (CaSO₄·2H₂O), commonly known as gypsum.

The total capital cost of the FGD ranges from US \$84,364 to US \$109,091 per megawatt (Ebi, Hess, & Watkiss, 2017). The current FGD costs appear prohibitive for small and medium-sized industries. Looking ahead, it is imperative to prioritize research and development (R&D) efforts to explore more efficient and cost-effective FGD technologies. The goal is to substantially decrease the overall cost, making FGD implementation affordable for small and medium-sized industries in the future. Another option would be to plan for a common FGD at the cluster level, where feasible, to reduce cost.

* Recommendation 6.2 is being made considering the anticipated substantial increase in future secondary particulate matter. It also acknowledges the escalating significance of secondary pollutants as a major concern. This recommendation delineates a prospective course of action in the case that the industry persists in using high sulfur fuel. However, the authors specifically endorse transitioning from high sulfur to low sulfur fuel instead of installing FGD.

3.8 Recommendation-7: Transitioning from coal to natural gas: A transitional energy shift

Amidst the worldwide drive to curtail GHG emissions and address the challenges of climate change, the adoption of natural gas over coal-based boilers, furnaces, and thermic fuel heaters has gained prominence as a compelling strategy within various industries. This transition signifies a crucial advancement in the pursuit of cleaner and more sustainable methods of energy production (Calabria, 2019).

Need for transition

Environmental imperatives: Shifting from coal to natural gas is primarily driven by environmental concerns. Coal combustion is notorious for releasing significant amounts of pollutants, including SO₂, NO₂, particulate matter, and CO₂. These emissions contribute to air pollution and GHGs. In contrast, natural gas is a cleaner-burning fuel, emitting fewer harmful pollutants except NO₂ and reducing the carbon footprint of energy production. Natural gas combustion may result in increased NO₂ emissions. Therefore,

while shifting from coal to natural gas, lower NO₂ producing technologies (such as low Nitrogen oxides (NO_x) burners) and appropriate flue-gas control technologies (such as selective catalytic reduction and selective non-catalytic reduction) shall be considered to mitigate NO₂ emission.

Climate change mitigation: Natural gas is considered a bridge fuel because it produces lower CO₂ emissions during burning as compared with coal. While it is not a long-term solution to climate change, it can serve as a transitional step towards more sustainable energy sources, such as renewable energy, while continuing to meet energy demands.

Economic benefits

Cost savings: The economic advantages of transitioning to natural gas are significant. Natural gas is often more cost effective than coal due to lower fuel prices and increased boiler efficiency.

The coal-to-natural gas transition has led to a substantial 40% reduction in GHG emissions and an impressive reduction of over 90% in particulate matter emissions, with an investment of ₹30-125 lakhs per unit in technology. Returns on this investment can be achieved in a short period of one year (Market, For, Micro, & Enterprises, 2015a).

Operational efficiency: Natural gas boilers/furnaces/TFH are known for their quick start-up time and operational flexibility. This allows industries to respond promptly to fluctuations in energy demand, improving overall operational efficiency.

Challenges and considerations

Infrastructural modifications: Converting from coal to natural gas may necessitate adjustments in the existing infrastructure, including combustion systems, fuel storage, and emissions control equipment. Adequate planning and investment are essential to ensure a smooth transition.

Safety protocols: Ensuring the safe operation of natural gas equipment is crucial. Comprehensive training and safety protocols should be established to minimize the risks associated with gas handling and storage.

Policies for energy transition in the industrial sector should consider gender-responsive approaches

Policies aimed at facilitating the transition to sustainable energy within the industrial sector should incorporate gender-responsive approaches to ensure inclusivity and effectiveness. By integrating gender considerations, such policies can better account for the diverse needs, roles, and contributions of both men and women in the workforce, thereby fostering equitable outcomes.

Failure to explicitly address gender and equity concerns within energy transition policies may inadvertently perpetuate existing disparities. Without targeted interventions, there is a risk of reproducing and reinforcing entrenched inequalities, such as unequal access to employment opportunities, wage gaps, and limited representation of women in decision-making roles within the energy sector. This lack of inclusivity not only undermines the effectiveness of energy transition efforts but also hampers broader societal progress towards gender equality and social justice. Therefore, acknowledging

and addressing these challenges is crucial for developing policies that promote fair and sustainable outcomes for all stakeholders.

Impact analysis of the proposed recommendation

A comprehensive analysis of the fuel-saving potential of the recommendations proposed in this Solution Strategy Paper was conducted, and the findings were applied in specific industrial clusters in Indore. As an initial step, the reduction in fuel consumption for each cluster was determined. To standardize and facilitate comparison, the total fuel savings was converted into tons of oil equivalent (TOE) or kilo TOE. This conversion was based on established fuel-specific calorific values from the literature sources listed in Table 2 as precise calorific values for the fuel types used in the industrial areas in IMC could not be accessed.

After the recommendation-specific reductions in fuel usage or improvements in APCD efficiency were quantified, the corresponding changes in the baseline emissions data of the air pollutant was estimated. The baseline emissions data was sourced from an emissions inventory prepared by the WRI India team.

Table 2: Fuel-wise calorific value

Category	Fuel	GCV	Unit	Reference
Oil	FO	10500	kcal/kg	(Bureau of Energy Efficiency (BEE), 2015; Ministry of Petroleum & Natural Gas, 2022)
	LSHS	10600	kcal/kg	
	LDO	10700	kcal/kg	
	HSD	10800	kcal/kg	
Coal	South African Coal	6000	kcal/kg	
	Indian Coal	4000	kcal/kg	
	Lignite	4500	kcal/kg	
	Indonesian Coal	5500	kcal/kg	
Agro Residues	Deoiled Bran	3151	kcal/kg	
	Paddy Husk	3568	kcal/kg	
	Saw Dust	4801	kcal/kg	
	Coconut Shell	4565	kcal/kg	
Gas	Natural Gas	9350	kcal/Nm ³	
Petcoke		7800	kCal/kg	(Indian Oil The Energy of India Indian Oil Corporation Ltd., n.d.)

The focus of this effort is to transition from high emission technologies to low emission technologies, which is anticipated to help reduce air pollution and improve human health. While an attempt has been made to consider gender and equity issues, a few major solutions, such as recommendations 4, 5 and 7 may result in the potential elimination of jobs due to automation and the transition to new technology. To ensure sustainable job options, there a plan to build appropriate capacity for impacted workers through upskilling should be formulated.

After a thorough analysis, the calculations made as part of this Solution Strategy Paper reveal a comprehensive fuel savings and reduction in overall PM_{2.5} emissions, as outlined in Table 3. Figure 13 illustrates the overall PM_{2.5} emissions and avoided emissions, based on the recommendations made in this paper. Notably, Recommendation 7 emerges as the most effective with respect to avoided PM_{2.5} emissions.

Table 3: Summary of recommendations

S.No.	Recommendations	Timeline	Energy use (kilo TOE/year) (energy reduction % compared to baseline)	Overall PM _{2.5} % reduction from baseline emission	Suitable sector/equipment	Case study brief	Reference
	Baseline (2019-2020)		106.2	-	-	-	-
1	R1: Replacement of ordinary burner with swirl burner in reheating furnace	Short term (1-3 months)	106 (0.16)	0.6	Metal industry: Reheating furnace	Furnace Capacity-10TPH coal fired Investment- ₹4 lakhs Payback- 6 months Baseline- 85 kg/MT Proposed- 83.3 kg/MT Annual cost saving- ₹8.5 lakhs	(Efficiency & Limited, 2015)
2	R2: Reduction of boiler steam pressure	Short term (1-3 months)	104.3 (1.81)	1.3	Boiler	-	(Bureau of Energy Efficiency (BEE), 2015)
3	R3: Automatic blowdown control in boiler		103.7 (2.4%)	1.5	Boiler	Natural Gas (NG)-based boiler Investment- ₹4-8 lakhs Payback- 1.3-3 years Annual cost saving- ₹3 lakhs Annual water saving- 1988-2609 m ³ /year NG saving- 32,170- 42,163 m ³ /hour Operating condition-Industry-1 No. of boiler-2 Boiler capacity- 5 and 3 TPH Steam production- 3-4 TPH at 8.0 bar pressure Type of blowdown- Manual	(U.S. Department of Energy, 2012)

						Frequency of blowdown- 10-12 per day Duration of blowdown- 30 seconds Operating condition-Industry 2 No. of boilers 3 Boiler capacity- 6'2 and 10 TPH Steam production- 13-16 TPH at 8.0-8.5 bar pressure Type of blowdown- Manual Frequency of blowdown- 10-12 per day Duration of blowdown- 20 seconds	
4	R4: Controlling excess air to an optimum level	Short term (1-3 months)	102.5 (3.5)	3.5	All the industries using thermal equipment	Coal-based Boiler/TFH Investment- ₹21.26 lakhs Payback- 2.5 years Annual cost saving- ₹8.80 lakhs Baseline (Boiler)-1,563 kg/h Baseline (TFH)-1,083 kg/h Proposed (Boiler)-1,540 kg/h Proposed (TFH)- 1,067 kg/h Coal saving- 315 MT/yr Operating condition- No. of boiler-1 No. of TFH-1 oiler capacity- 10 TPH TFH capacity- 30 lakh kCal	(Market, For, Micro, & Enterprises , 2015b)
5	R5: Transitioning of baby boiler/TFH to electrified boiler/TFH: A sustainable energy shift	Mid-term (1-1.5 years)	98.5 (7.3)	32	Baby boiler/TFH	-	("Electric Steam Boiler," n.d.)

6	R6: Efficient operation of the existing APCDs	Short term (1-3 months)	106.2 (0)	50.4	All the industries using thermal equipment	-	(Department of Environment and Natural resources, 2008)
7	R7: Transitioning from all the fuels to natural gas: An energy shift	Long term (1.5 -2 years)	106.2 (0)	Almost 100	All the industries using thermal equipment	Wood /briquettes fired boiler to NG fired Boiler: - Wood /briquettes fired boiler: 600 kg/hr NG fired Boiler: 1,000 kg/hr Investment: ₹15.23 lakhs Annual saving: ₹6.59 lakhs Pay back: 2.3 years Reheating furnace: - Specific energy consumption coal based- 50-60 kg/ MT Specific energy consumption NG based- 40-50 Standard cubic meter (Sm³/MT Investment- ₹30-125 lakhs Payback- 1 year approx.	a: (Market et al., 2015a), b (Jatinder Kaur Arora, Pritpal Singh, 2023)

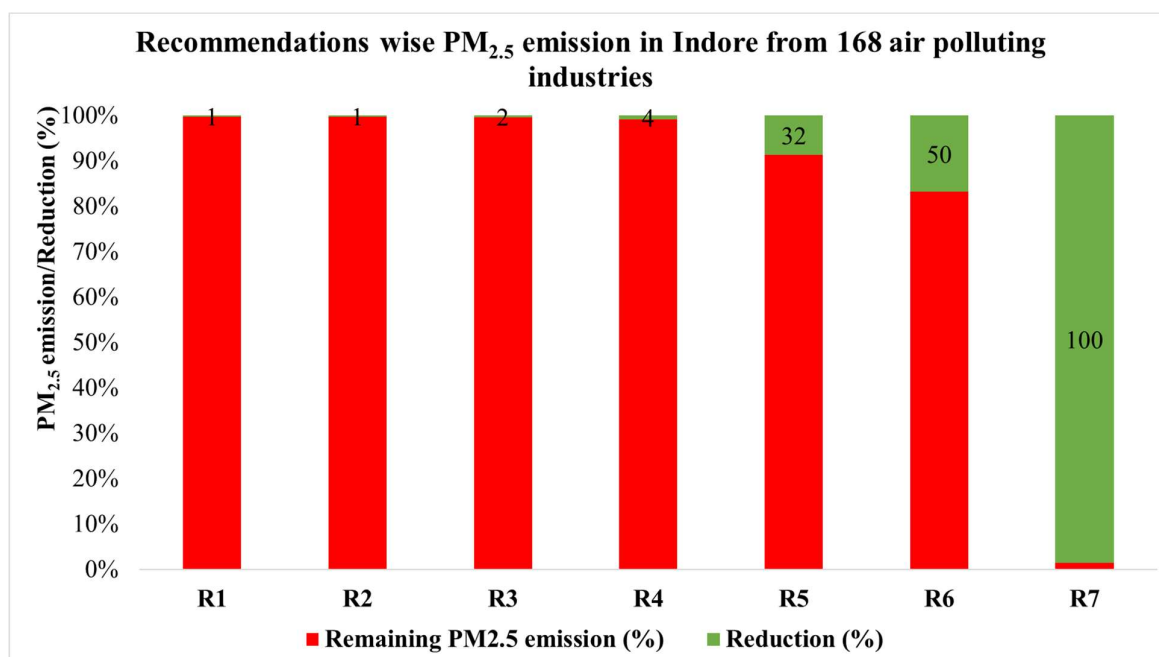


Figure 13: Recommendations-wise PM_{2.5} emission in Indore from 168 air polluting industries

In Figure 13, Recommendation 7, which is the transition to natural gas and expected to eliminate PM_{2.5} emissions, is shown to significantly improve air quality and public health. Implementing Recommendations 1 to 5 collectively will yield substantial energy savings of 15% in the IMC area, consequently leading to an impressive 35% reduction in PM_{2.5} emissions. The most significant emissions reduction is expected in Sanwer Road, with an estimated reduction of 100 MT/yr, followed by Manglia Road with 45 MT/yr, Palda with 20 MT/yr, and additional reductions from other clusters.

Recommendation 6 is optimizing the efficiency of these APCDs, potentially leading to a 50% reduction in PM_{2.5} emissions. This improvement is expected to have the greatest impact on reducing emissions in Sanwer road (172 MT/yr), followed by Manglia Road (62 MT/yr), Palda (8 MT/yr), Laxmi Bai Nagar (5 MT/yr), and additional areas.

These are highly technical scenarios, and the impact is estimated in terms of reduction in air pollutant emissions. However, technical interventions/policy changes do result in a material impact on people and, very likely, both positive and negative gender-differentiated impacts. However, this paper recommends gender-responsive policies in the transition from coal to clean energy.

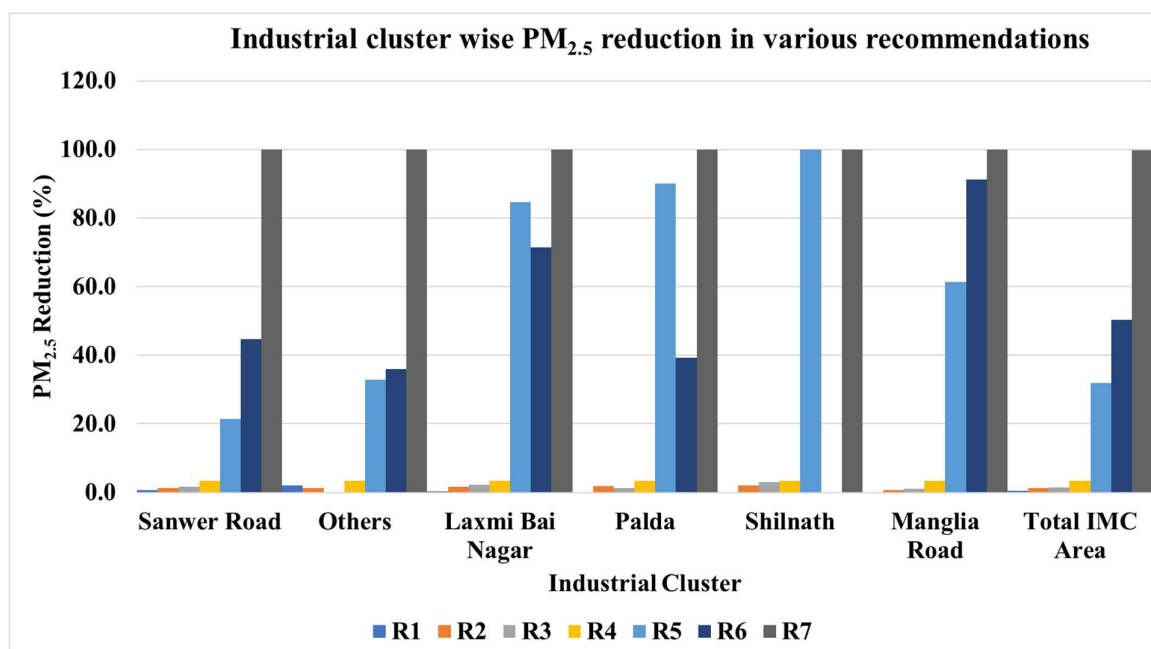


Figure 14: Industrial cluster-wise PM_{2.5} reduction through various recommendations

Table 4: Recommendation-specific PM_{2.5} emissions in Indore's industrial cluster

Recommendations	Sanwer Road	Others	Laxmi Bai Nagar	Palda	Shilnath	Manglia Road	Total IMC Area
Baseline	384.7	11.3	7	20.8	7.2	68	498.9
R1: Replacement of ordinary burner with swirl burner in reheating furnace.	382.2 (0.6)	11.1 (2)	7 (0.3)	20.8 (0.2)	7.2 (0)	67.9 (0.1)	496.1 (0.6)
R2: Reduction of boiler steam pressure	379.6 (1.3)	11.2 (1.3)	6.9 (1.7)	20.4 (1.8)	7 (2)	67.5 (0.7)	492.6 (1.3)
R3: Automatic Blowdown Control in Boiler	378.3 (1.7)	11.3 (0)	6.8 (2.2)	20.6 (1.2)	7 (3)	67.3 (1)	491.2 (1.5)
R4: Controlling excess air to an optimum level	371.2 (3.5)	10.9 (3.5)	6.7 (3.5)	20.1 (3.5)	6.9 (3.5)	65.6 (3.5)	481.5 (3.5)
R5: Transitioning of Baby Boiler/TFH to Electrified Boiler/TFH: A Sustainable Energy Shift	302.4 (21.4)	7.6 (32.9)	1.1 (84.7)	2.1 (90)	0 (100)	26.2 (61.5)	339.3 (32)
R6: Efficient operation of the	212.5 (44.8)	7.2 (36.1)	2 (71.6)	12.7 (39.2)	7.2 (0)	6 (91.2)	247.6 (50.4)

existing Air pollution control devices							
R7: Transitioning from all the fuels to Natural Gas: An Energy Shift	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	1.5 (99.7)

In Table 4:

- PM2.5 emission is in (MT/yr)
- Values in bracket are the %PM2.5 reduction from baseline

4. WAY FORWARD

Reducing air pollution from industries in Indore requires a comprehensive and multi-faceted approach involving various stakeholders, including government authorities, industries, and communities most impacted by air pollution. The recommendations and the potential path for the future are illustrated in Figure 15.

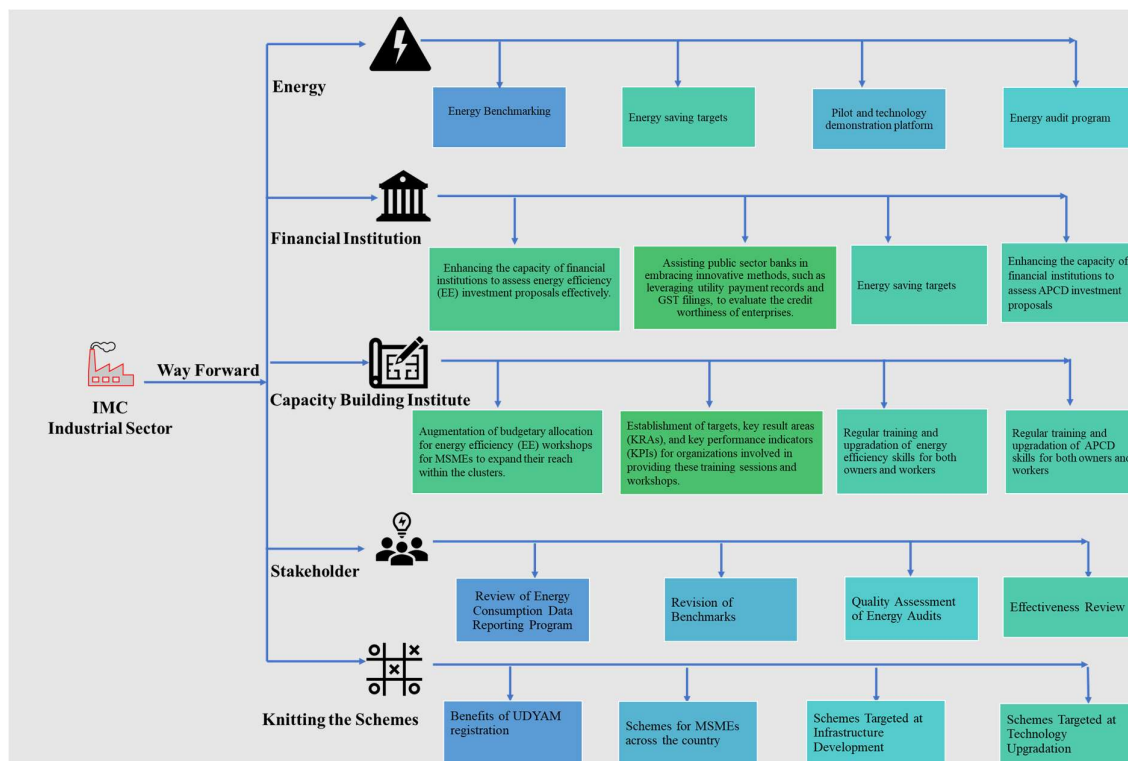


Figure 15: Potential paths for the future

4.1 Energy benchmarking

The lack of energy consumption and benchmarking information for the micro, small, and medium enterprises (MSMEs) sector forces policymakers and researchers to rely on estimates that are, at most, rough approximations. Currently, records of energy consumption are being maintained by individual businesses. The Ministry of Micro, Small, and Medium Enterprises (MoMSME) can collect this data through the MSME databank initiative. Encouraging voluntary reporting within other programs can supplement this effort. In this manner, a comprehensive database can be established, thus helping create sector- and process-specific benchmarks. The specific ways in which this can be done are the following:

- Encouraging voluntary energy data reporting within the MSME sector by providing non-monetary incentives
- Enforcing mandatory energy data reporting to the MSME databank
- Enhancing the capabilities of the survey, research, and policy division within the MoMSME to conduct assessments aimed at evaluating the sector's energy utilization and operational procedures

4.2 Pilot and technology demonstration platform

One of the key findings of a study conducted by Council On Energy, Environment and Water (CEEW) (Biswas, Sharma, & Ganesan, 2018) was that businesses were inclined to adopt energy saving measures (ESMs), when influenced by peer recommendations. To foster this trend, it is advisable to conduct numerous demonstrations and pilot projects in a variety of enterprises, not restricting them to the clusters typically associated with high activity. Establishing an institution, committee, or organization to oversee these pilots in collaboration with financing agencies is necessary to mitigate the perceived risks associated with investing in these ESMs. The roles and responsibilities of such an institution, committee, or organization should include the following:

- Identify and establish implementing agencies with allocated budgets for pilot projects and technology demonstrations.
- Develop connections between agencies and R&D laboratories to act upon feedback from MSMEs and offer pertinent technical guidance on EE.
- Establish an online resource repository on performance benchmarks for technologies used in various processes as well as success stories of enterprises that have implemented EE technologies.

4.3 Energy audit program

Numerous state programs encourage energy audits in MSMEs. To enhance participation, these voluntary initiatives should either become obligatory or be encouraged by linking successful completion to incentives or financial support, such as reduced interest loans from public financial institutions. This approach would empower enterprises to gain a deeper understanding of their energy consumption and, consequently, increase the number of enterprises reporting their energy usage data to the MSME databank. Key strategies to achieve this include the following:

- Development of standardized energy audit reporting formats tailored to specific sectors
- Provision of financial support for the execution of energy audit recommendations

- Establishing of a connection between energy audits and the accessibility of assistance from publicly funded programs (such as interest rate subsidies and capital subsidies) to encourage and facilitate energy audits, especially for energy-intensive manufacturing enterprises

4.4 Energy saving targets

Perform, Achieve and Trade (PAT) is a regulatory instrument to reduce Specific Energy Consumption (SEC) in energy-intensive industries. It incorporates market-based mechanism to enhance the cost effectiveness through certification and trading of excess energy savings and should be extended to benefit the MSME sector. To accomplish this, a comprehensive policy framework should be put in place to motivate businesses to embrace energy-efficient practices. The initial phase of this endeavor should involve the establishment of Minimum Energy Performance Standards (MEPS) for various appliances and equipment, such as motors, with the aim of enhancing EE and streamlining overall processes. Importantly, these mandatory programs should not be viewed as administrative hurdles by MSMEs. It is, thus, advisable to integrate incentives within existing schemes or instruments.

- Combining loans for energy-efficient equipment with the existing capital expenditure (CAPEX) loans obtained by MSMEs, thereby minimizing the extra transaction expenses linked with smaller EE loans
- Enforcing the requirement for large companies to disclose energy consumption data throughout their vendor chain as part of the "Greening the Supply Chain" initiative

4.5 Financial and technical support to reduce emissions

Financial constraints pose as the main barrier in introducing new safe and clean technologies, as the management is often hesitant to invest capital. As most MSMEs have a modest annual turnover, significant financial constraints discourage firms from adopting cleaner technologies. In addition, there is a lack of awareness regarding credit schemes (Credit Linked Capital Subsidy for Technology Upgradation, Performance Linked Incentive, Micro & Small Enterprises Cluster Development Programme, Technology and Quality Upgradation Support) for the MSME sector, and most units rely on self finance. Key strategies to address these challenges include:

- Enhance the capacity of financial institutions to assess EE investment proposals effectively
- Assist public sector banks in embracing innovative methods, such as leveraging utility payment records and GST filings, to evaluate the credit worthiness of enterprises
- Ensure gender training on subjects such as how to include women equally, fully, and meaningfully at all stages and levels of a just transition as leaders and agents of change, designers, implementers, and end users of renewable energy policies, technologies, and practices.
- Ensure education, training and recruitment, retention, and advancement of women in "green" industries so that the benefits of reduced pollution are shared more equally.
- Consider setting targets for women's representation and work in collaboration with local communities to recruit and train women.

In the 2022-23 Budget, the Government of Haryana unveiled a plan to transition fossil fuel-dependent boilers to cleaner fuel alternatives, such as natural gas, in the National Capital Region (NCR) districts of the state. To support MSMEs, the state government also introduced a policy through which 30% of the capital expenditure was allocated for conversion from fossil fuels to cleaner fuels, with a maximum limit of ₹15 lakhs (Haryana & Department, 2023).

This policy can be adopted and implemented by the Government of Madhya Pradesh and the IMC in the IMC area.

4.6 Creating awareness and training on EE, energy monitoring, and efficient operation of APCDs

There is a need to improve the capacity of industries for potential energy and cost savings through technologies, management, and skill building. There is also an opportunity to push for greater gender inclusion in these industries. The EE, energy monitoring, and efficient operation of the APCD training module will target issues such as optimizing boiler efficiencies, inspection and maintenance of pollution control technologies, EE opportunities, and retrofitting or upgrading APCDs. The MSME sector lacks awareness in identifying, selecting, and installing suitable APCDs and optimizing their use to ensure maximum efficiency and productivity. Relevant training would enable MSMEs to choose suitable and cost-effective APCDs and install and use these correctly, thus producing the desired results. The training program that focuses on the O&M of furnaces and boilers should include a broad overview of boilers and thermopac. It should also include a module on the boiler combustion process and overall boiler/furnace efficiency. To reduce energy consumption, lower air pollution control costs, and lower particulate matter along with other pollutants, the program should focus on the following:

- Augmentation of budgetary allocation for EE workshops for MSMEs to expand their reach within clusters
- Establishment of targets, key result areas (KRAs), and key performance indicators (KPIs) for organizations involved in providing these training sessions and workshops
- Ensure ongoing training and skill development in APCDs for owners and workers, with guidance from a diverse range of experts, including technical specialists, manufacturers, representatives from NGOs and think tanks, the Department of Boilers, and other knowledgeable individuals and organizations.

4.7 Key stakeholder engagements

Engaging key stakeholders, such as MSMEs, Small Industries Development Bank of India (SIDBI), BEE, states' Department of Industries, industry associations, and people living and working in the industrial areas is crucial for monitoring the progress of EE adoption. The following are some important actions to consider:

- Review of energy consumption data reporting program: Evaluate and assess the effectiveness of the energy consumption data reporting program to ensure its accuracy and relevance.

- Revision of benchmarks: Update benchmarks to accurately reflect the current state of technology and establish energy saving targets that align with the industry's advancements.
- Quality assessment of eEnergy audits: Implement a mechanism for independently verifying the quality of energy audits and the recommendations provided, ensuring their reliability and effectiveness.
- Effectiveness review: Review the effectiveness of the EE program, and consider setting targets for the immediate upcoming target period, making necessary adjustments to enhance its impact.

4.8 Benefits of Udyam Registration

The MoMSME launched the portal Udyam Registration to digitize India and streamline processes. It is an improved, tech-first system to assist small and medium businesses to grow and provide the necessary support. Udyam Registration, also known as MSME Registration, involves the government sign-off and the provision of an Udyam Recognition Certificate and a Unique Number. This certification is essential for those seeking legal and operational certification for small or medium businesses. The MoMSME conducts Udyam Registration for micro and small businesses. The benefits provided by Udyam Registration provides to MSMEs include the following:

- Subsidies and incentives
- Protection against delayed payments
- Government tenders
- Income tax exemption
- International trade

4.9 Schemes for MSMEs across India

There are various schemes in India that provide credit and financial assistance, skill development training, infrastructure development, and technology upgrades for MSMEs.

4.9.1 Schemes on credit and financial assistance

4.9.1.1 Prime Minister's Employment Generation Programme (PMEGP)

- Implemented by the Khadi and Village Industries Commission ((KVIC) to create job opportunities in rural and urban areas
- Aims to establish self-employment microenterprises/projects
- Provides steady employment to artisans and unemployed youth
- Enhances earning capacity and contributes to employment growth
- Eligibility criteria includes age 18 years and above and education up to Standard VIII for larger projects

4.9.1.2 Credit Guarantee Trust Fund for Micro and Small Enterprises (CGTMSE)

- A Government of India initiative to provide unsecured credit to the micro and small business sector
- Covers fund-based and non-fund-based credit facilities

- Guarantees vary from 50-85%, depending on factors such as business size, ownership, and location
- Settles claims in case of default of up to 75% of the credit facility amount extended

4.9.1.3 MSME schemes for empowering women entrepreneurs (Indifi, n.d.)

- **Mahila Udyam Nidhi Scheme:** The scheme was first launched by SIDBI in 1987 and is currently operational under the Punjab National Bank. There are various other similar schemes offered by banks for women entrepreneurs.
- **Trade-related Entrepreneurship Assistance and Development (TREAD) scheme:** TREAD is aimed at supporting women entrepreneurs in non-farm activities. It provides training, counselling, and information on various aspects of business enterprises and trades. The scheme was first launched in 1998.
- **Economic Empowerment of Women Enterprises and Start-up by Women:** The National Institution for Transforming India (NITI Aayog) launched the Women Entrepreneurship Platform (WEP) on March 8, 2018, on International Women's Day. It is a scheme offered by the Ministry of Skill Development and Entrepreneurs, Government of India, which provides an incubation and acceleration programme for female micro entrepreneurs to launch new businesses and scale up existing ones.
- **Udyogini Scheme:** The Udyogini Scheme for Women Entrepreneurs was launched by the Women Development Corporation, Government of India, on March 29, 2024. The scheme aims to help underprivileged women entrepreneurs become self-reliant and financially independent through self-employment.
- **Pradhan Mantri Rozgar Yojana:** The objective of Pradhan Mantri Rozgar Yojana (PMRY), a government scheme for women, is to provide opportunities of self-employment to the educated, young people of India. Initiated in 1993, the scheme provides the unemployed Indian youth a loan amount to commence their personal business project and, in turn, create employment for others.
- **Mudra loans:** Pradhan Mantri Mudra Yojana (PMMY) was launched in April 2015 to provide collateral-free loans to small and micro enterprises based in the manufacturing, retail, agriculture, and service sectors. Mudra offers a 25% reduction on interest rates to women entrepreneurs.
- **Annapurna Scheme:** Annapurna Yojana, offers women entrepreneurs loans up to ₹50,000 for starting a food catering business. The scheme was first announced in the 1999-2000 Union Budget.
- **Dena Shakti Scheme:** Dena Bank, a public sector bank, was set up to provide women with a platform to avail business loans. Under the Dena Shakti Scheme, financial support is extended to women entrepreneurs who focus on agriculture, retail trade, education, housing, and the SME segment.

4.9.2 Schemes for skill development training

4.9.2.1 Entrepreneurship and Skill Development Programmes (ESDP)

- Organized by the MoMSME to enhance the skills and knowledge of entrepreneurs
- Focuses on capacity development for business project management
- Implemented by MSME Development Institutes, Technology Centers, and Enterprise Development Centers (EDCs)

4.9.3 Schemes for infrastructure development

4.9.3.1 Scheme of Fund for Regeneration of Traditional Industries (SFURTI)

- Aims to organize traditional and artisan industries into competitive clusters
- Supports long-term sustainability, product marketing, innovation, and technology improvement
- A program steering committee oversees the program's implementation.

4.9.3.2 Scheme for Micro and Small Enterprises Cluster Development Programme (MSECDP)

- Adopts a cluster development approach to enhance productivity and competitiveness of MSEs
- Provides funding to establish Common Facility Centers (CFC) and Infrastructure Development Projects (IDP)

4.9.4 Schemes for technology upgradation

4.9.4.1 Financial support to MSMEs in ZED certification

- Promotes Zero Defects and Zero Effects (ZED) production among MSMEs
- Encourages continuous improvement in product and process quality
- Aims to adopt environment-friendly manufacturing processes

4.9.4.2 Support for entrepreneurial and managerial development of SMEs through incubators

- Supports the creativity of MSMEs and the adoption of the latest technologies.
- Provides financial assistance for development of ideas, technology-related R&D activities, and seed funding for start-ups through business incubators.

4.10 Gender-responsive approach

Gender issues related to air pollution from industries are multifaceted and interconnected with broader social, economic, and environmental challenges. These need to be addressed through a holistic approach to ensure policy solutions are gender-responsive or, at the very least, do-no-harm.

The following areas should be considered:

Considering gender differential health impacts

- Who is the most affected by industry pollutants? Are occupations segregated by gender within sectors, Including all level of employees/labor?
- What data is available /can be obtained/accessed?

Livelihood and economic opportunities

- In the just transition away from fossil fuels, will women be left behind?
- Do policies ensure women's participation in the labor force in the industrial sector?

Environmental justice

Marginalized communities, including women, often bear the brunt of industrial pollution due to their proximity to polluting industries and limited resources to mitigate its impacts.

- Do policies/systems ensure that women and marginalized populations are not disproportionately affected by environmental injustices? Is there a framework for legal recourse to address barriers?

Empowerment and participation

- Do policies/systems ensure that there are no gender disparities in decision-making and participation in industries' governance?

5. CONCLUSION

The industrial sector accounts for 27% of the PM 2.5 emissions in the IMC area and is, therefore, a significant contributor. This substantial share is primarily attributed to the prevalent use of conventional fuels. Conventional fuels, such as coal, wood, and furnace oil, contribute hugely to the overall emissions load in the city. Urgent attention is required to encourage a shift towards cleaner fuel alternatives, especially by MSMEs and large industrial units heavily reliant on conventional fuels.

Various interventions can be implemented to address this issue, ranging from replacing ordinary burners with swirl burners in reheating furnaces, reducing boiler steam pressure, implementing automatic blowdown control in boilers, optimizing excess air levels, transitioning from baby boilers/ TFH to electrified boilers/TFH, efficiently operating existing APCDs, and switching from various fuels to natural gas. These interventions exhibit a potential reduction in PM 2.5, ranging from 0.6% to nearly 100%, and can be applied within a timeframe ranging from 1-3 months to 2 years. Targeting industrial clusters, such as Sanwer Road, Mangaliya Road, Palda, Pologround, Laxmibai Nagar, Bhagirathpura, and others, by implementing these programs could yield significant improvements.

It is anticipated that industry associations will play a crucial role in spearheading the implementation of air pollution mitigation measures. The solutions proposed can be executed through various mechanisms, including setting energy benchmarks, demonstrating efficient technologies, conducting energy audit programs, and incorporating these industries into a program similar to PAT while establishing energy reduction targets. Building awareness about EE, managing and monitoring energy consumption, and ensuring the effective operation of APCDs among industrial owners and workers are essential components of the implementation strategy. Additionally, making industrial stakeholders aware of various government financial incentive schemes can further facilitate the adoption of cleaner technologies and practices.

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ANNEXURE-1 (MONITORING AND MANAGEMENT PLAN FOR BAG FILTER AND ESP OPERATION)

BAG FILTER UNIT

Daily maintenance: Check pressure drop to be within manufacturer specified maximum pressure drop limit and normal operating range. Monitor gas flow rate, observe stack outlet visually, monitor discharge system, make sure dust is removed as needed.

Weekly maintenance: Check all moving parts on the discharge system; screw conveyor bearings, check damper operation; bypass, isolation, etc. Spot-check bag tensioning, reverse air, and shake bags. Check compressed air lines, including boilers and filters. Blow out manometer lines. Verify temperature-indicating equipment. Check the bag-cleaning sequence to see that all valves are seated properly. Check the drive components on the fan.

Monthly maintenance: Spot-check bag seating condition, check fan for corrosion and blade wear. Check all hoses and clamps. Spot-check for bag leaks and holes. Inspect bag filter units housing for corrosion.

Quarterly maintenance: Thoroughly inspect bags, check duct for dust build-up, observe damper valves for proper seating, check gaskets on all doors, inspect paint on bag filter unit, calibrate opacity monitor or particulate monitor if one is fitted, inspect baffle plate for wear.

Annual maintenance: Check all welds and bolts, hopper for wear. Replace high-wear parts in the cleaning system.

Routine monitoring

Weekly:

Check the bag filter unit's exit for visible emissions. If observed, investigate and rectify within eight hours. In adverse weather, note conditions and attempt opacity readings later, if required.

Monitor and document the bag filter unit's pressure drop per shift. If it falls outside the manufacturer's range, correct it within eight hours.

For large or less visible units, install continuous particulate monitoring devices with high alarms. Record readings per shift.

Monthly

Check the cleaning sequence of the bag filter unit. For pulse jet bag filters, check the air delivery system.

Check the hopper functions and performance. If leaks or abnormal conditions are detected, the appropriate measures for remediation are to be implemented within eight hours.

Quarterly

Thoroughly inspect bags for leaks and wear and tear. (Look for obvious holes or tears in the bags.) If leaks or abnormal conditions are detected, the appropriate measures for

remediation are to be implemented within eight hours. Bag replacement should be documented by identifying the date, time, and location of the bag in relationship to the other bags. The location should be identified on an overhead drawing of the bag layout in the bag filter unit.

Six-monthly

Every six months, inspect all components that are not subject to wear and tear or plugging, including structural components, housing, ducts, and hoods. If leaks or abnormal conditions are detected, the appropriate measures for remediation are to be implemented within eight hours.

ELECTROSTATIC PRECIPITATORS (ESP)

Start-up: Ensure tools and safety devices are removed, conduct a final inspection, and perform an air load test to confirm readiness. Activate insulator heaters and purge air systems, and operate the rapping system during start-up. Shutdown: De-energize components sequentially from inlet to outlet, allowing rappers to remove residual dust. Routine operations: Monitor parameters, maintain records, perform preventative maintenance, and address malfunctions promptly.

Preventative maintenance

Daily inspection and maintenance: The dust discharge system should be operating continuously, with all conveyors, airlocks, valves, and other associated equipment functioning properly. Vacuum gauges should be checked prior to ash and dust removal, which occurs three times per day. Indicator lights on the hopper level alarm system, hopper access doors, ESP, T-R high voltage bus duct, and localized sparking should be inspected for leaks, sparking, or arcing.

Weekly inspection and maintenance: Routine ESP maintenance tasks include checking, cleaning, or replacing T-R cabinet air filters, and inspecting circuit boards and heat sinks for dust build-up, and cleaning them, as required. A thorough assessment of rapper operation is to be conducted, ensuring that all rappers or rapper systems activate. Those not functioning require repair or replacement. Adjustments to rapper operating parameters can be made, with new settings recorded and performance closely monitored in the following week. Additionally, the maintenance routine involves checking the operating temperature and oil level in the high voltage transformer, inspecting insulator purge air and heating systems, cleaning or replacing air filters as required, and verifying insulator pressurization and heating in negative pressure systems. Access hatches are checked for air leaks, ensuring they are fully closed and locked, with the door gasket inspected for any cracks or tears.

Semi-annual inspection and maintenance: Routine maintenance and inspections for the ESP involve several critical tasks. Before entry, an air load check is conducted to confirm proper maintenance for each field. Control cabinets for rappers and T-R sets are cleaned, gaskets inspected, and switch contacts cleaned. T-R sets undergo inspection, cleaning, contact removal, and adjustments. High voltage components are checked and cleaned, with the replacement of surge arresters as needed, while bus ducts are maintained. The operation of all rappers is verified, rod connections inspected, and pneumatic systems adjusted. The ash hopper is emptied, residue removed, and level detectors inspected and repaired, as necessary, along with maintaining dust discharge valves. ESP instrumentation is calibrated, the transmissometer cleaned and realigned,

and an interior inspection conducted to identify ash build-up on electrodes. Wires and plates' alignment is checked in each field, addressing short circuits and broken wires, as well as ensuring the proper alignment of the discharge guide frame assembly. Insulators are cleaned and inspected, damaged ones replaced, and general maintenance includes checking door gaskets, inspecting ductwork, and testing transformer oil. Throughout these tasks, comprehensive written records of inspections and actions taken are meticulously maintained.

Monitoring

The voltage and amps at each T-R set are recorded hourly during ESP operation. Continuous particulate monitoring takes place via a stack Continuous Emissions Monitoring System (CEMS).