

ADVANCING TOWARD NET-ZERO: REPURPOSING DEDUSTING EXHAUST AIR FOR HYBRID AIRSLIDE CONVEYING IN CEMENT MANUFACTURING

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Abstract

The cement industry is among the most energy- and carbon-intensive sectors worldwide, contributing significantly to global CO₂ emissions through high thermal and electrical energy demands. On average, cement plants consume nearly 100 kWh of electricity per ton of cement, with a substantial portion dedicated to material handling and auxiliary systems such as airslides. Conventional airslides rely on dedicated blower fans, which add notably to a plant's overall electrical load. This study presents a hybrid airslide conveying system designed to enhance energy efficiency and support the transition toward net-zero cement manufacturing. The proposed system repurposes the exhaust airflow from dedusting units and excess blower pressure as the conveying medium for airslides, replacing the need for separate blower fans. By utilizing this secondary airflow—traditionally released into the atmosphere—the system reduces redundant electrical consumption without requiring major capital investment or structural changes. Implementation across two stages—first through dedusting stack integration and later by recovering blower discharge pressure—resulted in annual electricity savings exceeding 141,000 kWh, equivalent to Rs 2.26 million in cost reduction and a CO₂ emission decrease of approximately 29 tonnes per year per plant. Considering there are about 3,117 cement plants globally, if this approach were applied to just 80% of them, the collective impact could exceed 350 GWh of electricity savings and over 72,000 tonnes of CO₂ reduction annually. Furthermore, as several additional air-conveying systems exist within each plant, broader implementation could yield even higher savings, potentially scaling these reductions into the hundreds of thousands of tonnes of CO₂ per year worldwide. This hybrid approach therefore offers a practical, low-cost pathway toward large-scale decarbonization, aligning directly with global sustainability, energy efficiency, and circular economy goals for net-zero industrial operations..

INTRODUCTION

With rapid industrialization, global energy demand continues to rise, intensifying concerns surrounding energy security, climate change, and sustainable development [1, 2]. According to the U.S. Energy Information Administration (EIA), global energy consumption has increased significantly since 2000, reflecting the growing pressure on existing energy resources [3]. Industrial activities alone account for approximately 30–70% of total worldwide energy use, covering both thermal and electrical forms. Within this sector, the cement industry is a major consumer, utilizing nearly 75% thermal energy and 25% electrical energy, highlighting its substantial contribution to global industrial energy demand [4, 5]. Cement, with an annual global production of about 4.1 billion tons, is the second most consumed material in the world after water and serves as a major driving force behind the modernization of cities and infrastructure [6]. It enables the construction of towering skyscrapers for commercial and business purposes, creating compact urban spaces and conserving land that would otherwise be spread out more widely. Beyond buildings, cement enables the construction of bridges, seaports, and airports—critical infrastructure that facilitates the movement of people and goods and supports global trade.

However, this progress comes at a cost: cement manufacturing requires intensive energy consumption and is a major source of global CO₂ emissions [7]. On average, cement plants worldwide consume about 100 kWh of electricity per ton of cement produced [8]. Of this, nearly two-thirds is used for size reduction of raw materials and clinker, while the remaining share is consumed by rotating machinery—such as pyro-kiln drives, preheater exhaust fans, clinker cooling fans, and other auxiliary systems. A considerable portion of this energy is also devoted to material transportation within the plant.

Airslides are widely employed for transporting dry particulate materials such as cement. A typical airslide consists of a rectangular flow channel divided into two compartments: one for the particulate material and the other for the airflow that propels the material above, with a canvas cloth separating the two [9]. Airflow is particularly critical at points where material drops into the airslide, such as at chutes; without sufficient airflow, the material may choke the channel. To facilitate continuous movement, airslides are typically installed at an inclination of 2° to 6° [10]. For this conveying air, airslides conventionally rely on dedicated blower fans, which consume electrical energy and add significantly to the overall power demand of cement plants.

In light of the cement industry's substantial energy requirements and its significant share of global CO₂ emissions, there is a pressing need for innovative strategies that enhance energy efficiency without compromising production performance [11, 12]. While conventional approaches have primarily focused on optimizing individual processes or equipment, limited attention has been given to the reutilization of secondary energy streams within the plant. This research addresses this gap by investigating a hybrid system that repurposes the exhaust air from dedusting units (bag filters)—which operate with high-capacity suction fans to capture particulates and discharge cleaned air into the atmosphere—as a substitute for dedicated airslide blower fans. By channeling this otherwise wasted exhaust air into the airslides, the requirement for separate blower fans can be eliminated. Since bag filters are installed at nearly all material transfer points, including dropping chutes, or can be interconnected for multiple nearby chutes, they provide a reliable and distributed source of conveying air. This strategy not only reduces electrical energy consumption at a plant-wide scale but also contributes

to lowering associated CO₂ emissions and overall environmental footprints.

LITERATURE REVIEW

The optimization of pneumatic and airslide conveying systems has long been a central topic of research within the cement industry, primarily emphasizing improvements in energy efficiency and transport reliability [13]. Conventional airslides operate by using dedicated blower fans to supply the required airflow for material transport, typically installed at a slight inclination of 2°–6° to facilitate gravity-assisted movement. Previous studies have extensively examined aspects such as air velocity distribution, pressure drop characteristics, and the influence of fabric permeability on conveying performance [14]. However, there has been little to no focus on the potential reutilization of secondary air sources—particularly the clean exhaust air from dedusting units or bag filters—for airslide operation.

In recent years, the broader industrial sector has increasingly adopted hybrid and integrated energy recovery systems aimed at reducing overall energy consumption and minimizing CO₂ emissions [15]. Within this context, the cement industry has made significant progress in implementing waste heat recovery systems and process optimizations; nevertheless, the possibility of repurposing dedusting exhaust air for material conveying remains largely unexplored. This study aims to bridge that research gap by proposing a hybrid system that utilizes bag filter exhaust air as the conveying medium for airslides. The approach offers a novel pathway to reduce redundant blower operations, lower electrical energy consumption, and enhance plant-wide energy efficiency while contributing to sustainable cement manufacturing practices.

System Design and Methodology

The proposed hybrid airslide conveying system integrates existing dedusting exhaust air and excess blower pressure into the airslide network to minimize

redundant fan operation and optimize plant-wide energy use. The system was designed to utilize available clean exhaust air from dedusting units as the primary airflow source for airslides, effectively replacing dedicated blower fans without affecting material transport performance.

To ensure stable operation and controlled airflow distribution, manual damper valves were installed along the dedusting exhaust lines. These dampers allow operators to adjust and regulate airflow and pressure manually, ensuring that the exhaust is not fully diverted to the airslide system but controlled as per operational needs. This helps maintain steady pressure in the airslide air lines, ensuring consistent conveying efficiency.

The installation of these dampers also provides an indirect operational insight into the performance of bag filters. By observing the characteristics of the exhaust air—such as flow rate and dust content—operators can identify potential filter bag leakages or dust-carrying issues, since clean exhaust air is a sign of proper bag filter operation. This setup thus enhances both process efficiency and plant monitoring without requiring any complex instrumentation.

Dedusting Exhaust Integration

In the first stage of implementation, the clean air outlet from the dedusting units (bag filters) was redirected to supply the adjacent airslides. A dedicated duct was fabricated to connect the outlet of dedusting fan 218FA11 with the main airslide air distribution line, while exhaust from 218FA28 was used to supplement the flow for other connected slides. This arrangement enabled the shutdown of blower fans 218FA25 (4 kW), 218FA06 (7.5 kW), and 218FA05 (7.5 kW), which had previously been operating independently.

The system design ensured that airflow parameters—such as pressure, velocity, and flow rate—remained within the operational range required for stable material movement. Manual valves and dampers were

installed along the connecting ducts to regulate airflow and balance pressure fluctuations arising from dedusting fan speed variations. The design process included evaluating available airflow at the dedusting outlet, comparing it with the airslide's demand, and selecting optimal duct diameters and routing to minimize energy losses. Importantly, the airslide fabric permeability, slope (2–6°), and construction remained unchanged. The slightly elevated temperature of the dedusting exhaust air further improved material fluidity and minimized the risk of blockages, ensuring smooth and reliable conveying operation.

Blower Pressure Recovery

After validating the dedusting integration, the same principle was extended to recover excess pressure from operational blowers. For instance, the 311BL52 blower, which supplies air to the CF silo spider airslides, continuously vented excess pressure through its pressure relief valve (PRV). To harness this wasted pressure, a connecting duct was installed from the blower's discharge point to the outlet air duct of fan 311FA53 (7.5 kW). This modification enabled the complete shutdown of 311FA53 without affecting conveying performance.

Similarly, the 311BL49 blower serving the kiln feed bin exhibited comparable excess discharge pressure. This was redirected toward the air duct of fan 312FA12 (3 kW) located beneath the feed Pfister airslide. As a result, 312FA12 was also deactivated, saving additional electrical power while maintaining stable material flow.

Both modifications—dedusting exhaust reuse and blower pressure recovery—were achieved through simple duct fabrication and air balancing measures

without any major capital investment. The approach effectively recovered and reused previously wasted air energy, stabilized conveying performance, and reduced overall electrical demand for airslide operations. System monitoring during operation confirmed consistent airflow stability, indicating the robustness and reliability of the modified setup.

RESULTS AND DISCUSSIONS

The implemented system modification demonstrates the practical potential of utilizing existing dedusting exhaust air as a substitute for dedicated blower fans in airslide conveying. The project aims to minimize electrical energy consumption by redirecting the available clean exhaust air from dedusting units toward airslide systems, thereby ensuring stable material transport while reducing redundant fan operation. The modification involves minor duct fabrication and interconnection between blower discharge lines and dedusting exhaust outlets, ensuring smooth airflow transition and minimal pressure losses.

Case 1: Dedusting Stack Integration with Multiple Airslides

In the first stage, dedusting exhaust air was harnessed to supply airflow to several airslides, replacing the need for separate blower fans. Exhaust from dedusting fans 218FA28 (11 kW) and 218FA11 (15 kW) was redirected through newly fabricated ducts and connected to the main airslide distribution network. This modification provided adequate air volume and pressure for stable conveying, allowing the shutdown of blower fans 218FA25 (4 kW), 218FA06 (7.5 kW), and 218FA05 (7.5 kW). The integration ensured efficient reuse of available clean air while maintaining uniform flow conditions across all connected slides.

Table 1: *Energy savings and CO₂ reduction achieved through dedusting exhaust integration with multiple airslides (Case 1).*

Fan ID	Type	Rated Power (kW)	Est. Operating Power (kW)	Annual Energy Saved (kWh)	Annual Cost Saving (Rs)	CO ₂ Reduction (kg)	CO ₂ Reduction (t)
218FA25	Blower	4	3.2	23,822	381,152	4,935	4.94
218FA06	Blower	7.5	4.5	33,372	533,952	6,910	6.91
218FA05	Blower	7.5	4.5	33,281	532,499	6,890	6.89
Total	–	–	–	≈ 90,475	≈ 1,447,600	18,735	18.7

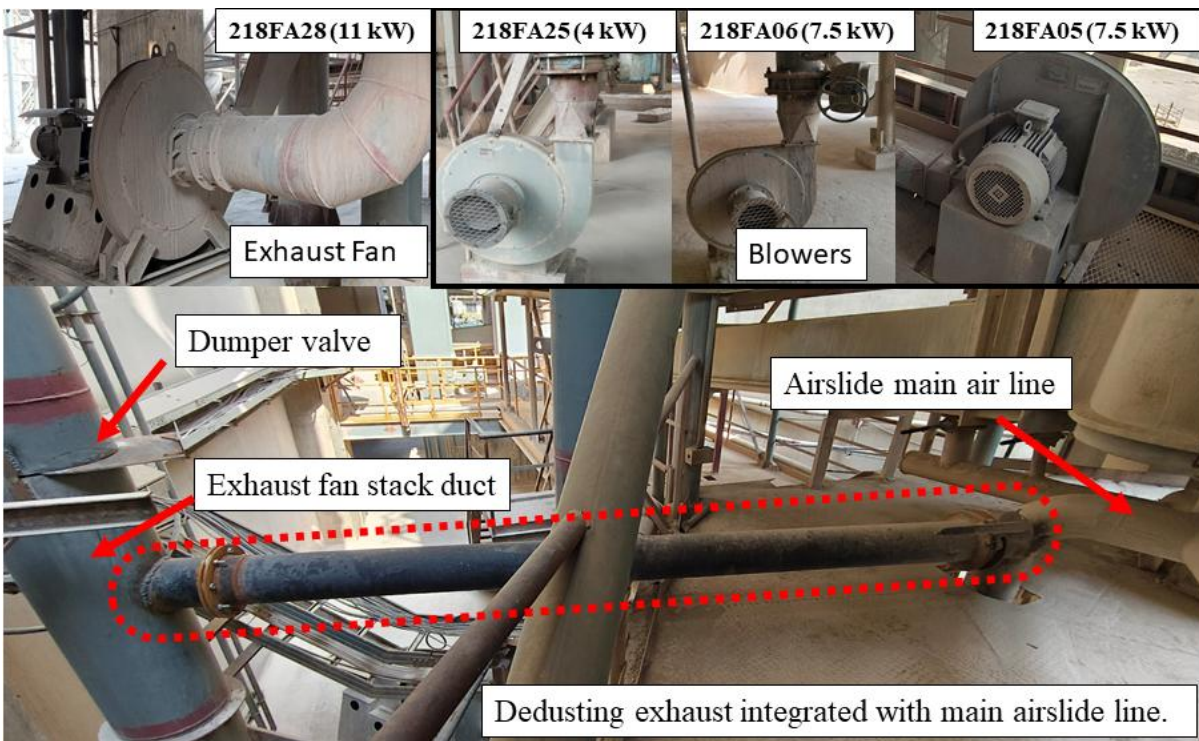


Fig. 1 Actual plant layout showing the connection of dedusting fan 218FA28 to the main airslide pipeline, along with blower fans 218FA25, 218FA06, and 218FA05, highlighting the modified airflow integration and fan tagging.

The integration of dedusting exhaust fans successfully replaced three blower units, resulting in an annual electricity saving of approximately 90,475 kWh. At an average tariff of Rs 16 per kWh, this translates to Rs 1.45 million in annual cost savings and a reduction of about 18.7 tonnes of CO₂ emissions per year.

Remarkably, this level of reduction was achieved through minimal system modifications and without any major capital investment. If similar integrations were extended across all available dedusting exhausts and air-conveying systems in the plant, the cumulative energy and environmental impact could reach significantly higher levels—potentially amounting to CO₂ reductions in the order of hundreds of tonnes annually, contributing meaningfully to large-scale decarbonization goals.

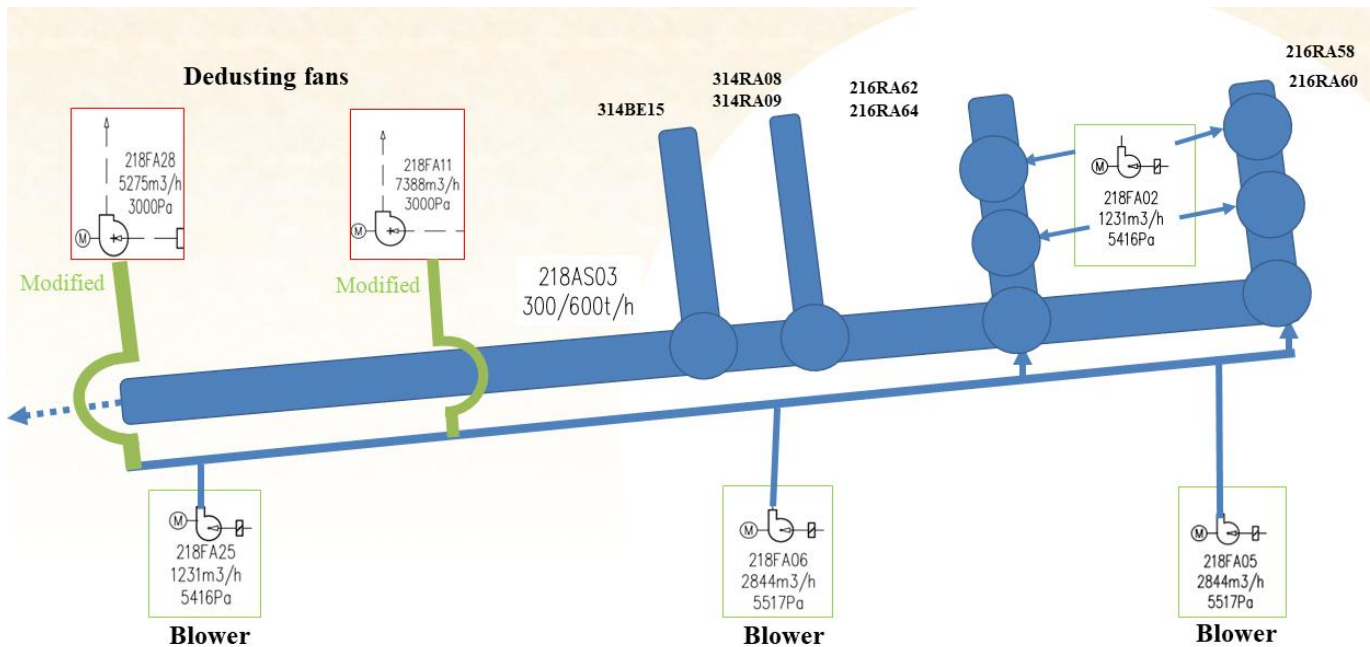


Fig. 2 Integration of dedusting exhaust lines with the main airslide pipeline showing all modified connections for hybrid airslide conveying.
Case 2: Integration of 311BL52 and 311BL49 Systems

Following the success of the dedusting integration, the same concept was applied to the 311BL52 and 311BL49 blowers, where excess pressure was observed being continuously vented through pressure relief valves (PRVs). By installing a connecting duct between the discharge of blower 311BL52 and the outlet air duct of fan 311FA53, and similarly rerouting pressure from blower 311BL49 toward the 312FA12 airslide, the redundant blower fans were eliminated.

Table 2: *Energy savings and CO₂ reduction achieved through blower pressure recovery and airlide integration (Case 2).*

Parameter	Fan 311FA53	Fan 312FA12	Total
Rated Motor Power (kW)	7.5	3	–
Operating Power (kW)	4.5	2.4	–
Operating Days (2024–25)	309	309	–
Annual Energy Consumption (kWh)	33,372	17,798	51,170
Electricity Tariff (Rs/kWh)	16	16	–
Annual Energy Cost Saving (Rs)	533,952	284,768	818,720
CO ₂ Emission Factor (kg/kWh)	0.20707	0.20707	–
CO₂ Reduction (tonnes/year)	6.91	3.69	10.6

This configuration achieved an estimated annual energy saving of 51,170 kWh, equivalent to Rs 818,720 in cost reduction and a CO₂ footprint reduction of 10.6 tonnes per year. Operational data confirmed that the airlides functioned reliably after the modification, with consistent flow and pressure, validating the efficiency and stability of the air reuse design.

Both implementation phases clearly demonstrate that reusing dedusting exhaust and excess blower air can deliver substantial energy and environmental benefits with minimal system changes. Combined, the two cases resulted in annual energy savings exceeding 141,000 kWh, cost savings of over Rs 2.26 million, and a CO₂ emission reduction of approximately 29 tonnes per year. These outcomes confirm that even small, localized modifications—such as duct interconnections and airflow balancing—can produce significant efficiency improvements.

Moreover, the broader potential of this concept is considerable. If similar integrations were applied across all dedusting exhausts and air-conveying networks throughout the plant, the cumulative impact could lead to CO₂ reductions in the range of hundreds or even thousands of tonnes annually, representing a transformative opportunity for large-scale energy optimization and decarbonization in the cement industry. The approach thus not only supports operational cost reduction but also aligns strongly with

the plant's sustainability goals and global CO₂ reduction commitments.

CONCLUSIONS AND RECOMMENDATIONS

The implemented hybrid airlide conveying system—repurposing exhaust air from dedusting units and excess blower pressure as the conveying medium—demonstrates a practical and sustainable approach to improving energy efficiency in cement manufacturing. By leveraging existing plant infrastructure and redirecting clean exhaust air toward nearby airlides, the system effectively eliminates the need for dedicated blower fans without requiring significant capital investment or process interruption.

The two-phase implementation, beginning with dedusting stack integration and later expanding to include the recovery of blower discharge pressure, proved both reliable and impactful. Together, these modifications delivered annual energy savings exceeding 141,000 kWh, cost reductions of more than Rs 2.26 million, and a CO₂ emission decrease of approximately 29 tonnes per year. These results validate the effectiveness of secondary airflow reutilization as a means of achieving tangible environmental and economic gains with minimal system modification.

Importantly, this initiative highlights a scalable opportunity for larger sustainability impact. If similar exhaust-air integrations were extended to all dedusting and air-conveying systems across the plant, the

cumulative effect could translate into CO₂ reductions reaching hundreds or even thousands of tonnes annually, aligning closely with global decarbonization and circular economy goals.

The approach stands out for its simplicity, low implementation cost, and adaptability, making it an ideal model for replication across the cement industry. Future advancements should emphasize automated airflow control, digital monitoring, and predictive performance management to further enhance efficiency, reliability, and system responsiveness under varying operating conditions.

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