The Danish Energy Agency

Anonymous Audit Report from a Granite tile manufacturing company

ENERVI Vietnam Energy and Environment Joint Stock Company, 16/04/2026

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Introduction to the context

On March 13, 2019, the Decision No. 280/QD-TTg on approval of the National Energy Efficiency Programme (VNEEP) for the period of 2019-2030 was issued by the Prime Minister.

The VNEEP implements synchronously activities in the field of economical and efficient use of energy, showing commitments of all levels of government, associations, businesses, organizations, individuals to energy efficiency in particular and to climate change resilience and environmental protection in general.

The Vietnam-Denmark Energy Partnership Program Phase 3 (DEPP3) for the period 2020-2025 implement a number of activities, making substantial and effective contributions to help Vietnam's energy sector transition towards green growth, reduce carbon emissions through the development of a green energy system, operate a flexible power system, efficiently enforce policies and measures promoting energy efficiency and conservation.

One of the very important activities of promoting energy efficiency through Energy Audit in a broad variety of industrial sectors in Vietnam.

This document contains an anonymised summery of a specific energy audit report conducted as a part of the DEPP3 program. The audit has been conducted on a granite tile production plant, by ENERVI Vietnam Energy and Environment Joint Stock Company, in collaboration with an international expert from Viegand Maagøe.

Summary

This is a granite tile manufacturing plant operating large-scale, continuous production lines with a high level of automation. The plant produces high-quality granite tiles for both domestic and export markets, with production processes characterized by intensive use of thermal and electrical energy.

The high-quality energy audit assessed all major energy-consuming and energy-generating systems within the plant, including production equipment and utility systems. The audit identified energy consumption patterns, key performance indicators (KPIs), and operational characteristics of major processes such as wet grinding, spray drying, pressing, drying, firing, and polishing. Based on these findings, the audit team developed energy efficiency (EE) measures to improve energy performance while ensuring both technical feasibility and financial viability.

The audit focused on key energy systems and processes, including:

- ***Electricity:*** used extensively across the production line, including ball mills, spray drying fans, presses, conveyor systems, and utility systems such as air compressors, pumps, lighting and cooling;
- ***Thermal energy (LPG/CNG):*** primarily used in kiln and drying systems for granite tile firing and drying processes;
- ***Coal (gasification system):*** used to generate producer gas supplying heat to the spray drying process;
- ***Compressed air system:*** serving multiple production stages, including control systems, cleaning, and automation equipment;
- ***Waste heat flows:*** particularly from kiln exhaust and spray drying systems, representing significant opportunities for heat recovery.

Through on-site measurements, energy mapping, and data analysis, the audit team identified major energy-consuming areas and quantified energy losses. Key approaches included load profiling, flue gas analysis, surface temperature measurement, and evaluation of system efficiencies. The energy mapping played a critical role in identifying high-impact areas such as the kiln system, spray dryer, and compressed air system.

Based on the analysis, a range of energy efficiency opportunities were identified, including both management and technical solutions. These include improvements in energy management systems, optimization of compressed air systems, installation of advanced control systems, waste heat recovery, and fuel switching solutions. The proposed measures demonstrate significant potential for energy savings, cost reduction, and CO_2 emission mitigation.

Table 1. Summary of proposed EE measures

No.	List of proposed EE measures
I. Management measures	
1	Enhance the Energy Management System (EnMS) in compliance with ISO 50001:2018
2	Implement an Energy Monitoring and Management System (EMMS)
II. Technical measures	
3	Detect and repair compressed air leakages
4	Improve ventilation and cooling for the air compressor station
5	Install a central control system with integrated VFDs for air compressors
6	Recover waste heat from the inlet of the kiln for combustion air preheating
7	Convert the coal gasification system to a biomass-based combustion system
8	Install an advanced combustion monitoring and control system for the kiln
9	Install an active harmonic filtering system (AccuSine PCS+)
10	Install an on-grid solar PV system with load-following control
III. Recommended measures	
11	Replace ball mills with vertical roller mills (VRM)
12	Utilize waste heat from spray dryer exhaust to preheat slurry
13	Replace low-efficiency motors with IE4 high-efficiency motors

These identified EE measures were evaluated in terms of energy savings, financial benefits, and implementation feasibility. Based on their impact, investment requirements, and alignment with the company's operational strategy, priority projects were selected to form a structured roadmap for future energy efficiency improvements. The combined implementation of these measures is expected to achieve total energy savings of approximately 30,553,490 kWh, mainly from reductions in coal and LPG consumption through biomass conversion, waste heat recovery, and improved kiln operation along with additional electricity savings from compressor and electrical system optimization. The overall environmental benefits is an estimated emission reduction of around 13,278 tCO_2.

1 About the enterprise

The audited enterprise is a large-scale manufacturer in the construction materials sector, specializing in the production of high-quality granite tiles for both domestic and export markets. The plant operates modern, integrated production lines with a high level of automation and applies advanced technologies throughout the manufacturing process to ensure product quality, consistency, and efficiency.

The production process includes key stages such as wet grinding, spray drying, pressing, drying, firing in kilns, and polishing. Granite tiles are produced from high-quality raw materials and undergo high-temperature firing processes, resulting in products with superior mechanical strength, durability, and aesthetic properties that meet stringent requirements of modern construction applications.

In addition to the main production lines, the facility includes supporting workshops and utility systems necessary for continuous operation. These include raw material handling and storage, compressed air system, gasification system, and internal logistics. The plant operates continuously with multiple shifts, reflecting the energy-intensive nature of the production process.

Major utility systems play a critical role in the plant's operation, including electrical systems supplying power to production equipment, compressed air systems for process and control applications, and thermal energy systems. Thermal energy is primarily used in spray drying and kiln operations, supplied through a combination of fuel-based systems such as LPG/CNG-fired kilns and coal gasification units. Supporting systems such as lighting, cooling & ventilation, and internal transport equipment also contribute to overall energy consumption.

Due to the continuous operation and high thermal and electrical energy demand of key processes, particularly spray drying, kiln firing, and compressed air systems, the enterprise is characterized by significant energy consumption. At the same time, this creates substantial potential for energy efficiency improvements through process optimization, system upgrades, and waste heat recovery solutions.

1.1 Description of the company

- Sector: Granite tile manufacturing
- Main raw materials:
  - Raw kaolin F6A: 6,289,740 tons/year;
  - Clay T12: 8,018,517 tons/year;
  - Hoang Anh kaolin C31: 2,754,332 tons/year;
  - Kaolin C33: 1,962,807 tons/year;
  - Finished Product F6D: 1,244,803 tons/year;

        - Finished product F28A: 1,465,999 tons/year.
    - Main products:
        - Inkjet 600×600: 271,865 m^2 /year;
        - Granite 600×600: 235,010 m^2 /year;
        - Granite 800×800: 841,651 m^2 /year;
        - Inkjet 300×600: 170,228 m^2 /year;
        - Inkjet 150x900: 68,279 m^2 /year.
    - Annual energy total consumption in 2025:
        - Electricity:
            - Grid: 9,490,800 kWh, equivalent to 1,464 TOE, 9,491 MWh;
            - Rooftop Solar: 0 kWh
            - Co-generation: 0 kWh
        - Diesel oil (DO): 519,172 kWh, equivalent to 39 TOE, 519 MWh
        - Coal: 21,663,184 kWh, equivalent to 2,425 TOE, 21,663 MWh
        - LPG/CNG: 36,612,480 kWh, equivalent to 3,118 TOE, 36,612 MWh
    - Annual carbon footprint: Approximately 23,900 tCO_2

To further support the description of the company's energy profile, energy mapping was conducted to analyze the distribution of electricity consumption, thermal energy use, and waste heat potential across the main production processes and utility systems.

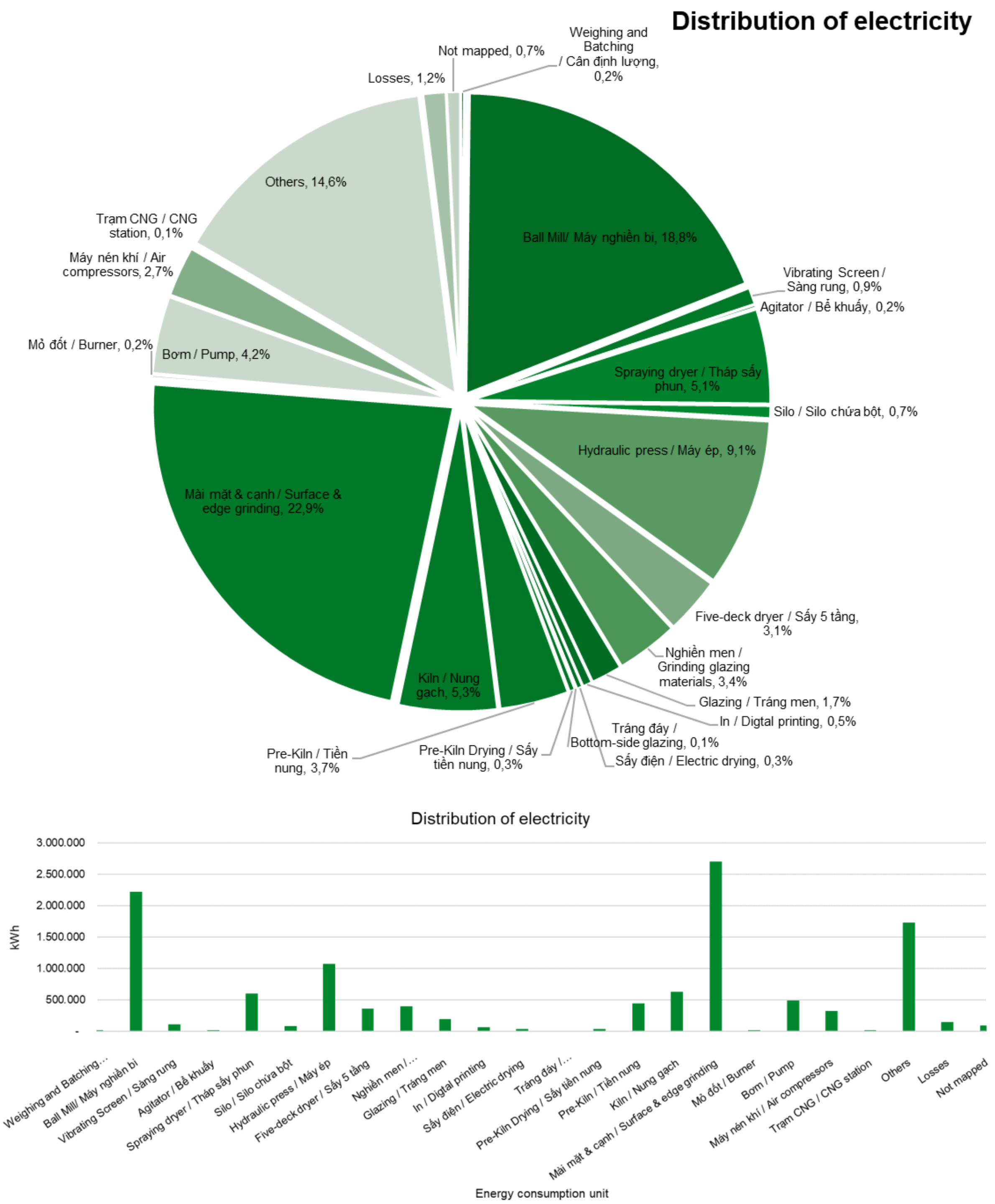


Figure 1. Electricity distribution in the production line

The electricity consumption is mainly concentrated in core production processes. The largest consumers are:

- Surface and edge polishing (~22.9%);
- Ball mills (~18.8%);
- Hydraulic pressing (~9.1%);
- Spray drying (~5.1%);

- Kiln systems (~5.3%).

Electricity consumption is dominated by mechanical and material processing stages, particularly grinding and milling. This reflects the energy-intensive nature of raw material preparation and finishing processes in granite tile manufacturing. Therefore, improving motor efficiency, optimizing polishing systems, and reducing idle loads represent key opportunities for electrical energy savings.

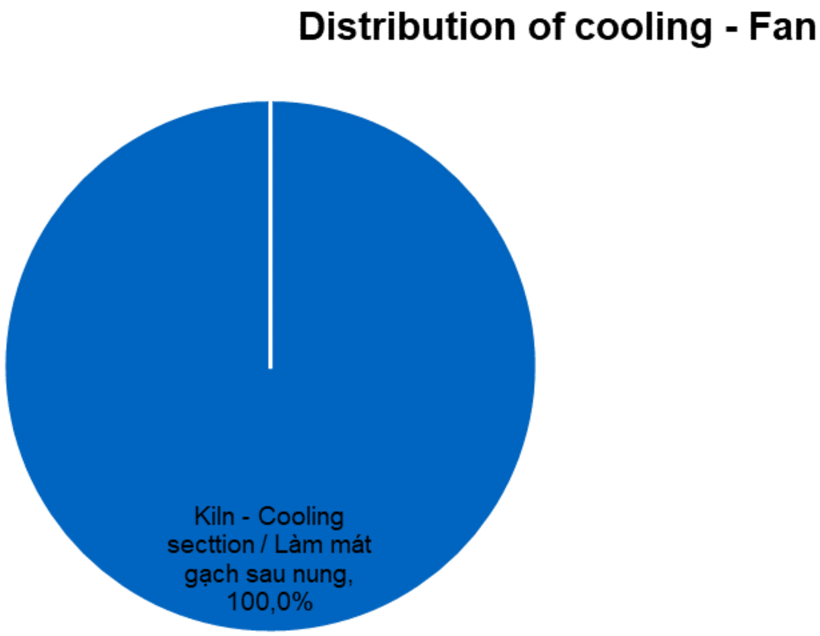
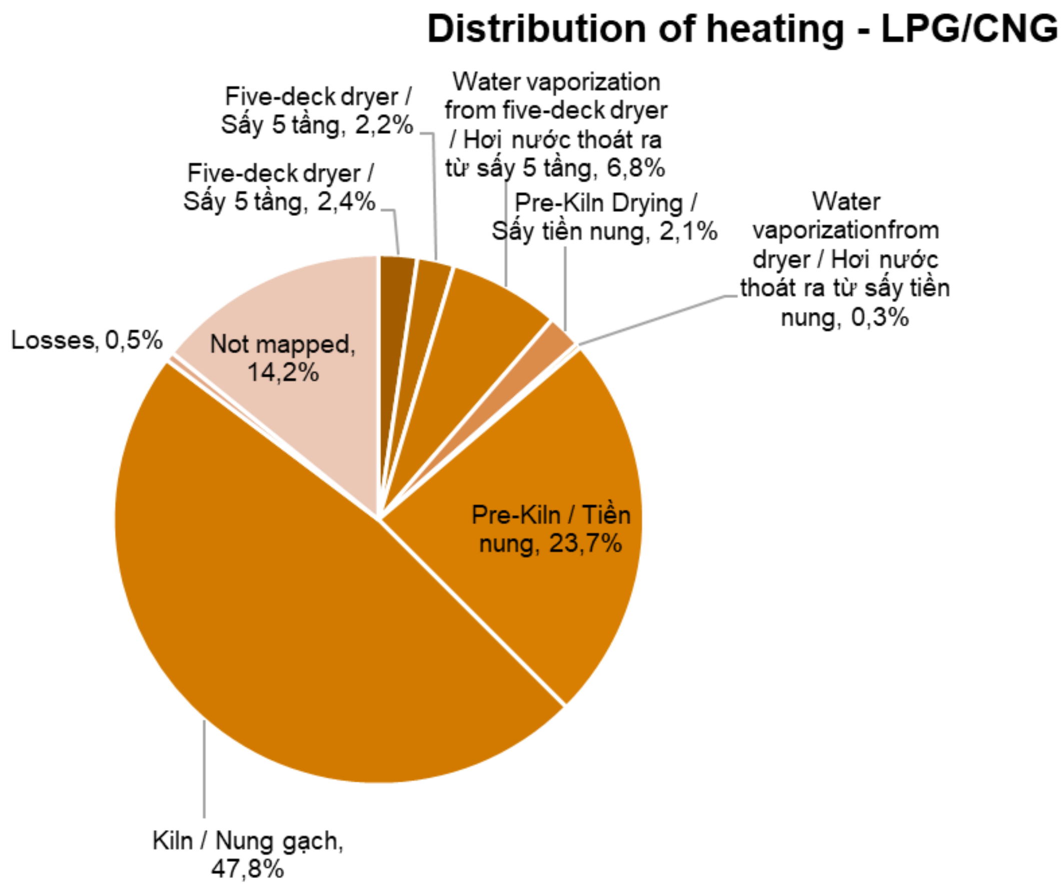


Figure 2. Cooling distribution in the production line

This indicates that the cooling demand is entirely driven by kiln operation. Since kiln cooling is essential for product quality, energy-saving measures should focus on fan efficiency, airflow optimization, and control strategies (e.g., VFDs) rather than load reduction.



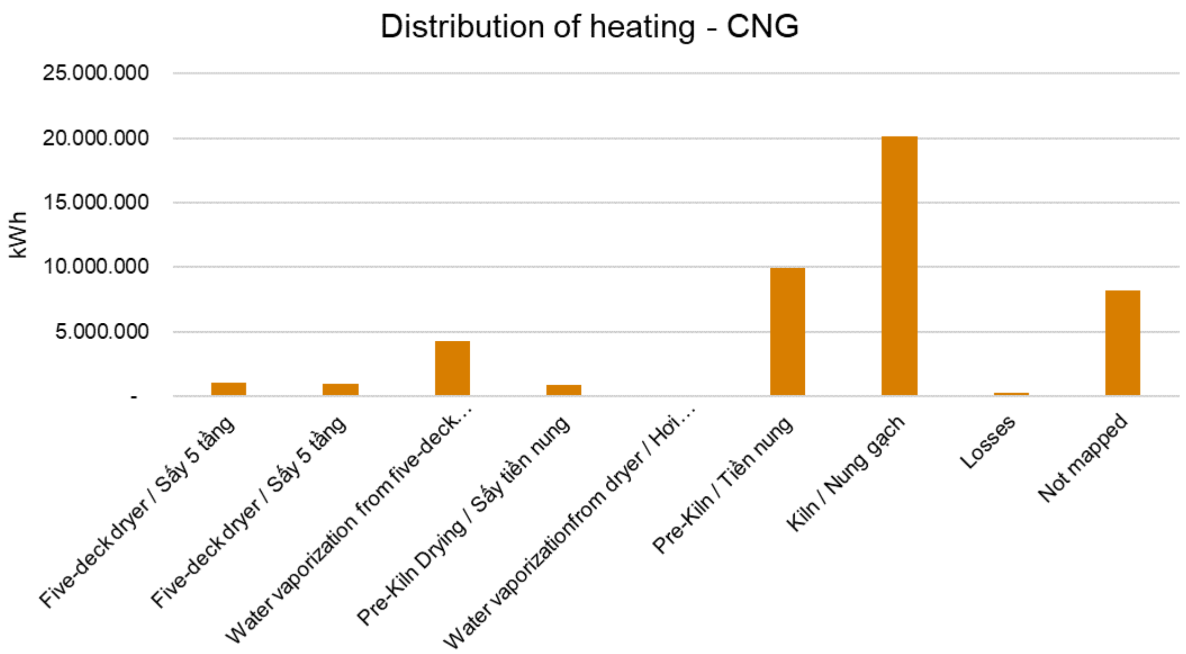


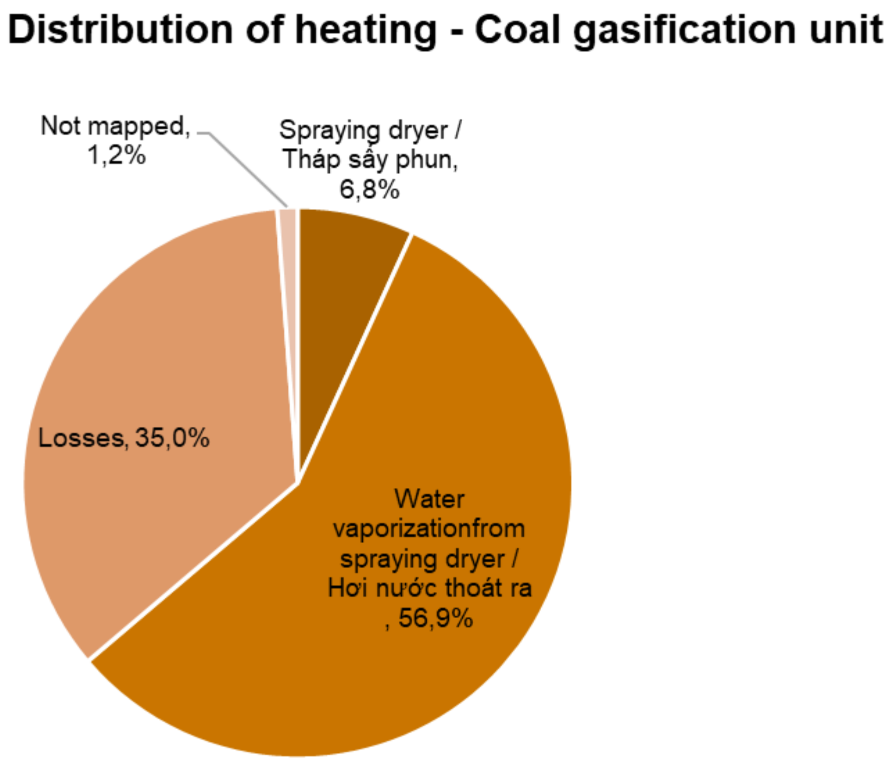
Figure 3. LPG/CNG distribution in the production line

The thermal energy supplied by LPG/CNG is mainly used in:

- Kiln firing (~47.8%);
- Pre-kiln drying (~23.7%);
- Remaining energy is distributed across drying processes and heat losses.

The kiln is the dominant thermal energy consumer, followed by drying processes. This confirms that high-temperature processes are the main drivers of fuel consumption. Significant energy-saving potential lies in:

- Combustion optimization;
- Heat recovery from exhaust gases;
- Improved insulation and process control.



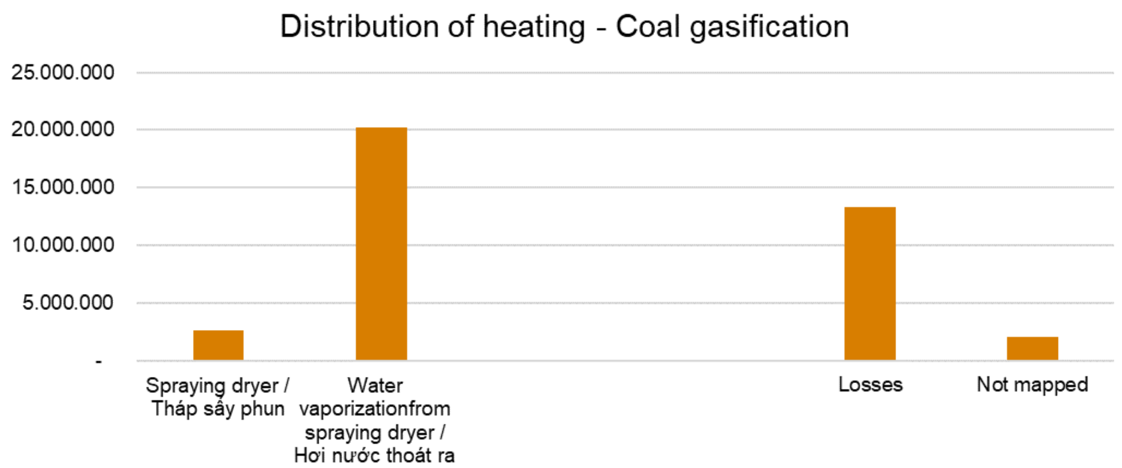


Figure 4. Coal gasification distribution in the production line

A large portion of energy is lost as heat, indicating low overall thermal efficiency of the system. The spray drying process is highly energy-intensive due to moisture evaporation. This suggests strong potential for:

- Waste heat recovery;

- Improved insulation;
- Process optimization in spray drying.

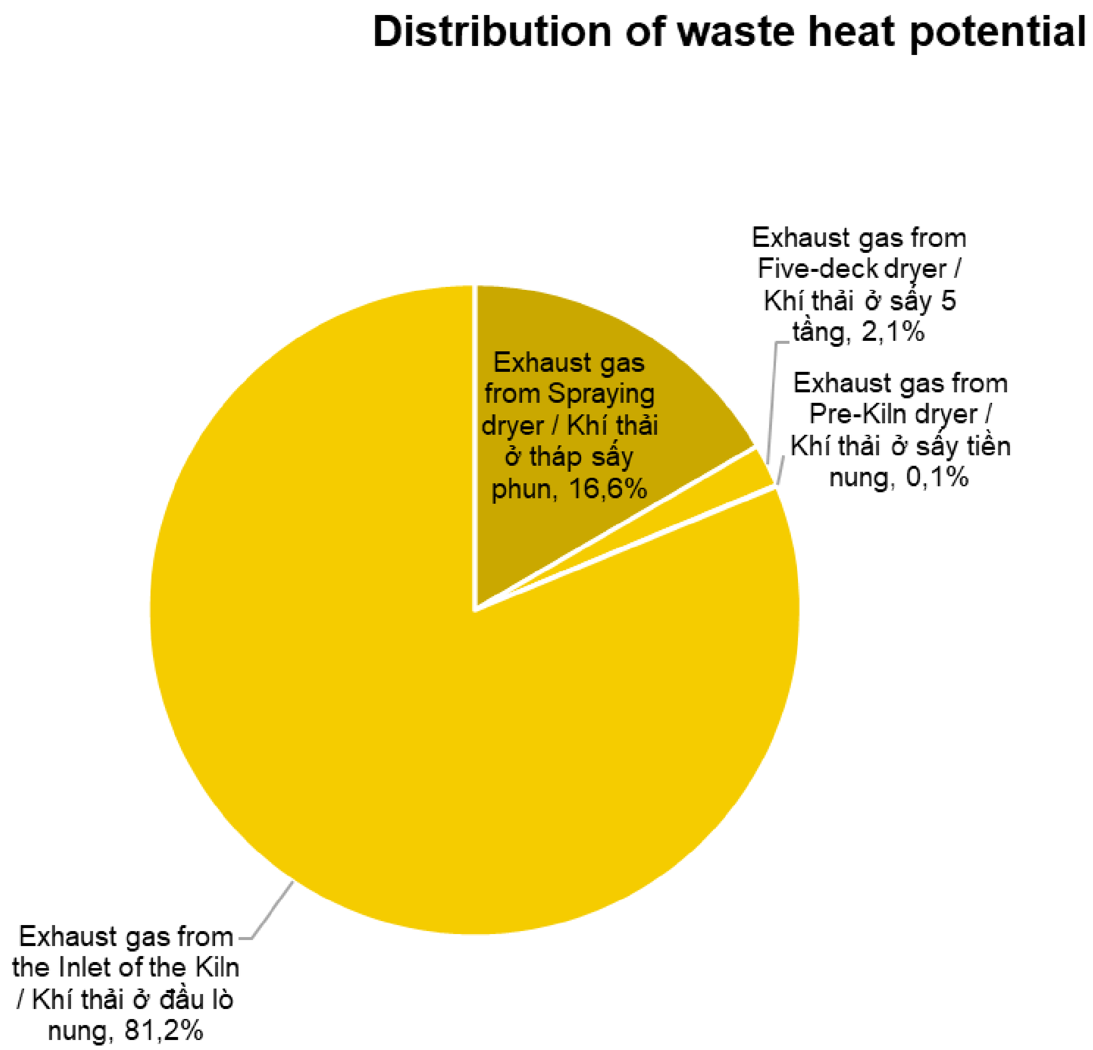


Figure 5. Waste heat potential distribution in the production line

The waste heat analysis shows:

- Kiln exhaust gas (~81.2%) is the largest recoverable heat source;
- Spray dryer exhaust (~16.6%) is the second major source;
- Other sources are negligible.

The kiln exhaust represents the most significant opportunity for heat recovery in the plant. Recovering waste heat from kiln exhaust for reuse (e.g., combustion air preheating or drying processes) can yield substantial energy savings and emission reductions.

1.2 Description of the process

The audited enterprise operates an integrated granite tile manufacturing line with a high level of automation. The plant converts mineral raw materials into finished granite tiles through a continuous sequence of material preparation, shaping, thermal treatment, surface finishing, and packaging. In practice, the factory operates as one main production flow supported by several utility systems and 02 kilns, with energy-intensive sub-systems concentrated in spray drying, pressing, drying, and polishing.

- Input Materials: Clay, Kaolin, Feldspar;
- Output product: Granite tiles;
- Main energy sources used: Electricity, coal-based producer gas, LPG/CNG.

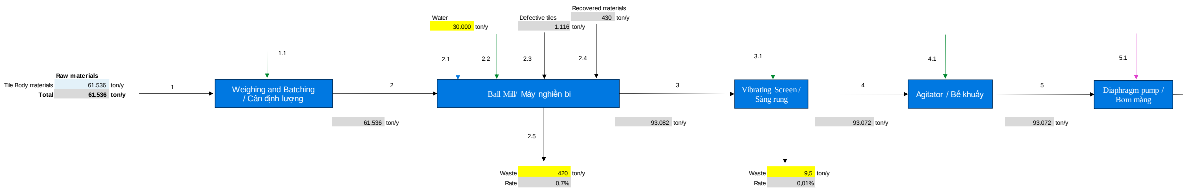


Figure 6. Mass Flow Balance Diagram (1)

The production process begins with raw material preparation, where clay, kaolin, feldspar, and other additives are received, stored, and proportioned accordin g to the batch formula. The materials are then fed to the ball mills for wet grinding and homogenization.

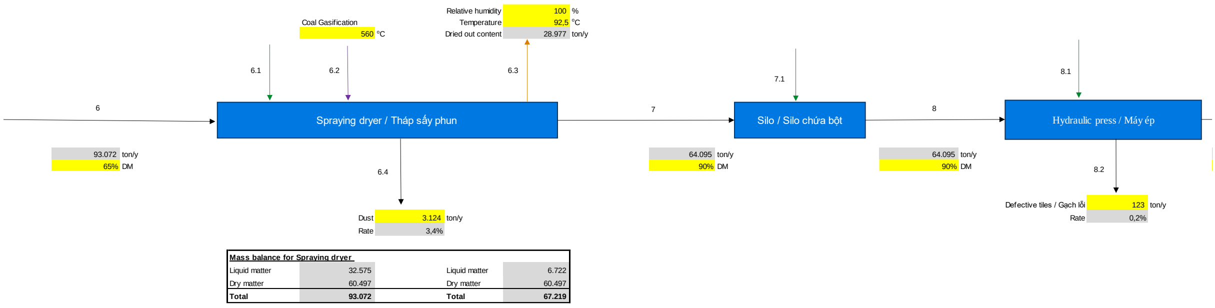


Figure 7. Mass Flow Balance Diagram (2)

After grinding, the slurry is screened, mixed in agitation tanks, and pumped to the spray drying tower, where it is converted into powder with a controlled moisture content suitable for pressing. The dried powder is stored in silos and transferred to the pressing section. Here, the powder is automatically dosed into hydraulic presses to form green tiles.

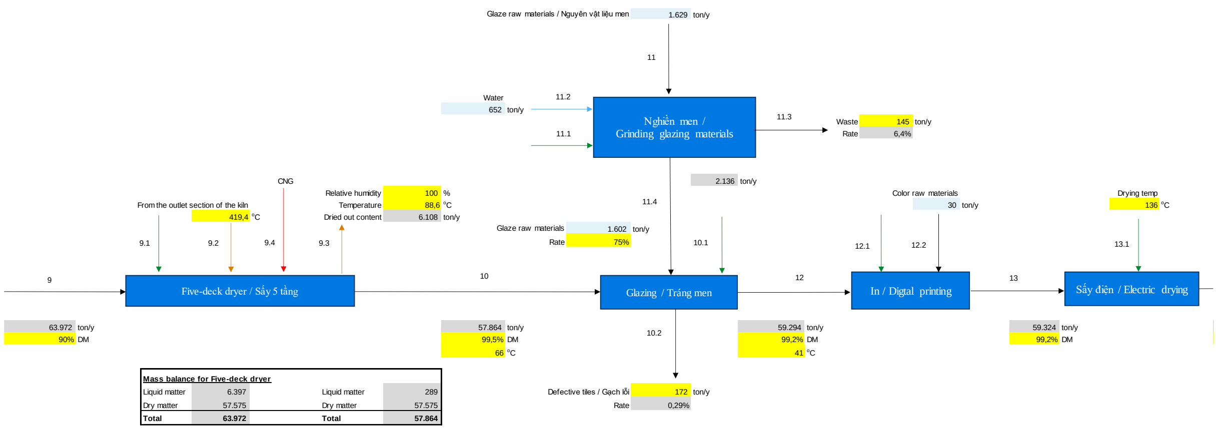
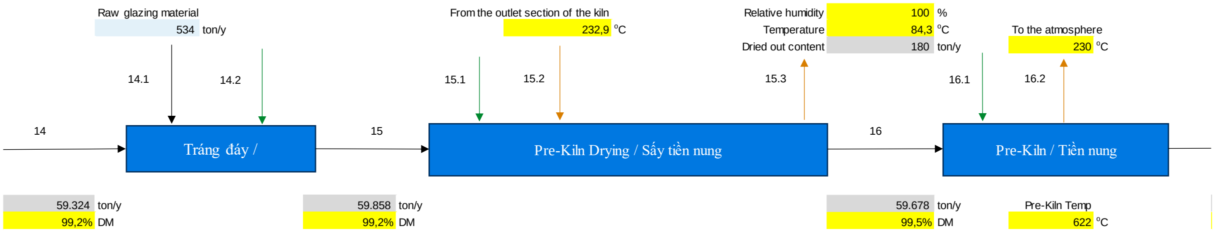


Figure 8. Mass Flow Balance Diagram (3)

The green tiles are then dried in the five-deck dryer and related pre-kiln drying stages to remove residual moisture and improve mechanical strength before firing. After drying, the tiles proceed to the glazing and decoration section, where glaze is applied and digital printing is used to create the final surface pattern.



Mass balance for Pre-Kiln Drying			
Liquid matter	479	Liquid matter	298
Dry matter	59.379	Dry matter	59.379
Total	**59.858**	**Total**	**59.678**

Figure 9. Mass Flow Balance Diagram (4)

The glazed tiles are then fired in roller kilns using LPG/CNG, passing through preheating, firing, and cooling zones. The kiln system is the main thermal process in the plant and operates continuously to ensure product quality and stable output.

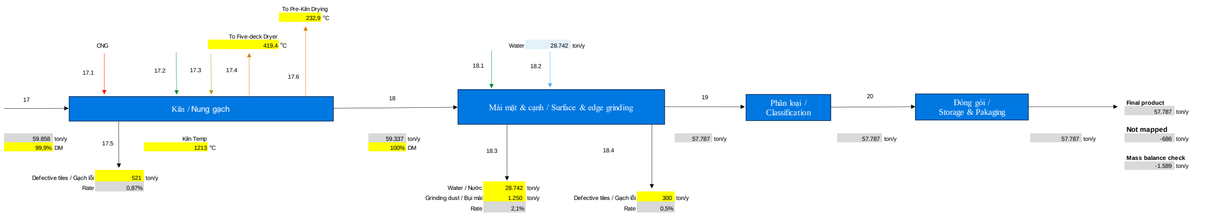


Figure 10. Mass Flow Balance Diagram (5)

After firing, the tiles are transferred to the finishing section, where they undergo surface & edge grinding, polishing, sorting, packing, and warehousing.

1.3 Description of the utility systems

The plant operates 02 main utility systems that are essential to stable production: the compressed air system and the coal gasification system. These systems support both mechanical operation and thermal processing across the production line. The compressed air system mainly serves pneumatic equipment, lifting functions, and control mechanisms, while the coal gasification system supplies hot gas to the spray drying tower. Both systems operate under continuous industrial conditions and have a direct influence on production stability and energy consumption.

1.3.1 Compressed air system

The company’s compressed air system consists of 02 compressor stations with a total of 08 screw-type air compressors. The compressors operate alternately depending on production demand and are equipped with receivers, filters, and air dryers. However, there is currently no compressed air flow metering system installed, so system operation is mainly monitored through pressure gauges and operator observation.

The main technical characteristics of the compressors are summarized as follows:

Table 2. Air compressor specifications

No.	Air Compressor	Type	Rate Power *(kW)*	Capacity *(m^3/min)*	Operating Hours *(hr/day)*
1	Air Compressor No. 1 – Polishing Workshop	Screw type	55	9.2	16
2	Air Compressor No. 2 – Polishing Workshop	Screw type	37	6.3	16
3	Air Compressor No. 3 – Polishing Workshop	Screw type	75	11	16
4	Air Compressor No. 4 – Polishing Workshop	Screw type	37	6.3	16
5	Air Compressor No. 1 – M&E Workshop	Screw type	37	6.3	16
6	Air Compressor No. 2 – M&E Workshop	Screw type	37	6.3	16
7	Air Compressor No. 3 – M&E Workshop	Screw type	37	6.3	16
8	Air Compressor No. 4 – M&E Workshop	Screw type	37	6.3	16

All compressors are equipped with variable frequency drives (VFDs) and operate within preset pressure ranges. However, the compressors are controlled independently and there is no centralized control system. As a result, system optimization depends largely on manual intervention by operating personnel.

Figure 11. Energy balance in the compressed air system

The compressed air system primarily supports lifting mechanisms, pneumatic control devices, and production-line actuators. Stable pressure supply is essential for continuous operation, but the current arrangement would benefit from improved flow monitoring and centralized control.

1.3.2 Coal gasification system

The coal gasification furnace is the plant's main thermal utility system for supplying hot gas to the spray drying tower. The system uses lump coal grade 4B as fuel and has an average production capacity of approximately 5,000 m³/h. The produced gas is used directly as fuel for the combustion chamber of the spray drying tower.

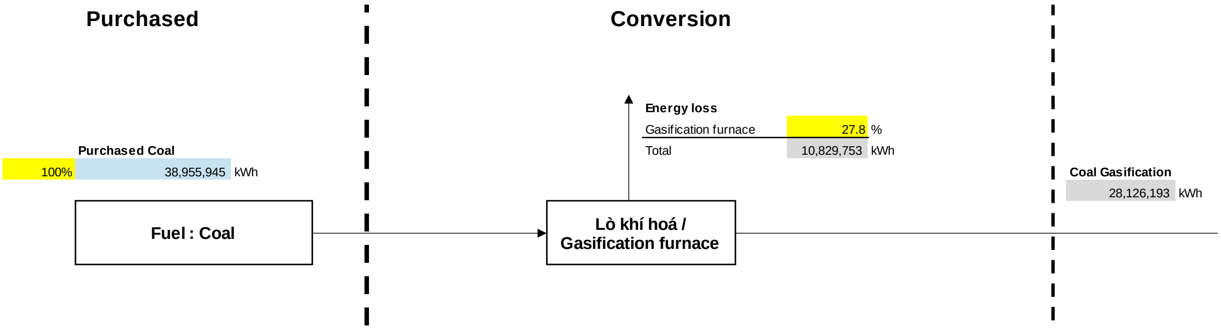


Figure 12. Energy Balance in coal gasification system

The furnace operates at a temperature of approximately 400 – 500°C. Coal is fed from the top of the furnace at intervals of around 45 – 60 mins/batch, depending on the amount of coal in the furnace and the steam and air supplied. The furnace operates in a semi-automatic mode, which means several operating steps are still performed manually. In particular, the water supply pump to the steam drum is monitored by sight glass and switched on and off manually.

The audit team observed that the gasification system has several technical limitations that affect energy performance and operational reliability:

- The system doesn't include a gas washing or cleaning stage;
- Several furnace wall locations exhibit high surface temperatures, resulting in avoidable heat losses;
- The steam drum and steam valves are not insulated, which increases thermal losses and may create safety risks;
- The manual control of steam drum water level indicates that the system would benefit from automatic control instrumentation, ideally through a PLC-based control system.

The coal gasification system supplies hot gas to the spray drying tower, which is one of the most energy-intensive processes in the plant. Because the system supports a critical thermal process, its performance has a direct impact on the efficiency of the spray dryer and overall fuel consumption. The audit concluded that insulation improvement, automatic control, and operating optimization would provide meaningful energy-saving potential.

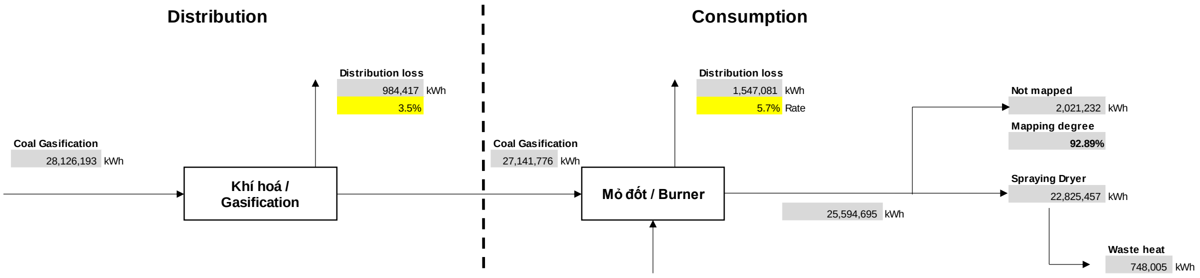


Figure 13. Energy balance in the spray drying tower

The main end-user of this system is the spray drying tower combustion chamber, which requires a stable hot gas supply for the drying process. The gasification furnace therefore plays a central role in maintaining the correct thermal conditions for powder production.

2 Methodology used to identify EE projects

2.1 How EE projects have been identified and developed

The energy audit was carried out in accordance with Circular No. 25/2020/TT-BCT, "Regulations on Planning and Reporting the Implementation of Energy Efficiency and Conservation Plans; Conducting Energy Audits", and it was further developed following the additional methodological requirements set out in the DEPP3 Energy Audit Guideline. While Circular 25 defines the core structure and content of the report, the energy audit guideline expands the methodology by requiring a clearer explanation of project identification, energy mapping, process analysis, and the selection of energy efficiency opportunities for further development.

The audit covered the company's main production and utility systems, including raw material grinding, spray drying, pressing, pre-kiln drying, kiln firing, surface polishing and finishing, compressed air, and the coal gasification system. These areas were selected because they represent the main energy-consuming stages of the granite tile production line and therefore offer the greatest potential for energy savings.

Project identification was based on a combination of document review, site inspection, interviews with operational staff, and on-site measurements. The audit team collected production data, utility operating data, electricity and fuel consumption records, and technical information on the main equipment. Where utility data were not directly available, the team used measurements, energy balances, and engineering calculations to estimate consumption by process and by system. This approach is consistent with the energy audit guideline, which emphasizes the use of process-level energy mapping, temperature analysis, thermal and electrical loss analysis, and quantitative SEC indicators to identify improvement opportunities.

Table 3. List of Measuring Equipment

No.	Equipment	Model	Quantity	Origin
1	Kyoritsu Power Analyzer	KEW6315	01	Japan
2	Power Meter	KEW6305	02	Japan
3	Power Analyzer	ME440	04	Taiwan
4	Power Analyzer	PEL 103	01	France
5	Clamp Meter Kaise	SK – 7615	01	Japan
6	Lux Meter – Light meter	LX –1102	01	Taiwan
7	Infrared thermometer	Cole – Parmer 800	01	USA

No.	Equipment	Model	Quantity	Origin
8	Microcomputer thermometer	HI 9050	01	Singapore
9	Infrared Thermal Camera	Testo 871	01	Germany
10	Boiler/Kiln Flue Gas Analyzer	Sauermann SICA 230	01	France
11	Compressed Air Leak Detector	Leakshooter V3 Pro	01	USA
12	Steam Trap Tester	Leakshooter V3 Pro	01	USA

Energy mapping was used as the main analytical tool to identify the major energy-consuming processes and the corresponding waste heat and loss streams. For this plant, the mapping showed that electricity use is concentrated in surface & edge polishing, ball mills, hydraulic presses, spray drying tower, and auxiliary drives, while thermal energy use is concentrated in the kiln, pre-kiln drying, spray drying tower, and coal gasification system. The mapping also highlighted recoverable heat from kiln exhaust gas and spray dryer exhaust, which supports the identification of high-priority heat recovery projects.

In line with the DEPP3 methodology, the audit team also applied the Onion Diagram approach to structure the analysis from the outer layers of management and operation down to the core process and energy service. This helped determine whether opportunities should be pursued through improved housekeeping, better operation and maintenance, process modification, equipment upgrade, control optimization, or energy supply-side changes. The guideline specifically notes that the potential should be examined step by step, starting from the process need and then testing whether the same service can be delivered with lower energy input.

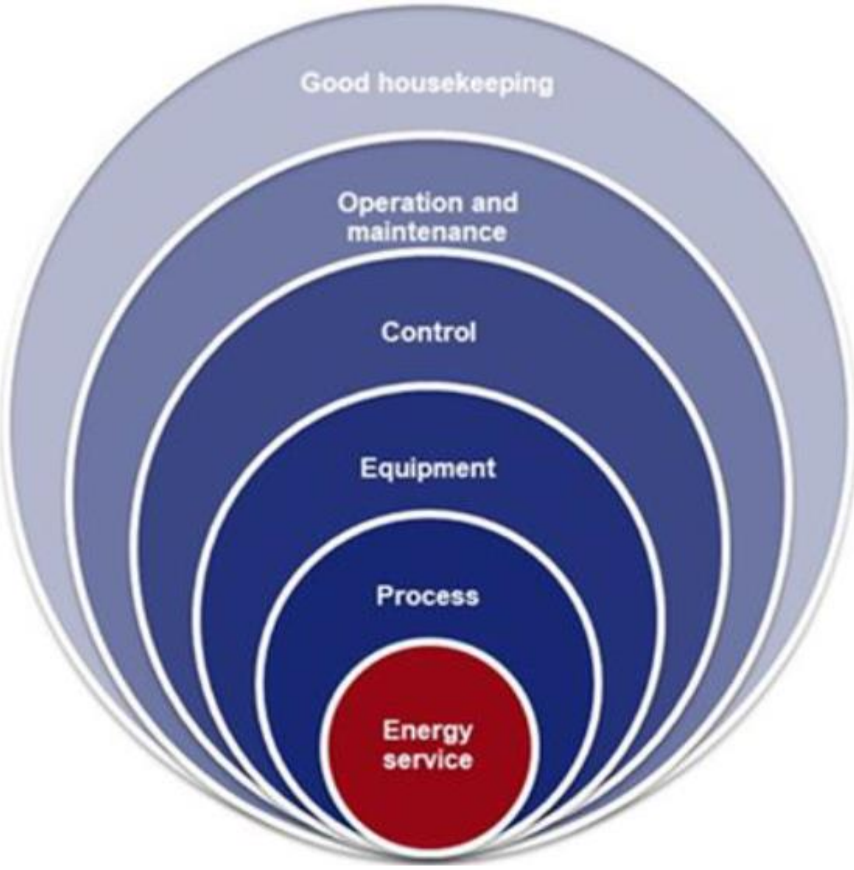


Figure 14. Onion diagram approach for identifying energy efficiency (EE) opportunities

The onion diagram illustrates a structured approach to identifying energy efficiency (EE) opportunities by analyzing a system from its core energy demand outward through multiple influencing layers. This method ensures that solutions aren't limited to equipment upgrades but also consider process design, control strategies, and operational practices.

- At the center is "the Energy Service", which represents the fundamental function that must be delivered, such as heating, drying, cooling, or compressed air. This is the core objective of the system, and all efficiency improvements should ensure that this service is maintained while reducing energy input;
- Moving outward, the next layer is "the Process", which defines how the energy service is delivered. At this level, alternative process designs or technologies can be considered to reduce energy demand or improve efficiency;
- "The Equipment" layer represents the machines and devices used to carry out the process. Energy efficiency at this level depends on equipment performance, selection of high-efficiency technologies, and lifecycle cost considerations;
- The next layer is "Control", which governs how the system operates. Effective control strategies ensure that equipment operates under optimal conditions, adapts to load variations, and avoids unnecessary energy consumption;

- Beyond that is "Operation and Maintenance", which includes how the system is managed on a daily basis. Proper operation, routine maintenance, and timely adjustments can significantly improve energy performance with minimal investment;
- Finally, the outermost layer is "Good Housekeeping", which reflects general management practices, awareness, and organizational behavior related to energy use.

The key principle is that outer layers depend on inner layers, and energy efficiency analysis should always start from the core (energy service) and move outward. This ensures that solutions address the root cause of energy use rather than only treating surface-level inefficiencies.

For thermal systems, the team carried out temperature analysis, flue gas measurements, surface temperature inspection, and energy balance calculations to quantify losses and heat recovery potential. For electrical systems, the team used load measurements, operating-hour data, and installed-capacity calculations to estimate electricity use by major end-use system. This allowed the audit team to compare actual operating conditions with design expectations and to identify cases where energy use could be reduced through better control, reduced idle running, or higher-efficiency equipment.

The audit also followed the DEPP3 recommendation to assess energy use at the level of main energy services and to estimate specific energy consumption indicators where direct metering was incomplete. In this report, the SEC analysis was used to compare energy consumption across product output and to support the identification of processes with unusually high energy intensity. Where relevant, the team also considered non-energy factors such as production stability, product quality, and operational reliability, because these factors affect the feasibility of the proposed measures.

The project development process followed a screening and prioritization pathway. First, a broad list of observations and opportunities was compiled from the site survey and energy mapping. Next, the most promising items were developed into Level B projects, for which energy savings, investment cost, and simple payback were estimated using preliminary assumptions. Finally, the projects with the strongest technical and economic potential were selected as Level A projects for deeper development and further support. This staged approach matches the DEPP3 guideline, which requires moving from a gross list to Level B and then to Level A for the most promising opportunities.

2.2 EE Project evaluation

During the energy audit, proposed energy efficiency (EE) measures were evaluated based on technical, economic, and environmental criteria, using both measured data and calculated estimates derived from energy mapping and system analysis. The evaluation focused on the following key aspects:

- **Annual energy savings:** Energy savings were quantified in terms of both electricity and thermal energy (kWh/year), based on measured operating conditions, load profiles, and system efficiencies. Particular attention was given to high-energy-consuming systems such as kiln, spray dryer, grinding systems, and compressed air systems, where the largest saving potentials were identified;
- **Cost savings:** Financial benefits were calculated based on the reduction in energy consumption (electricity, LPG/CNG, coal) and associated operating costs. Additional indirect savings, such as reduced maintenance requirements and improved system reliability, were also considered where relevant;
- **Investment cost:** Investment requirements were estimated for each measure, including equipment costs (e.g., VFDs, heat recovery systems, control systems), installation, integration, and potential production downtime during implementation;
- **Payback period:** The simple payback period was calculated to classify projects into short-term, medium-term, and long-term investments. Priority was generally given to measures with shorter payback periods, particularly those requiring low capital investment;
- **CO_2 emission reduction:** Emission reductions were estimated based on reduced fuel and electricity consumption. Significant CO_2 reduction potential was identified in measures related to waste heat recovery from kiln exhaust, fuel switching (e.g., biomass conversion), and process optimization;
- **Operational and technical impact:** The evaluation also considered the impact of each measure on production stability, product quality, and operational complexity, ensuring that proposed solutions do not negatively affect the continuous operation of the plant.

2.3 EE Project prioritisation

Following the evaluation stage, EE measures were prioritized based on a combination of technical, financial, and operational criteria. The prioritization reflects both the audit findings and the practical conditions of the enterprise. The main prioritisation criteria include:

- **Energy saving potential:** Measures with high absolute energy savings, particularly in major energy-consuming systems such as kiln, spray drying, and grinding, were given the highest priority;
- **Investment cost and payback period:** Projects with low investment cost and short payback periods (e.g., compressed air leakage reduction, control optimization) were prioritized for immediate implementation, while capital-intensive projects (e.g., biomass conversion, waste heat recovery systems) were classified as medium- to long-term;

- **Impact on production operations:** Measures that can be implemented without disrupting production or affecting product quality were preferred. For example, control system improvements and maintenance-related measures were prioritized over major process modifications;
- **Technical feasibility:** Priority was given to solutions that are compatible with existing equipment and infrastructure, and that can be integrated into the current production system with minimal complexity;
- **Environmental benefits and compliance:** Projects contributing to CO_2 emission reduction and alignment with energy management standards (e.g., TCVN ISO 50001:2019) were given additional consideration;
- **Scalability and future potential:** Measures with the potential for expansion or replication across multiple production lines were prioritized, particularly in systems such as compressed air and electrical motor drives.

Based on this approach, EE measures were categorized into:

- Immediate implementation (low-cost, high impact);
- Medium-term projects (moderate investment, significant savings);
- Long-term strategic projects (high investment, high impact).

2.4 Enterprises feedback

During and after the audit process, the enterprise actively participated in discussions, site inspections, and validation of proposed EE measures. Feedback from technical staff and management was collected to ensure the practicality and relevance of the proposed solutions.

The enterprise showed a high level of interest in EE measures, particularly those that:

- Require low investment and offer quick returns (e.g., compressed air leakage reduction, system optimization);
- Improve operational efficiency without affecting production;
- Reduce energy costs in major systems such as kiln and spray drying.

For more capital-intensive measures, such as waste heat recovery systems and fuel switching to biomass, the enterprise expressed interest but indicated that further detailed feasibility studies and financial planning would be required before implementation.

The enterprise also acknowledged several current limitations, including:

- Lack of centralized control systems for utilities (e.g., compressed air);
- Incomplete energy monitoring systems;
- Existing heat losses in thermal systems (e.g., kiln exhaust, gasification system).

As a result, the enterprise committed to:

- Gradually improving its energy management system (EnMS);
- Enhancing monitoring and control of major energy-consuming systems;
- Considering pilot implementation of selected EE projects in the next phase.

The audit results and recommendations were considered useful and practical, providing a clear basis for future energy efficiency improvements. The enterprise expressed willingness to continue cooperation in future audit rounds, particularly for developing Level A projects into detailed feasibility studies and investment plans.

3 EE Projects identified

The identified EE opportunities reflect the main energy-intensive areas of the plant, especially the kiln, spray drying tower, ball mills, compressed air system, and electrical drive systems. In general, the gross list shows that the largest saving potential comes from fuel-related and thermal-process measures, while low-cost management and compressed air measures offer shorter payback periods and can be implemented more quickly. The total quantified savings from the Level B measures are substantial, with the strongest opportunities concentrated in waste heat recovery, fuel switching, combustion optimization, and solar PV integration.

Table 4. Gross list (Level B mapping)

Gross list							
Project no.	**Name of Project**	**Energy form**	**Investment Cost [$]**	**Saving**			**Simple Payback [Months]**
				Energy [kWh]	**CO_2 [ton]**	**Financial [$]**	
I	**Management Measures**						
1	Enhance the Energy Management System (EnMS) in compliance with ISO 50001:2018	Electricity, LPG/CNG, Coal	11,393	2,774,597	524	15,190	9.0
2	Implement an Energy Monitoring and Management System (EMMS)	-	-	-	-	-	-
II	**Technical Measures**						
3	Detect and repair compressed air leakages	Electricity	1,443	51,906	34	3,798	4.6
4	Improve ventilation and cooling for the air compressor station	Electricity	418	241,503	3	342	14.0
5	Install a central control system with integrated VFDs for air compressors	Electricity	21,646	84,560	56	6,152	42.2
6	Recover waste heat from the inlet of the kiln for combustion air preheating	LPG/CNG	52,975	2,879,474	675	160,141	4.0
7	Convert the coal gasification system to a	Coal	170,888	21,567,537	10,740	124,103	16.5

Gross list							
Project no.	Name of Project	Energy form	Investment Cost [$]	Saving			Simple Payback [Months]
				Energy [kWh]	CO_2 [ton]	Financial [$]	
	biomass-based combustion system						
8	Install an advanced combustion monitoring and control system for the kiln	LPG/CNG	59,811	1,688,385	411	93,913	7.6
9	Install an active harmonic filtering system (AccuSine PCS+)	Electricity	39,836	191,528	126	13,937	34.3
10	Install an on-grid solar PV system with load-following control	Electricity	455,702	1,074,000	708	101,963	53.6
III	Recommended Measures						
11	Replace ball mills with vertical roller mills (VRM)	Coal	-	-	-	-	-
12	Utilize waste heat from spray dryer exhaust to preheat slurry	Coal	-	-	-	-	-
13	Replace low-efficiency motors with IE4 high-efficiency motors	Electricity	-	-	-	-	-

The gross list shows 03 clear trends:

- The largest energy-saving potential lies in thermal-process measures, especially the conversion of the coal gasification system to biomass, which delivers by far the highest quantified saving.
- Waste heat recovery from the kiln inlet and kiln combustion control also provides high savings with relatively attractive payback periods.
- Compressed air measures and management improvements require lower investment and can be implemented earlier, making them suitable as quick-win actions.

Measures such as the solar PV system and active harmonic filtering offer additional operational and environmental benefits, but their payback periods are longer and they are therefore better treated as medium- to long-term investments.

The recommended measures are included as strategic opportunities for further study. These projects are important from a system-efficiency perspective, but their detailed technical and financial assessment requires additional analysis before final investment decisions are made.

4 Selected EE Projects for further supports

These projects (Level A) were shortlisted from the gross list based on their energy-saving potential, technical feasibility, financial attractiveness, and relevance to the plant's main energy-consuming systems.

Table 5. Project: "Implement an Energy Monitoring and Management System (EMMS)"

Project information		
Project: Implement an Energy Monitoring and Management System (EMMS)	**Project no. 2**	**Date:** April 15, 2026
Enterprise: Granite tile manufacturing company	**EAC company:** ENERVI Viet Nam Energy and Environment Joint Stock Company	**Lead Auditor:** Nguyen Xuan Quang

Project description

Current situation

The plant's electrical supply system is already separated by consumption area and major equipment groups. Electricity consumption data are currently collected mainly through mechanical meters at the electrical substations. However, monitoring, evaluation, and supervision of operating performance are still limited because the existing metering arrangement does not provide sufficient real-time visibility or detailed process-level data. In practice, energy data are recorded and compiled manually around mid-month and at month-end, which delays analysis and makes it difficult to detect abnormal consumption in time.

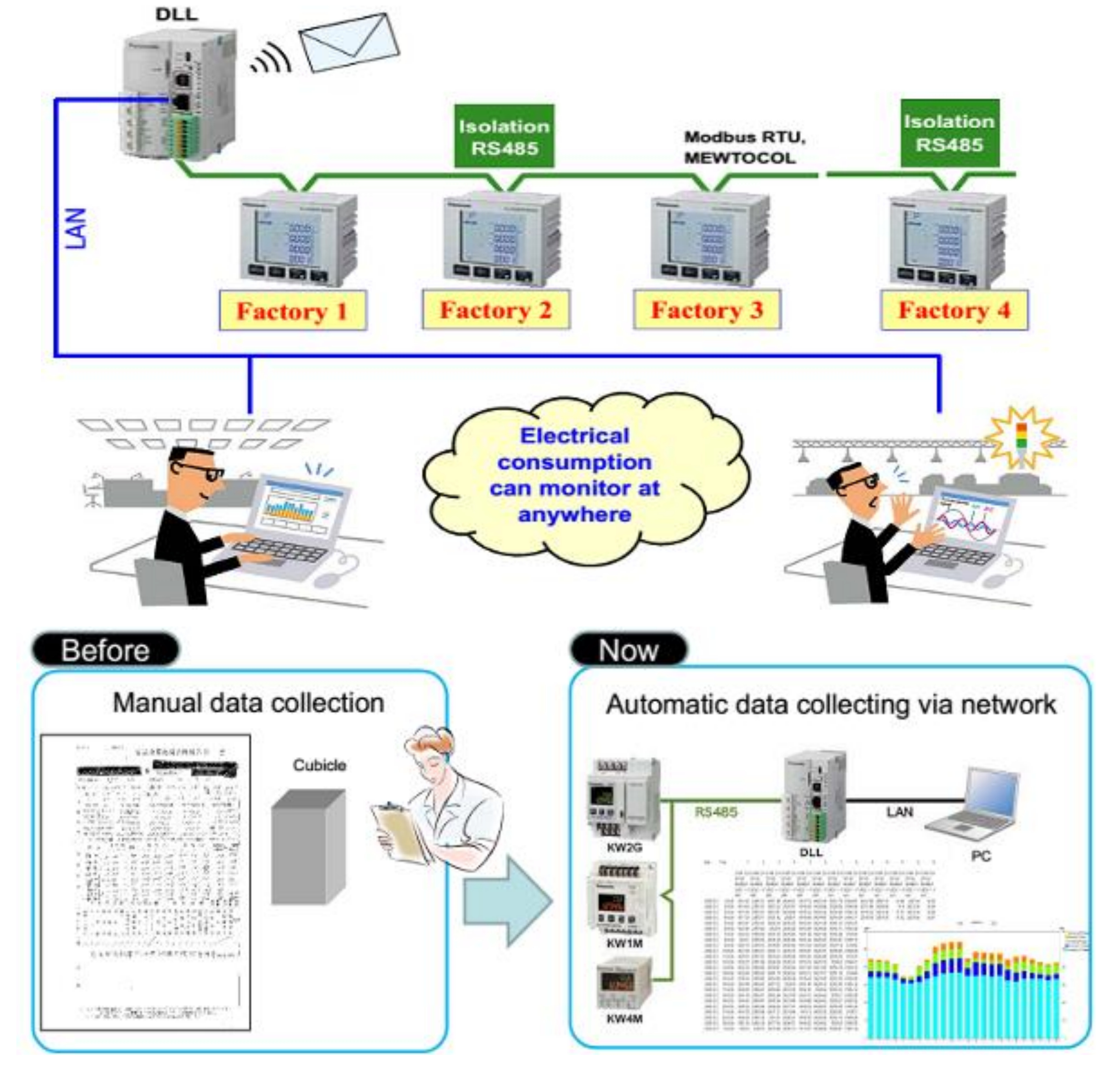
At present, the plant doesn't have a centralized energy monitoring platform. This means that load trends, power quality, abnormal operating conditions, and system losses cannot be continuously tracked across the main production areas. As a result, energy management is still largely based on manual review rather than automated supervision.

Proposed project

The proposed project is to install an Energy Monitoring and Management System (EMMS), or PMS-type platform, to enable continuous monitoring of electricity use across the factory. The system would use network-connected digital power meters and data loggers linked to a central computer and energy management software. The software would collect, store, and analyze data from key measurement points and display them in dashboard, table, and alarm formats.

The monitored parameters should include kW, kVA, kVAr, voltage, current, power factor, load profile, and abnormal operating conditions. The metering points should be placed at the main substations and at major energy-consuming areas such as grinding, pressing, spray drying, kiln operation, compressed air, pumps, and lighting. This would allow the company to identify energy waste locations, verify electricity bills, monitor total factory load in real time, and support quicker corrective action when abnormalities occur. The report notes that similar systems can support electricity saving of roughly 0.5 – 5% of total electricity consumption, depending on implementation quality and operating discipline.

Project illustration (PFD)



Project Budget	
Total	N/A

TIME SCHEDULE				
Year	**2026**	**2027**	**2028**	**After 2028**
Project timeline				

Saving	
Energy (annual): N/A	**Financial (annual):** N/A
CO_2 (annual): N/A	**Simple Payback (months):** N/A

Risk Analysis

- Incorrect selection of measurement points, leading to data that does not accurately represent actual energy consumption of each process or area;
- Insufficient number of meters installed, limiting system coverage and analysis capability;

- Communication errors or signal loss between meters and central system, causing data interruption;
- Lack of familiarity of operating personnel with the EMMS software, leading to ineffective system utilization;
- Integration challenges with the existing electrical system and infrastructure;
- Electrical safety risks during installation of meters (CTs, VTs) on live panels.

Non-Energy benefits

- Reduce time and labor required for manual data collection and reporting;
- Improve accuracy and reliability of energy consumption data;
- Enable continuous 24/7 monitoring of electricity consumption across the factory;
- Provide real-time alerts for abnormal load conditions and electrical incidents, reducing downtime;
- Support faster troubleshooting through recorded data and load profiles;
- Improve transparency in energy management and reporting;
- Enable verification of electricity bills based on actual consumption data;
- Help identify sources of power quality issues and harmonics;
- Maintain optimal equipment loading, avoiding underloading or overloading;
- Support data-driven decision-making for future investments and system expansion;
- Facilitate identification of energy waste and optimization opportunities across departments.

Table 6. Project: “Install a central control system with integrated VFDs for air compressors”

Project information		
Project: Install a central control system with integrated VFDs for air compressors	**Project no. 5**	**Date:** April 15, 2026
Enterprise: Granite tile manufacturing company	**EAC company:** ENERVI Viet Nam Energy and Environment Joint Stock Company	**Lead Auditor:** Nguyen Xuan Quang

Project description

Current situation

The plant currently operates 08 air compressors to supply compressed air for the pressing process, kiln system, grinding process, and other pneumatic applications. The compressors are already equipped with VFDs, but they operate independently and without a centralized control strategy. Compressed air pressure is maintained at around 5.5 – 6.3 bar to meet production requirements.

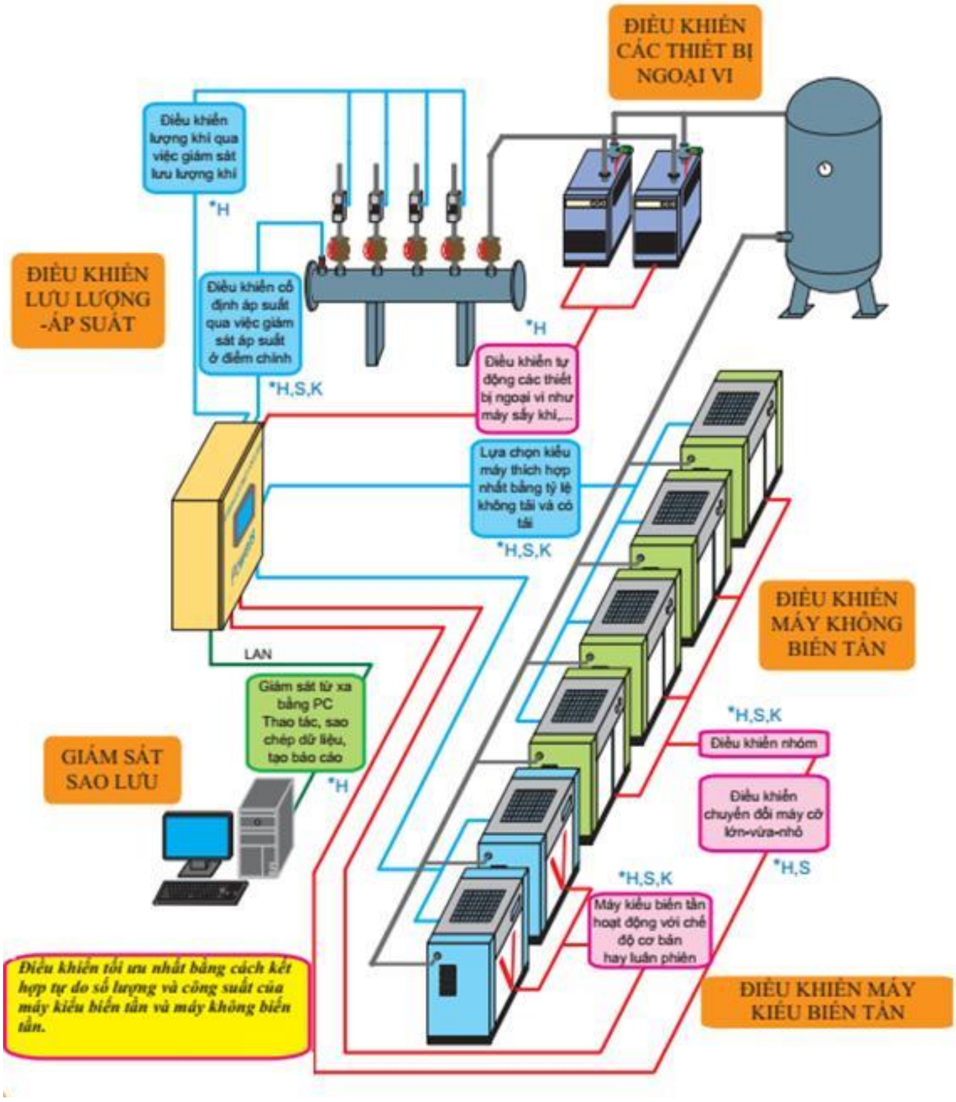
At present, compressor operation depends on fluctuating air demand and manual adjustment by operators. When demand is low, some compressors may still run inefficiently, which leads to unnecessary electricity consumption. Although pressure gauges and basic monitoring equipment are installed, the station still lacks a coordinated controller, so compressor loading, start-stop sequencing, and operating hours are not optimized as a system.

Proposed project

The proposed project is to install a central controller for the entire air compressor station integrated with the existing VFDs. The controller would automatically coordinate compressor operation according to actual compressed air demand, operating pressure, and compressor load condition. One compressor would be assigned as the main trim unit, while the others would operate as base-load units or be switched on sequentially as demand increases.

The system would optimize operating frequency, reduce idle running, balance operating hours among compressors, and improve overall compressed air station efficiency.

Project illustration (PFD)



Project Budget

Total	$21,646

TIME SCHEDULE

Year	**2026**	**2027**	**2028**	**After 2028**
Project timeline				

Saving

Energy (annual): 84,56 kWh	**Financial (annual):** $6,152
CO_2 (annual): 56 tons CO_{2e}	**Simple Payback (months):** 42.2

Risk Analysis

- The central controller may not be fully compatible with the existing compressors because of differences in manufacturer, model, or control protocol.
- The selected VFD capacity may not match the motor load characteristics, which may cause overheating, vibration, or reduced equipment life.
- Incorrect control logic may cause unstable compressed air pressure and affect production equipment.

- Existing compressed air leaks may reduce the effectiveness of the new control system.
- Installation work may require compressor shutdown and can affect production if not properly scheduled.
- EMI or electrical interference from VFDs may affect other control equipment.

Non-Energy benefits

- Improve stability of compressed air supply across the production line.
- Reduce operator workload by automating compressor sequencing and load control.
- Balance compressor operating hours, which can extend equipment life.
- Reduce start-stop frequency and avoid unnecessary partial-load operation.
- Improve maintenance planning by making compressor usage more predictable.
- Help maintain more consistent air pressure for pneumatic equipment and production processes.
- Improve visibility of station performance through centralized monitoring.
- Support faster troubleshooting when abnormal pressure or load conditions occur.

Table 7. Project: “Recover waste heat from the inlet of the kiln for combustion air preheating”

<table>
<tr><th colspan="3">Project information</th></tr>
<tr><td>Project: Recover waste heat from the inlet of the kiln for combustion air preheating</td><td>Project no. 6</td><td>Date: April 15, 2026</td></tr>
<tr><td>Enterprise: Granite tile manufacturing company</td><td>EAC company: ENERVI Viet Nam Energy and Environment Joint Stock Company</td><td>Lead Auditor: Nguyen Xuan Quang</td></tr>
</table>

Project description

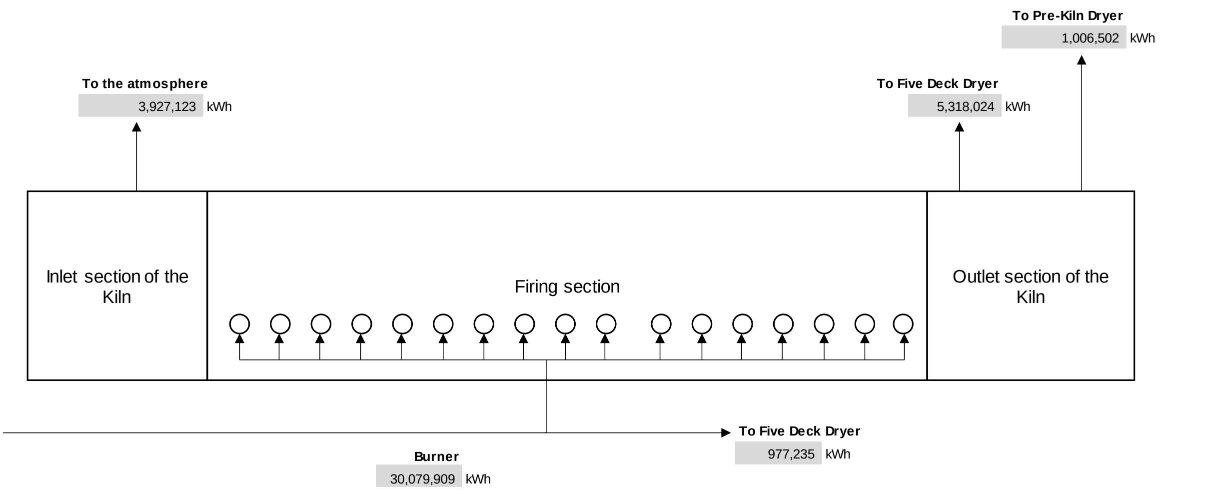
Current situation

The plant operates a kiln system using LPG/CNG fuel, and the kiln exhaust gas is currently discharged directly to the atmosphere after the firing process. Measurements at the kiln outlet show that the exhaust gas temperature remains high, around 230 – 233°C, which means a significant amount of useful heat is being lost.

At present, this heat is not recovered for reuse in the production process. As a result, the kiln must consume more fuel than necessary to maintain the required combustion conditions, increasing operating cost and energy intensity.

Waste heat potential- Tiềm năng nhiệt thải

Section	Proces	Medium	Stream no	Utility system	Temp. In	Temp. Out	Mass flow	Dry matter	Cp	KPI	Flow approach	KPI approach	Measurement	Total	Share of total
					˚C	˚C	m3	%	kJ/KgK	kWh/ton	kWh	kWh	kWh	kWh	
Granite tile production line	Exhaust gas from Spraying dryer / Khí thải ở tháp sấy phun	Air	6.3	Gasification furnace	92.5	25	39,695		1.01		748,005			748,005	15.6%
Granite tile production line	Exhaust gas from Five-deck dryer / Khí thải ở sấy 5 tầng	Air	9.3	CNG + Kiln	88.6	25	5,786		1.01		102,730			102,730	2.1%
Granite tile production line	Exhaust gas from Pre-Kiln dryer / Khí thải ở sấy tiền nung	Air	15.3	Kiln	84.3	25	154		1.01		2,549			2,549	0.1%
Granite tile production line	Exhaust gas from the Inlet of the Kiln / Khí thải ở đầu lò nung	Air	16.2	CNG	230	25	68,621		1.01		3,927,123			3,927,123	82.2%
TOTAL											**4,780,407**	-	-	**4,780,407**	**100%**

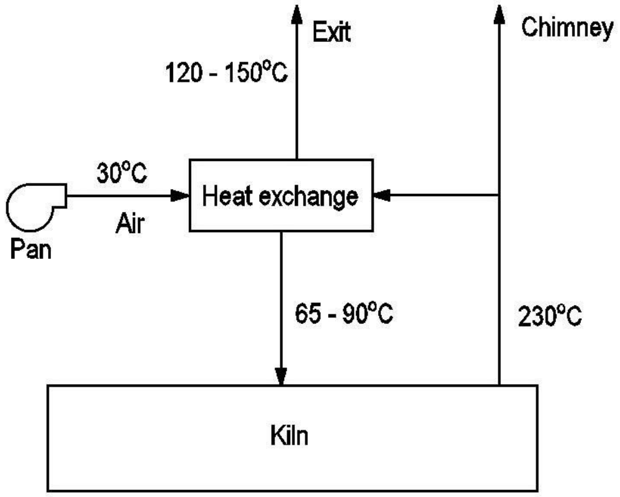


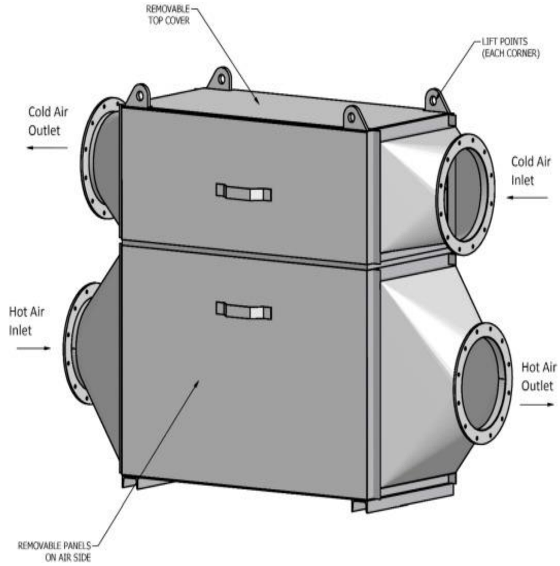
Proposed project

The proposed project is to recover waste heat from the kiln exhaust and use it to preheat combustion air before it enters the kiln. The exhaust gas would pass through a heat exchanger, where part of its thermal energy is transferred to incoming ambient air. The preheated air would then be supplied back to the kiln combustion system.

According to the audit calculation, the combustion air temperature can be raised from about 35.3°C to 65°C, while the exhaust gas temperature after heat recovery is reduced to about 130°C.

Project illustration (PFD)





Project Budget

Total	$52,975

TIME SCHEDULE

Year	**2026**	**2027**	**2028**	**After 2028**
Project timeline				

Saving

Energy (annual): 2.879.474 kWh	**Financial (annual):** $160,141
CO_2 (annual): 675 tons CO_{2e}	**Simple Payback (months):** 4

Risk Analysis

- Exhaust gas temperature and flow rate may vary by operating condition, which can reduce heat recovery stability.
- Dust, soot, and hot gas components may cause fouling or corrosion in the heat exchanger.
- Improper design may increase flue gas resistance and affect kiln draft or pressure balance.
- The recovered heat may not always be sufficient or stable enough to support the combustion process.
- Hot gas leakage or heat exchanger damage may create safety risks.
- Limited installation space may complicate the arrangement of ducts, exchanger, and auxiliary equipment.

Non-Energy benefits

- Improve kiln thermal stability through better preheating of combustion air.
- Reduce dependency on LPG/CNG consumption and improve operating cost predictability.
- Lower flue-gas losses and improve overall process efficiency.
- Reduce environmental impact through lower fuel use and lower CO_2 emissions.
- Support better use of existing thermal resources within the plant.
- Improve energy management performance and demonstrate progress toward efficient production.
- Provide a strong platform for future heat recovery projects in other thermal systems.

Table 8. Project: “Convert the coal gasification system to a biomass-based combustion system”

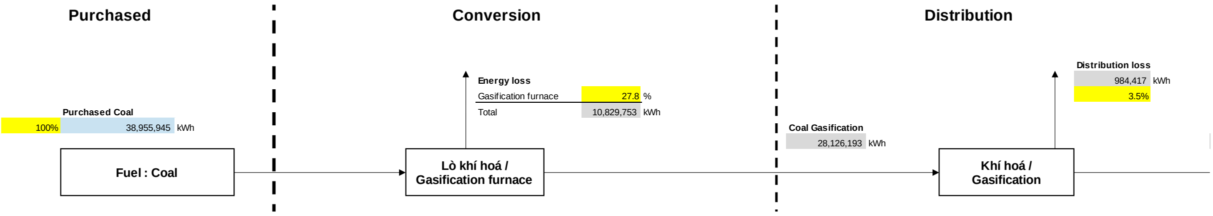
Project information

Project: Convert the coal gasification system to a biomass-based combustion system	**Project no. 7**	**Date:** April 15, 2026
Enterprise: Granite tile manufacturing company	**EAC company:** ENERVI Viet Nam Energy and Environment Joint Stock Company	**Lead Auditor:** Nguyen Xuan Quang

Project description

Current situation

The plant is currently operating a coal gasification furnace system to supply fuel for the brick drying process. Lump coal is gasified under oxygen-deficient conditions to produce syngas (mainly CO, H_2, and CH_4), which is then supplied to the drying chambers.



Although this system meets the thermal demand, several major limitations have been identified:

- The gasification process has relatively low energy conversion efficiency, with significant heat losses through exhaust gas and slag.
- The operation is complex and sensitive to operating parameters (fuel–air ratio, temperature), leading to unstable syngas quality.
- Frequent issues such as fuel feeding blockages, soot deposition, and equipment corrosion increase maintenance requirements.
- Coal combustion causes high emissions of CO_2, SO_x, NO_x, and particulate matter, negatively impacting the environment and compliance.
- Coal is a non-renewable fuel with volatile pricing and supply risks.
- Solid waste (ash and slag) requires handling, storage, and disposal, creating additional environmental risks.

Overall, the current system results in high operating costs, environmental concerns, and limited sustainability.

Proposed project

The proposed project is to convert the coal gasification system into a biomass-based direct combustion system.

Instead of producing syngas, the new system will:

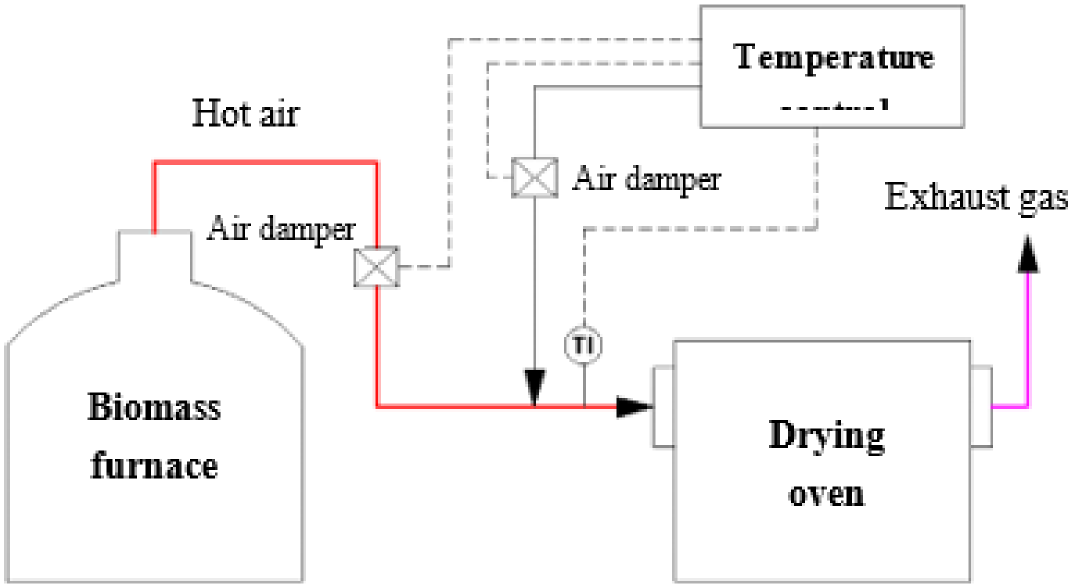
- Use biomass fuels such as rice husk, sawdust, wood pellets, or agricultural residues;
- Apply direct combustion technology in a dedicated biomass furnace;
- Generate high-temperature flue gas, which is directly supplied to the drying chambers.

Key characteristics of the proposed system:

- Eliminates the intermediate gasification stage → reduces energy losses;
- Simplifies system configuration → lower operation and maintenance complexity;
- Improves temperature control through adjustable fuel feed and air supply;

- Allows reuse of existing ducting and drying infrastructure → high compatibility.

Project illustration (PFD)



Project Budget

Total	$170,888

TIME SCHEDULE

Year	2026	2027	2028	After 2028
Project timeline		■	■	■

Saving

Energy (annual): 21.567.537 kWh	**Financial (annual):** $124,103
CO_2 (annual): 10,740 tons CO_{2e}	**Simple Payback (months):** 17

Risk Analysis

- Biomass fuel quality may vary (moisture, particle size, calorific value), causing unstable combustion.
- Heat supply capacity may not fully meet process demand if system design is inadequate.
- Increased workload in fuel handling, storage, feeding, and ash management.
- Risks of blockage, backfire, and dust explosion in biomass feeding systems.
- Significant modifications required for furnace, ducting, and control systems.
- Heat supply fluctuations may affect drying performance and product quality.
- Biomass supply may be unstable in terms of quantity and consistency.

Non-Energy benefits

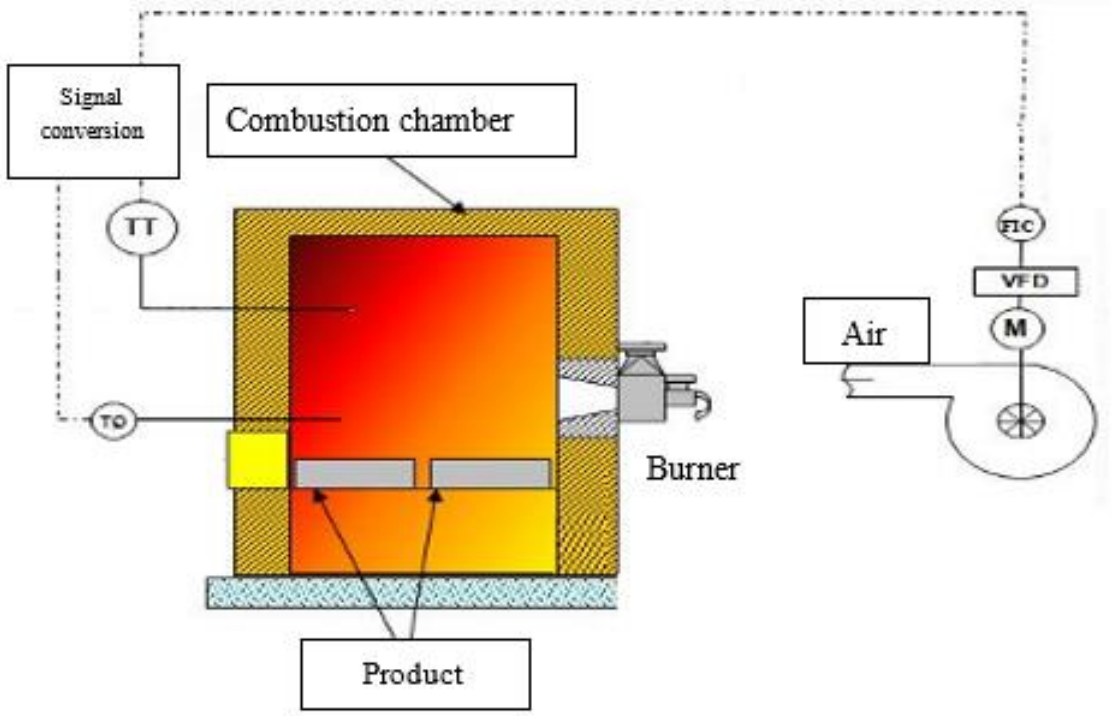
- Significant reduction of greenhouse gas emissions due to biomass being carbon-neutral.
- Reduction of air pollutants (SO_x, NO_x, dust), improving environmental compliance.
- Improved corporate image and sustainability performance.
- Reduced dependency on fossil fuels and improved energy security.
- Simplified system operation compared to gasification → easier control and maintenance.
- Reduced slag and hazardous waste generation compared to coal gasification.
- Alignment with green production trends and regulatory requirements.
- Potential access to green financing or carbon credit mechanisms in the future.

Table 9. Project: “Install an advanced combustion monitoring and control system for the kiln”

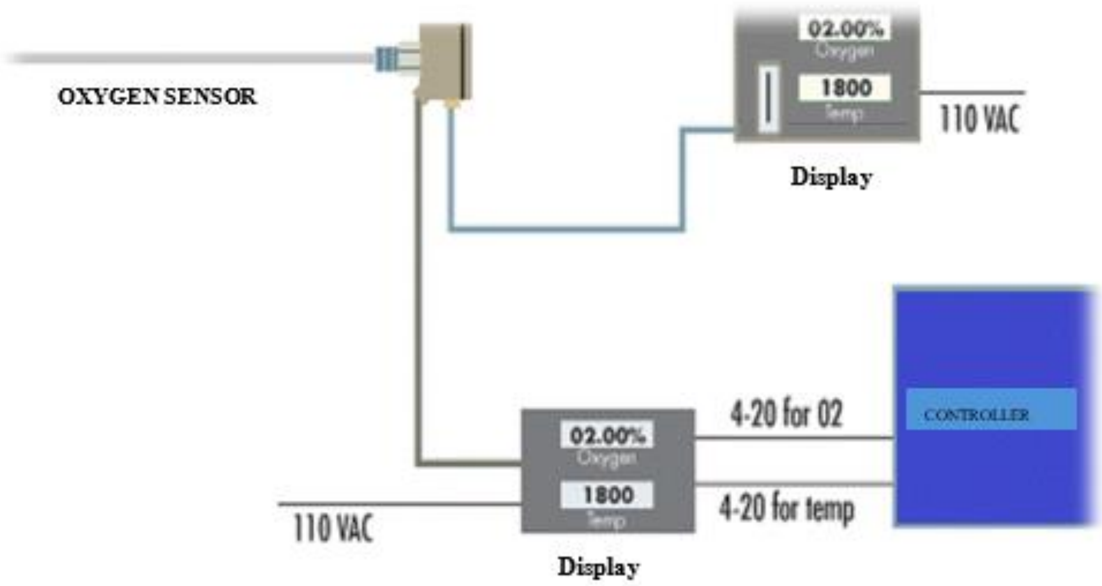
<table>
<tr><th colspan="3">Project information</th></tr>
<tr><td>Project: Install an advanced combustion monitoring and control system for the kiln</td><td>Project no. 8</td><td>Date: April 15, 2026</td></tr>
<tr><td>Enterprise: Granite tile manufacturing company</td><td>EAC company: ENERVI Viet Nam Energy and Environment Joint Stock Company</td><td>Lead Auditor: Nguyen Xuan Quang</td></tr>
<tr><th colspan="3">Project description</th></tr>
<tr><td colspan="3">Current situation
The kiln is currently operated with LPG/CNG as the main fuel source. Combustion air is supplied by a forced draft fan, and fan speed is adjusted based on kiln pressure and combustion chamber temperature. However, the plant doesn't yet have dedicated instrumentation to continuously verify combustion efficiency or to optimize the air-to-fuel ratio in real time. Measurements taken during the audit showed that excess oxygen in kiln flue gas was about 14.13%, while the recommended level for better combustion control was around 10.96%, indicating that the kiln was operating with more excess air than necessary.

</td></tr>
<tr><td colspan="3">Proposed project
The proposed project is to install an advanced combustion monitoring and control system for kiln operation. The system would combine O_2 sensors, temperature transmitters, a flow controller, and VFD-based fan control integrated into the plant PLC. In operation, kiln temperature would be used as the primary control signal, while flue gas oxygen concentration would be used as feedback to fine-tune the combustion air supply. This allows the kiln to maintain the required firing temperature while reducing excess air, improving combustion efficiency, and lowering fuel consumption.</td></tr>
</table>

Project illustration (PFD)



Air Flow Control Diagram



Excess Air Ratio Control System

Project Budget

Total	$59,811

TIME SCHEDULE

Year	**2026**	**2027**	**2028**	**After 2028**
Project timeline				

Saving	
Energy (annual): 1.688.385 kWh	**Financial (annual):** $93,913
CO_2 (annual): 411 tons CO_{2e}	**Simple Payback (months):** 7.6

Risk Analysis

- Temperature, O_2, pressure, or flow sensors may give inaccurate readings because of the high-temperature and dusty kiln environment.
- The control algorithm may not be properly tuned to kiln conditions, causing unstable temperature control or incomplete combustion.
- The new automation system may not integrate smoothly with the existing control system or PLC architecture.
- Excessive reliance on automatic control before logic is fully optimized may create operational instability.
- Kiln shutdown during installation and calibration may affect the production schedule.
- Monitoring data may be available but not regularly analyzed, reducing the value of the investment.

Non-Energy benefits

- Improve kiln temperature stability and combustion quality.
- Reduce product defects caused by unstable firing conditions.
- Improve process reliability and reduce unplanned shutdowns.
- Support faster operator response through real-time monitoring and alarms.
- Improve combustion control skills and data-based operation discipline.
- Reduce manual adjustment workload for operating staff.
- Improve compliance with energy management and efficiency objectives.
- Create a better basis for future process optimization and automation.

Table 10. Project: “Install an active harmonic filtering system (AccuSine PCS+)”

Project information		
Project: Install an active harmonic filtering system (AccuSine PCS+)	**Project no. 9**	**Date:** April 15, 2026
Enterprise: Granite tile manufacturing company	**EAC company:** ENERVI Viet Nam Energy and Environment Joint Stock Company	**Lead Auditor:** Nguyen Xuan Quang

Project description

Current situation

The audit team measured power quality at the distribution transformer system and found notable harmonic distortion. Transformer No. 1 showed higher current harmonic distortion than Transformer No. 2, with current harmonics ranging from 16.35% to 26.96% and voltage harmonics from 4.46% to 5.29%. Transformer No. 2 also showed harmonic distortion, though at a lower level. These results indicate that the plant has a real harmonic problem at the supply side.

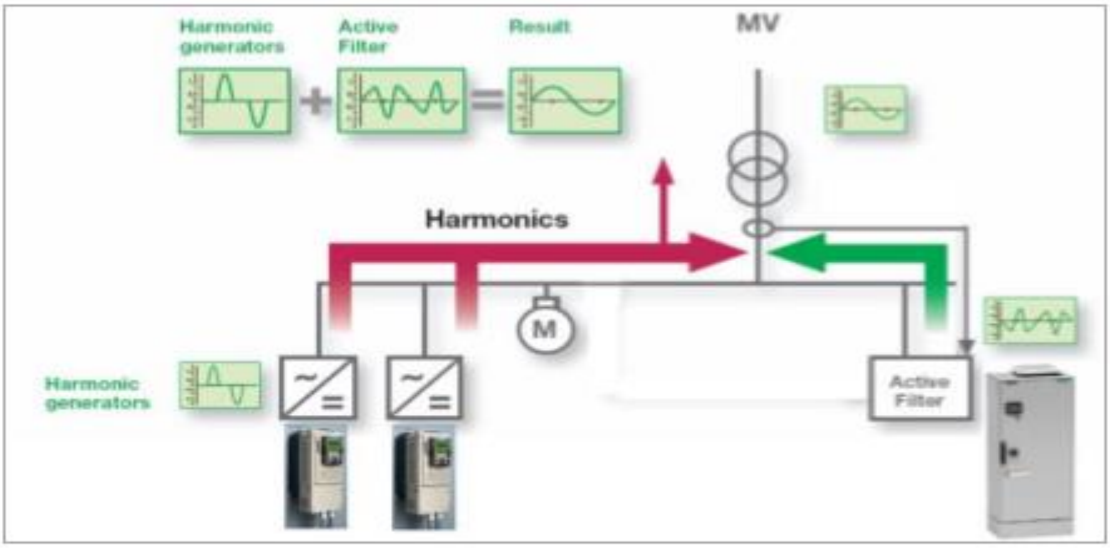
Transformer	Operating Capacity *(kVA)*	Current Harmonics *(%)*	Voltage Harmonics *(%)*
Transformer No 1	755	16,35 - 26,96	4,46 - 5,29
Transformer No 2	577	6,89 - 11,82	1,67 - 3,71

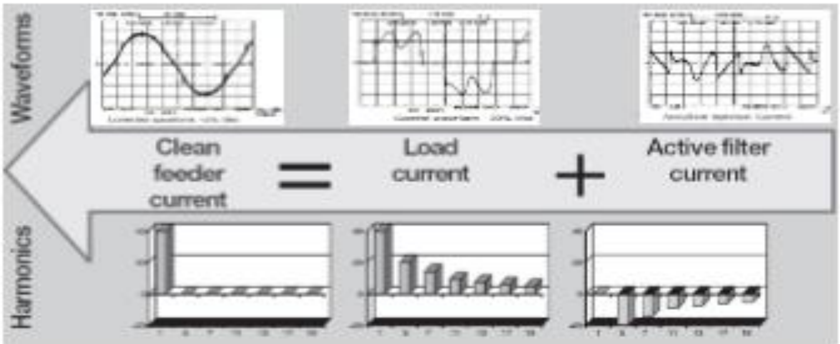
Such harmonics can cause overheating of cables and motors, insulation damage, higher power losses, flicker in lighting, nuisance tripping of protection devices, and reduced performance of the power factor correction system. In short, the existing electrical network is exposed to avoidable power quality risks that can affect both equipment reliability and operating efficiency. Results of Harmonic Distortion Measurement at the Transformers.

Proposed project

The proposed project is to install an AccuSine PCS+ active harmonic filtering system near the main harmonic sources. The filter uses digital FFT-based harmonic detection and fast IGBT switching to inject compensating current and reduce harmonic distortion in the electrical network. It can mitigate harmonics from the 2nd to the 51st order and can be configured to prioritize harmonic mitigation or power factor correction.

Project illustration (PFD)





Project Budget	
Total	$59,811

TIME SCHEDULE				
Year	**2026**	**2027**	**2028**	**After 2028**
Project timeline				

Saving	
Energy (annual): 191,528 kWh	**Financial (annual):** $13,937
CO_2 (annual): 126 tons CO_{2e}	**Simple Payback (months):** 34.3

Risk Analysis

- Incorrect assessment of harmonic levels or main harmonic sources may lead to selecting the wrong filter capacity.
- The filter may be incompatible with the existing electrical network configuration, capacitor banks, VFDs, or other nonlinear loads.
- Improper installation location may reduce filtering performance.
- Power electronic equipment generates heat and requires suitable ventilation and ambient conditions.
- Installation and connection may cause temporary load interruptions or electrical safety risks.
- The energy-saving effect may be limited if the main objective is power quality improvement rather than direct

electricity reduction.

Non-Energy benefits

- Improve overall power quality in the plant.
- Reduce overheating risk in cables, motors, transformers, and capacitor banks.
- Lower the likelihood of nuisance tripping and equipment malfunction.
- Protect sensitive electrical and control equipment from harmonic stress.
- Improve stability of lighting and electrical operation.
- Reduce maintenance frequency and extend equipment life.
- Improve reliability of the electrical system and reduce downtime risk.
- Support compliance with good electrical engineering practice and future capacity expansion.