The Danish Energy Agency

Anonymous Audit Report
from a porcelain and ceramic company

Vietnam Technology Solutions JSC., March, 2025

Content

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 anonymized summery of a specific energy audit report conducted as a part of the DEPP3 program. The energy audit has been conducted on a porcelain and ceramic tile production plant, by Vietnam Technology Solutions Joint Stock Company, in collaboration with an international expert from Viegand Maagøe.

Summary

Company status

In this chapter, the consulting team will present briefly about the **energy use** of the factory and **findings** in **main audited areas** (with mapping) and **selection of EE opportunities**. Along with specific **cost-benefit assessment** for each selection.

General situation of energy consumption at the factory:

Table 1.1. Structure of energy consumption of the Company in the period 2021-2023

No	Type of energy	Unit	Energy consumption	Converted (TOE)	Ratio (%)
			2021		
1	Electricity	kWh	23,118,270	3,567	18.60%
2	LPG	Kg	6,166,899	6,722	35.05%
3	Coal	Ton	13,542	8,125	42.37%
4	DO oil	Litre	865,001	761	3.97%
5	Water	m^3	13,827	0	
			Total	**19,176**	**100**
			2022		
1	Electricity	kWh	26,317,660	4,061	16.57%
2	LPG	Kg	7,058,540	7,694	31.40%
3	Coal	Ton	20,870	12,522	51.10%
4	DO oil	Litre	261,318	230	0.94%
5	Water	m^3	17,152	0	
			Total	**24,506**	**100**
			2023		
1	Electricity	kWh	21,748,419	3,356	14.77%
2	LPG	Kg	7,352,977	8,015	35.28%
3	Coal	Ton	18,530	11,118	48.95%
4	DO oil	Litre	256,934	226	1.00%
5	Water	m^3	12,983	0	
			Total	**22,715**	**100**

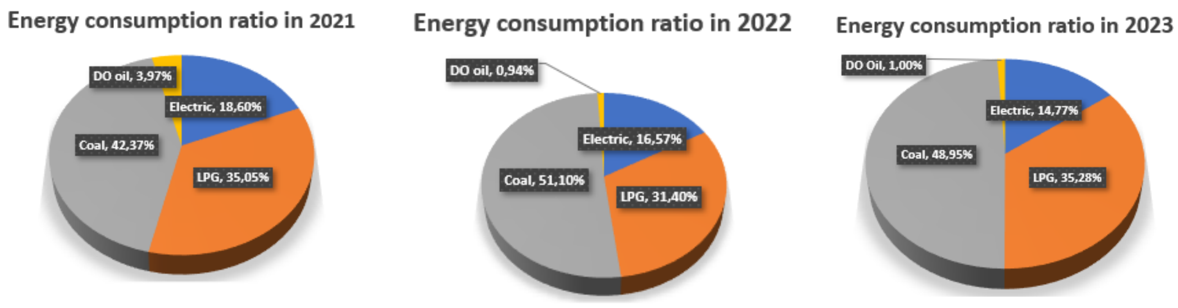


Figure 1.1. Energy consumption ratio in the period 2021-2023

Energy saving potential

After conducting a survey and assessment of the current status of energy use and management at the Company, the audit team found some potential for energy savings for the production machinery system, power supply and distribution system, air compressor system, kiln, etc. Conducting detailed analysis and calculation, the potential savings at the Company are specifically as follows:

The total annual saving potential is approximately **2,688,243 kWh/year, 4,325 liters of DO oil, 31 tons of LPG/year and 390 tons of coal/year**, equivalent to a saving of approximately **224,155 EUR/year**. To implement these solutions, the Company needs to invest approximately **959,922 EUR.**

A summary of energy saving opportunities at the Company is presented in the sections below.

1 About the enterprise

1.1 Description of the company

- Sector: porcelain and ceramic
- Main raw materials: Clay, aluminium ball, waste soil, liquid glass, talc, kaolin, feldspar, weathering soil
  - Consumption: 145,513.49 (ton/year)
- Main product: Ceramic tiles
  - 2021: 5,252,539 m².
  - 2022: 4,739,436 m².
  - 2023: 3,802,232 m².
- Annual energy total consumption Electricity, coal, LPG, DO
  - Electricity grid: 21,748,419 (kWh), equivalent to 1,870 (TOE), 21,748 (MWh)
  - Coal: 18,530 (ton), equivalent to 10,377 (TOE), 120,682 (MWh)
  - LPG: 7,352,977 (kg), equivalent to 347,796 (TOE), 4,044,865 (MWh)
  - Diesel: 256,934 (lit), equivalent to 216 (TOE), 2,510 (MWh)
  - Water: 12,983 (m3)
- Annual carbon footprint: 82,300 tons CO_2

1.2 Description of the process

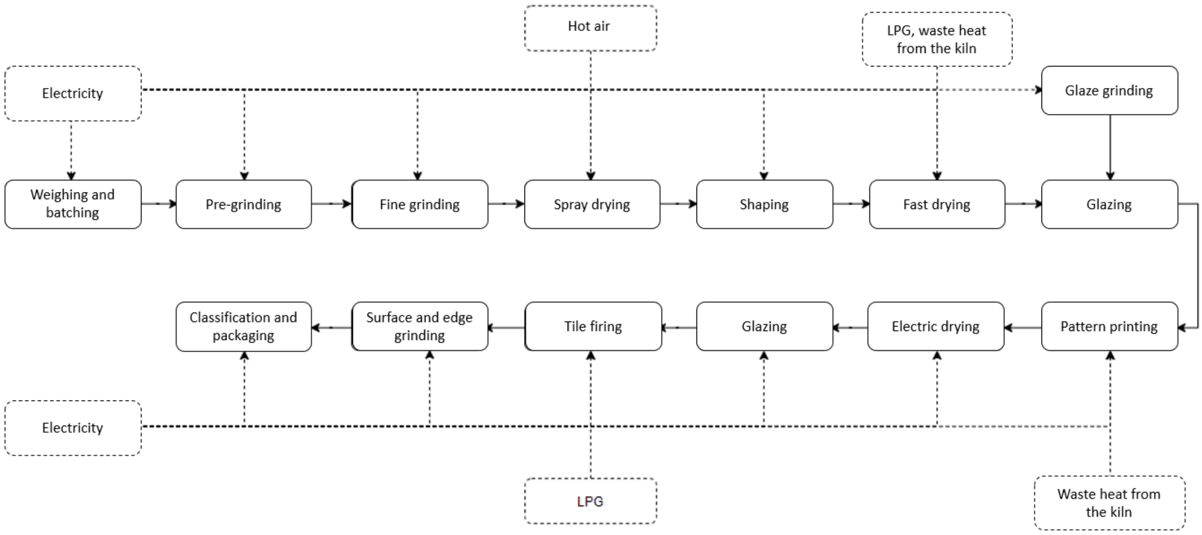


Figure 1.2: Stages in the technological process

Figure 1.3. Flow chart of the production process of two lines

Description of stages in the technological process:

- *Weighing:* Raw materials for making tiles such as clay and feldspar will be weighed and quantified according to each mixing method and then transferred to the preliminary grinding stage;
- *Preliminary grinding:* Raw materials after being put into the preliminary grinding system according to a certain time for each specific material. When the material parameters have reached the standard, they will be discharged into the tank;
- *Fine grinding:* The slurry tank uses a homogeneous stirring system and is then pumped to the fine grinding system. After reaching a certain fineness, the slurry will be discharged into the refined slurry tank and stirred evenly;
- *Vibrating screen:* After the slurry meets the standards, it will be pumped through the vibrating screen into an intermediate tank. When the slurry is full, the intermediate tank will be pumped up to the spray drying tower;
- *Spray drying:* The slurry is sprayed from the nozzles into the spray drying tower and dried by hot air supplied from the fluidized bed furnace. The amount of dried powder with a moisture content of 6.3 - 6.8% is brought to the storage silos and stored for a minimum of 24 hours;
- *Tiles pressing:* After being stored in the silo for a specified period of time, the slurry will be transported by conveyor belt through the tiles pressing stage. A certain amount of powder will be supplied to the hydraulic presses depending on the type of tiles;
- *Quick drying:* After being pressed, the raw tiles will be transferred by the conveyor system to the drying kiln, using the heat from the kiln and partly burned by LPG. Here, the raw tiles are dried and transferred to the enameling and KTS printing line;
- *Grinding and glazing:* The enamel, water color and additives are weighed and quantified according to the correct proportions of the ingredients and then transferred to the enamel grinding machine. The sieved enamel mixture is filtered to remove impurities to create enamel with suitable parameters. The enamel is then passed through the enamel coating line to be coated with 2-3 layers of enamel (1 base enamel layer, 1-2 top enamel layers);
- *Digital printing:* After being glazed, the tiles will be decorated with details using a high-precision digital printer. After the patterns are printed on the surface of the product, an additional layer of glaze will be applied to the surface to protect the printed patterns before firing the tiles;
- *Tiles firing:* The tiles after being glazed are put into the roller kiln, after a firing cycle of 47 - 55 minutes at a temperature of 1,130 - 1,175 ^{o}C. The semi-finished tiles after firing will be classified and broken tiles, defective tiles that do not meet

the standards will be removed. The tiles will be kept for at least 24 hours before being brought to the grinding stage;

- *Surface grinding and edge grinding:* Semi-finished tiles after being stored are transferred through the grinding system by conveyor system, then transferred through the nano grinding and dry edge grinding system and then transferred to the classification line;
- *Classification and packaging:* The products after grinding will be sent to the classification line, and the products that do not meet the quality standards will be eliminated. The products after classification will be automatically packaged and stored.

1.3 Description of the utility systems

- Power supply system:

Table 1.2. Transformer parameters

No	Equipment	Quantity	Voltage level (kV)	Rated power (kVA)	Power factor
Transformer station 1					
1	MSB – 11 (TR-11)	1	22/0.4	1,600	0.9
2	MSB – 12 (TR-12)	1	22/0.4	1,600	0.9
Transformer station 2					
1	MSB – 21 (TR-21)	1	22/0.4	2,500	0.9
2	MSB – 22 (TR-22)	1	22/0.4	2,500	0.9

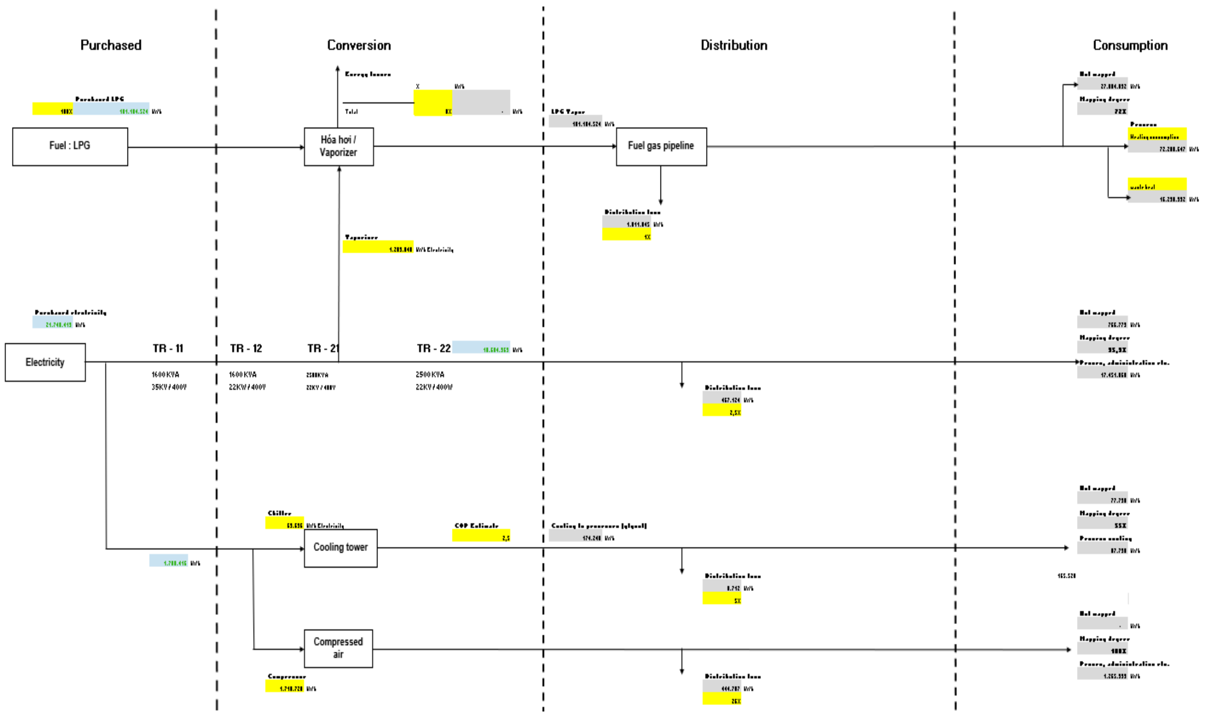


Figure 1.3. Power supply diagram and related subsystems

- Hot heat supply system:

The hot heat supply system accounts for a significant proportion of the company's total energy consumption structure. This system is used for various processes, including spray drying, quick drying, and tile firing. The company utilizes several types of furnaces: a fluidized bed furnace, which provides hot heat for the spray drying process; a spray drying tower, which dries materials into bone powder used for pressing into tiles; pre-drying rapid drying kilns (with five and seven floors), which dry raw tiles after pressing; and a furnace, which fires tiles after glazing.

Table 1.3. Parameters of the Company's hot heat supply system

No	Equipment	Quantity	Rated power (kW)	Operating hours per day	Operating days per year
1	Fluidized bed furnace	1	135	24	330
2	Quick drying kiln	2	228	24	330
3	Kiln	2	240	24	330

- LPG supply system:

LPG accounts for a relatively large proportion of the company's total energy consumption. The company purchases LPG from an external supplier and stores it in a tank within its premises. Through the LPG vaporization system, the fuel is converted from liquid to vapor and then supplied to the necessary systems. LPG is primarily used for drying and furnace operations.

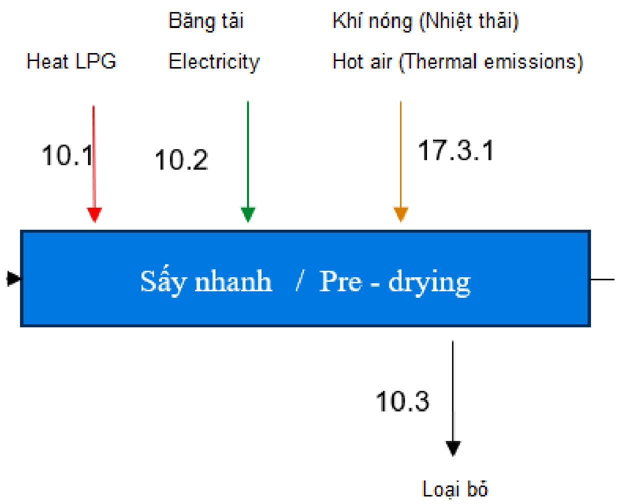


Figure 1.4. Rapid drying process using LPG

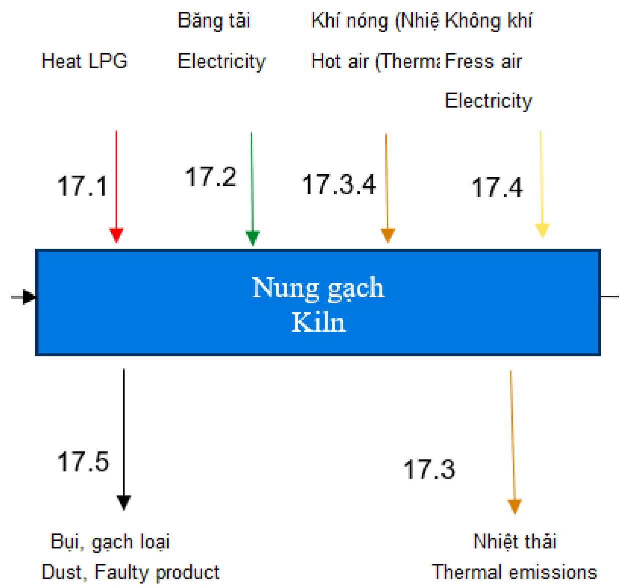


Figure 1.5. Tile firing process using LPG

Figure 1.6. The Company's LPG supply system

Table 1.4. LPG supply system equipment

No	Equipment	Quantity	Power (kW)	Operating hours per day	Operating days per year
1	Vaporizer	4	60	24	330

- Compressed air supply system:

The company's air compressor (AC) system consists of four screw compressors: one 125 kW AC, two 75 kW ACs, and one 55 kW AC. The system operates at a pressure range of 6–7 bar, depending on the requirements of the company's compressed air systems. The compressors function in Load/Unload mode.

Table 1.5. AC system equipment statistics

No	Equipment	Quantity	Setting pressure (bar)	Power (kW)	Operating hours per day (hours)	Operating days per year (days)
1	AC No. 1	1	6 - 7	55	24	330
2	AC No. 2	1	6 - 7	75	24	330
3	AC No. 3	1	6 - 7	75	24	330
4	AC No. 4	1	6 - 7	110	24	330

2 Methodology used to identify EE projects

2.1 How EE projects have been identified and developed

During the audit, the consulting team carried out work related to the following contents:

a) *Data collection and analysis*

Collect data related to facility operations and energy use for the past 3 years, including information on output, energy consumption KPI, energy usage data, equipment list, technological process diagram, system operation monitoring logbook and applied energy saving solutions.

b) *System survey implementation*

The system survey for this study includes an assessment of various key equipment to ensure a comprehensive evaluation of energy consumption and efficiency.

- Power supply system: Survey of power supply system and load diagram
- Production line system: Check equipment such as grinders, crushers, conveyor belts,...
- Boiler and drying tower systems: energy consumption measurement
- Pre-fire and kiln systems: Check kiln related systems, including measuring energy consumption
- Hydraulic press systems: collecting energy consumption data
- Cooling water system: temperature measurement and cooling tower survey
- Air compressor systems: Pressure, flow and air leak survey
- Pumping station system: collecting energy consumption data
- Electric motor systems: Performance evaluation of motors
- Lighting system: measure light intensity and lighting efficiency
- Other systems: additional testing to ensure comprehensive evaluation

c) *Preliminary assessment and determination of energy saving potential*

The preliminary assessment and determination of energy-saving potential began with a system survey to evaluate the current energy usage across various systems. This initial assessment helped identify areas with significant potential for energy savings. Following this, a structured plan was developed, emphasizing data collection and system testing to facilitate a thorough evaluation of energy-saving solutions.

A detailed survey was then conducted, involving in-depth observation and precise measurement of key systems and equipment. This step ensured the collection of accurate data for performance analysis, identification of energy-saving opportunities, and consideration of other influencing factors that could impact overall efficiency.

d) Building an energy mapping

To comprehensively assess the production and energy use systems for optimal energy conservation and environmental protection. This process includes mass balances and energy mapping, assessing energy performance, identifying potential areas for improvement, and recommending ways to reduce energy consumption for systems such as technological processes. The energy map helps the Plant's Energy Management Board have an overview of all energy consumption systems.

e) Energy performance assessment

The energy performance assessment evaluates system efficiency by analyzing actual energy consumption against optimal levels and calculating energy efficiency coefficients. These approaches help determine the overall performance of each system and identify areas for improvement.

Based on the findings, cost-saving solutions are proposed to enhance energy efficiency. Additionally, a preliminary assessment of the investment level, potential cost savings, and the payback period of the proposed solutions is conducted to ensure their feasibility and effectiveness.

f) Detailed analysis and evaluation

The detailed analysis and evaluation process involve summarizing, analyzing, and assessing collected data to establish a foundation for developing energy-saving solutions. This includes analyzing energy consumption rates and key performance indicators (KPIs) for energy efficiency. A comprehensive assessment of energy use is conducted by creating energy maps for each area and system.

Additionally, the current energy consumption of equipment in technological processes and production lines, such as crushers, grinders, and enamel mills, is evaluated. The study also assesses the energy consumption of boiler systems, furnace systems, water and compressed air-cooling systems, as well as pumps, fans, and other related systems.

g) Identify energy saving opportunities and options

The process of identifying energy-saving opportunities and options begins with a comprehensive review of process and equipment performance measured in the project. This involves a detailed study, investigation, and analysis of each system to assess its efficiency and potential for improvement.

Based on these evaluations, the consulting team will develop a plan for implementing energy efficiency investment projects, including a preliminary estimate of the potential energy savings. The focus is on optimizing current processes or systems to enhance efficiency, lower costs, minimize operational issues, and improve overall product or service quality.

Additionally, the consulting team will assess and prioritize potential energy-saving projects according to key criteria such as feasibility, payback period, and required investment levels.

Measuring methods and equipment

The energy audit team uses the direct measurement method: Using the equipment in Table 2.3 to measure in detail in each area, energy consuming equipment to determine parameters such as: Temperature, pressure, lighting quality, power consumption, voltage quality, power factor. In addition, the audit team also collects available storage data from the company's meters, monitoring, and energy consumption data in the past.

Energy audit implementation process

- *Detailed procedure for conducting energy audit:*

The energy audit process is carried out according to the instructions of Circular 25/2020/TT-BCT dated September 29, 2020. Specifically, as shown below:

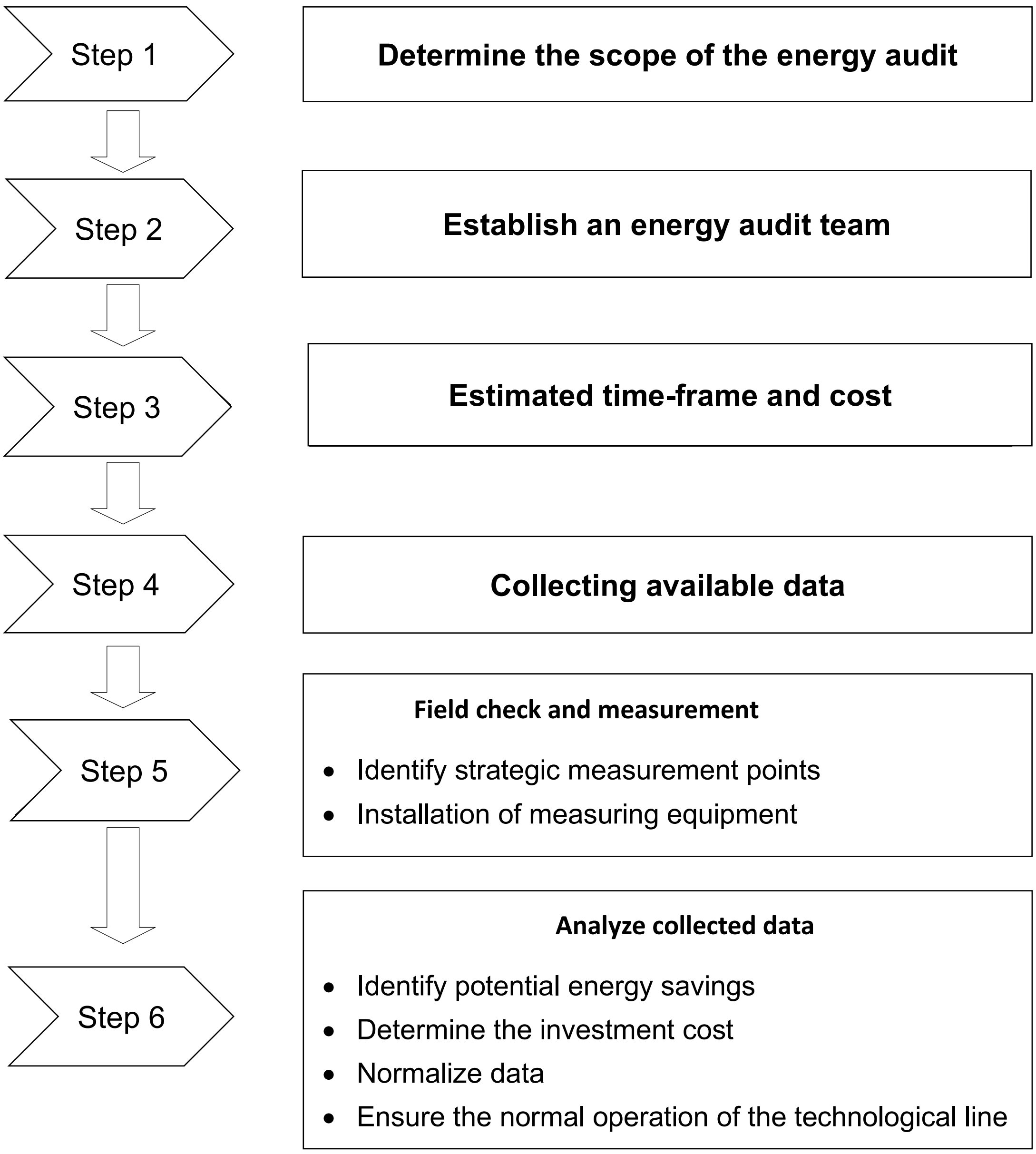


Figure 2.1. Audit procedure sequence .

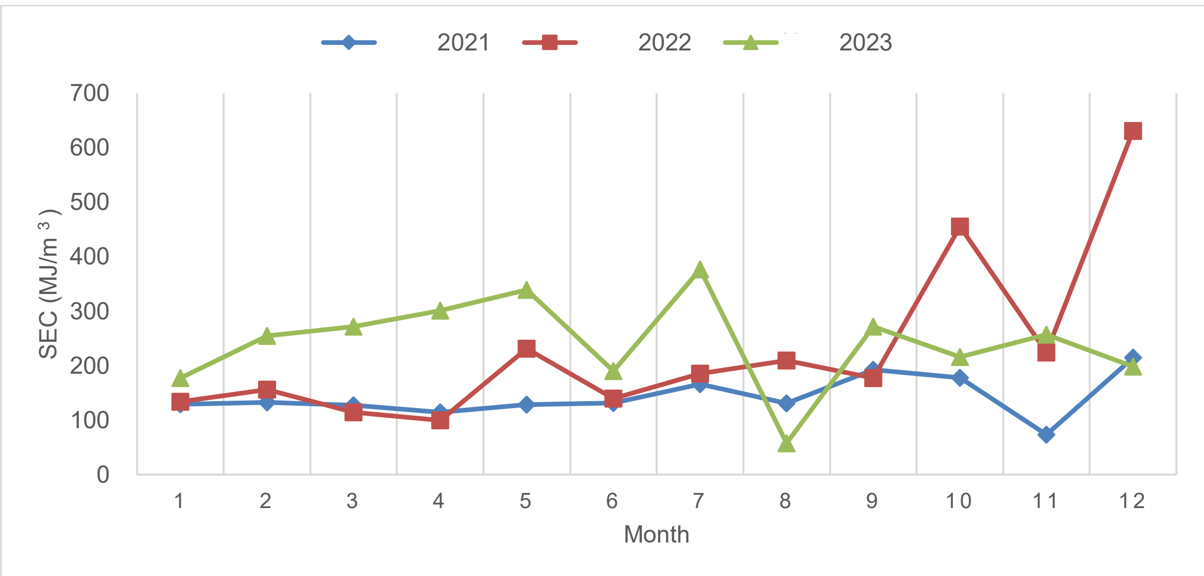


Figure 2.2. Energy consumption rate of the Company in the period 2021 - 2023

The analysis revealed that the company's energy consumption rate fluctuates between years and even between months within the same year. Specifically, in 2022, the average energy consumption increased by 47.98% compared to 2021, and in 2023, it continued to rise by 6.86% compared to 2022. These fluctuations are influenced by production plans and the maintenance schedules of machinery and equipment in the production line.

The overall trend indicates an increasing energy consumption rate over the years, suggesting inefficiencies in production that result in energy waste and higher production costs. Therefore, identifying and implementing energy-saving solutions is crucial to improving the current energy consumption rate. Additionally, abnormal fluctuations in the SEC index highlight areas that require improvement within the factory's management system. To address this issue, the company should monitor its production operations in accordance with ISO 50001:2018 standards. Implementing these standards will enable the factory's Board of Directors to better manage energy consumption at each stage of production and optimize the average SEC of the entire production line.

To identify potential energy savings, the consulting team combined system analysis using the Energy Mapping Tool with expert insights. Energy mapping helps pinpoint areas with the highest energy consumption, enabling the factory to focus on key improvement opportunities. This method serves as an essential tool for energy management, facilitating systematic energy-saving initiatives and enhancing overall efficiency.

Key insights from the energy mapping analysis include:

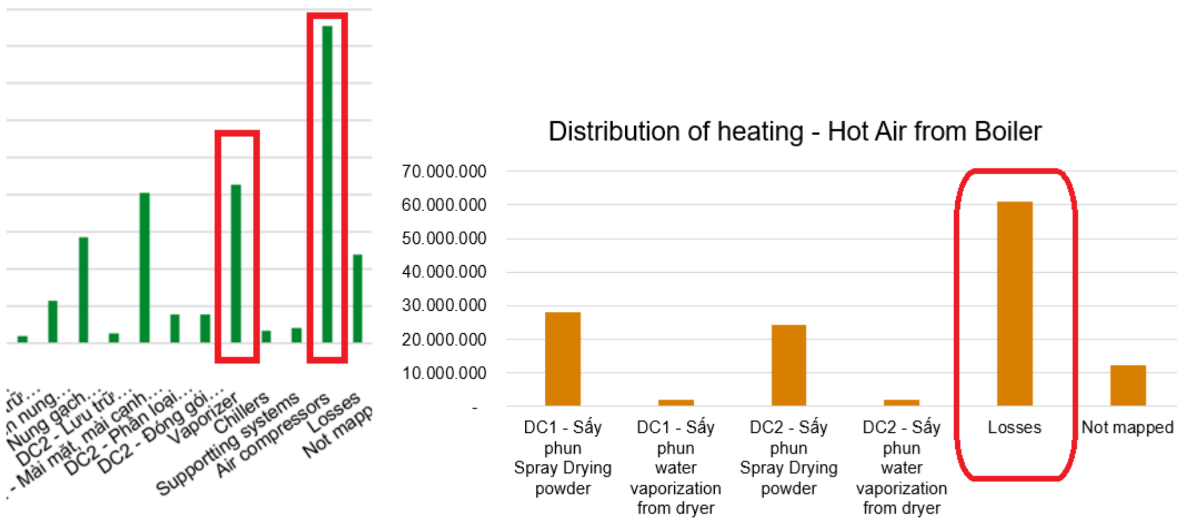


Figure 2.3. Identifying energy saving potential from mapping

- Electrical loads: The air compressor station and LPG vaporizer account for a significant share of total electricity consumption compared to other processes. This indicates the need for measures to optimize and reduce energy use in these systems.
- Thermal losses: In processes utilizing high-temperature heat from the coal-fired fluidized bed furnace, calculations reveal that only a small fraction of the heat is absorbed by textile clay powder and evaporated water in the spray drying tower. A substantial portion of heat is lost through exhaust gases, radiation, and coal slag, highlighting the need for waste heat recovery to improve system efficiency.
- Heat recovery potential: The factory features multiple heating and cooling processes alongside various waste heat sources, presenting opportunities for heat recovery and inter-process thermal optimization. Energy mapping provides a visual representation of energy flows, allowing Energy Managers to monitor, optimize, and implement improvements, such as equipment upgrades, process optimization, operational enhancements, and energy-efficient technologies.

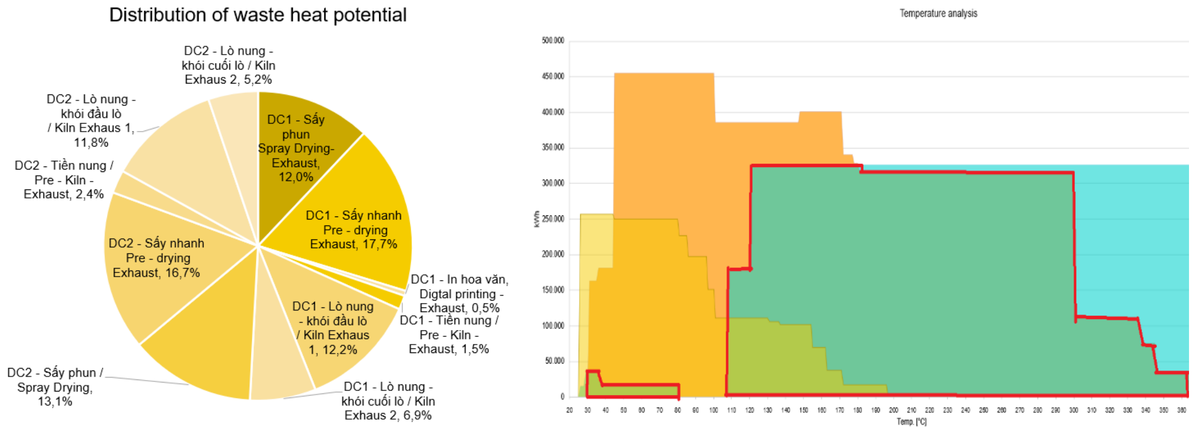


Figure 2.4. Identifying waste heat recovery potential and inter-process thermal optimization (red-circled areas)

By applying the above system analysis methods, the consulting team proposed a list of energy saving potentials (List level B) as shown in the chapter 3 of this report.

The potential for energy savings proposed by the consulting team is large. Implementing these solutions will significantly reduce energy costs. According to the audit team's assessment, the above solutions are highly feasible in terms of technology and economics. Based on the list of energy saving solutions proposed for the Factory, the consulting team will coordinate with the Factory to select solutions that need further study for investment (List level A). Investment costs are provisionally estimated and will be calculated in detail at the investment stage.

Table 2.1. Level A list - Energy saving solutions

No.	Project description	Location	Equipment	Type of saving	Potential Energy Saving (kwh)	Estimated Financial Savings (EUR)	Investment cost (EUR)	Payback time (year)	Solution description
1	Install inverter to control fan system in fast Rapid drying of 2nd line	Rapid drying	Inverter	Electricity savings	109,105	7,218	21,387	2.96	Exhaust fan of fast Rapid drying of 2nd line without inverter
2	Utilizing residual heat to pre-heat the air supply to the fluidized bed furnace	Fluidized bed furnace	Heat exchanger	Heat savings	1,538,401	10,949	28,515	2.60	The current LPG vaporizer consumes a lot of electricity so it can be replaced with a new type t that uses hot water from waste heat for vaporization.
3	Replace non-electric LPG vaporizer	Kiln	Vaporizer	Electricity savings	684,288	45,270	142,577	3.15	The current LPG vaporizer consumes a lot of electricity so it can be replaced with a new type that uses hot water from waste heat for vaporization.
4	Replacement of 1st line's spray drying tower	Spray drying tower	Spray drying tower	Heat savings	N/A	N/A	N/A	N/A	Research on replacing 1st line's spray drying tower with a new type of tower with higher efficiency.
5	Apply Energy Management System according to ISO 50001 standard	Energy Management		EnMS Improvement	2,043,663	37,857	89,111	2.35	-The factory has not applied the 50001 management system - The above abnormal increase and decrease of SEC shows that this is a point that needs improvement in the factory's management system.
	Total				**4,375,457**	**101,293**	**281,590**		

2.2 EE Project evaluation

The assessment of each energy saving solutions is based on a structured evaluation framework. The evaluation considers multiple factors, including energy savings, financial returns, and environmental impact, ensuring a comprehensive analysis of each proposed measure.

For each solution, energy savings are estimated by comparing baseline consumption with expected performance improvements. Financial viability is assessed using key metrics such as payback period, IRR, and NPV, considering both initial investment and long-term cost savings. Additionally, environmental benefits are quantified in terms of CO_2 emission reductions and TOE conversion, ensuring alignment with sustainability goals.

The detailed calculations for each energy efficiency solution are provided in the appendix.

2.2.1 Power supply system

- **Rooftop solar panel installation**

Input data:

- Expected installed capacity: 1,000 kWp;
- Installation cost of 1 kWp: 12,000,000 VND;
- Solution life: 20 years.

Summary of results of calculating economic efficiency of solutions:

- Energy savings: 1,071,000 kWh/year;
- Annual cost savings: VND 1,927,776,000 /year;
- Project investment cost: 13,000,000,000 VND;
- Payback period: 6.74 years.

For better investment efficiency, the Company can seek support capital from the Ministry of Industry and Trade's energy saving investment support program, financial support programs of non-governmental organizations or invest in the form of profit sharing from energy efficiency of Energy Service Companies (ESCOs).

2.2.2 Compressed air system

- **Reset the operating mode of the air compressors**

Input data:

- Rated capacity of AC No. 4: 110 kW;
- Rated capacity of AC No. 3: 75 kW;

- Number of operating hours per day: 24 hours/day;
- Number of operating days per year: 310 days/year;

Average electricity price in 2023: 1,856 VND/kWh.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 16,908 kWh/year;
- Cost savings per year: VND 31,381,248 /year;
- Project investment cost: 0 VND;

Conclusion: The solution is feasible both technically and economically.

- **Renovate the air compressor pipeline from branch circuit to loop circuit**

Input data:

- Average operating capacity of AC No. 4: 56.37 kW;
- Average operating capacity of AC No. 3: 80.80 kW;
- Average operating capacity of AC No. 2: 86.90kW.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 129,462 kWh/year;
- Cost savings per year: 168,197,290 VND/year;
- Project investment cost: 500,000,000 VND;
- Payback period: 2.97 years.

Conclusion: The solution is feasible both technically and economically.

- **Replace old air dryer with high efficiency air dryer**

Input data:

- Current air dryer average operating power: 2.4 kW;
- Average operating power of new air dryer: 3.15kW.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 41,796 kWh/year;
- Cost savings per year: 77,573,376 VND/year;
- Project investment cost: 426,000,000 VND;
- Payback period: 5.50 years.

Conclusion: The solution is feasible both technically and economically.

2.2.3 Fluidized bed furnace system

- **Insulation for fluidized bed furnace operating door**

Input data:

- The calculated area of the furnace door by: 0.42 m^2;
- Number of operating hours per day: 24 hours/day;
- Average coal cost in 2023: VND 1,812/kg.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 3.33 tons of coal/year;
- Cost savings per year: 6,034,065 VND/year;
- Project investment cost: 30,000,000 VND;
- Payback period: 4.97 years.

Conclusion: The solution is feasible both technically and economically.

- **Utilize residual heat to heat the air supply to the fluidized bed furnace**

Input data:

- Current furnace inlet air temperature: 25^{o}C;
- Inlet air temperature after adding heating: 70^{o}C ;
- Average coal cost in 2023: 1,812 VND/kg

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 169.52 tons of coal/year;
- Annual cost savings: VND 307,171,624 /year;
- Project investment cost: 800,000,000 VND;
- Payback period: 2.60 years.

Conclusion: The solution is feasible both technically and economically.

2.2.4 Production machine system

2.2.4.1 Raw material grinding system

- **Install time relay for stirring motor**

Input data:

- Total capacity of 2-line agitator: 117kW;
- Energy saving potential: 30%.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 208,915 kWh/year;
- Annual cost savings: VND 387,746,611 /year;
- Project investment cost: 60,000,000 VND;
- Payback period: 0.15 years.

Conclusion: The solution is feasible both technically and economically.

2.2.4.2 Spray drying and molding system

- **Utilize residual heat to raise the temperature of the material**

Input data:

- Current lake temperature: 44 ^{o}C;
- Temperature of the lake after solution implementation: 60 ^{o}C.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 149,363 kg of coal/year;
- Annual cost savings: VND 270,645,910 /year;
- Project investment cost: 1,200,000,000 VND;
- Payback period: 4.43 years.

Conclusion: The solution is feasible both technically and economically.

2.2.4.3 Quick drying system

- **Install inverter to control fan system in Line No.2 quick drying kiln area**

Input data:

- Rated capacity of quick drying system: 188.50kW;
- Quick drying system operating capacity: 112.01kW.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 109,105 kWh/year;
- Cost savings per year: VND 202,498,449 /year;
- Project investment cost: 600,000,000 VND;

- Payback period: 2.96 years.

Conclusion: The solution is feasible both technically and economically.

2.2.4.4 Tile firing system

- **Using residual heat of LPG vaporization furnace**

Input data:

- Current evaporator rated power: 60kW.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 684,288 kWh/year;
- Annual cost savings: VND 1,270,038,528 /year;
- Project investment cost: 4,000,000,000 VND;
- Payback period: 3.15 years.

Conclusion: The solution is feasible both technically and economically.

2.2.4.5 Grinding, sorting and packaging system

- **Replace low efficiency nano grinding motor with high efficiency IE4 motor**

Input data:

- Rated power of grinding system, nano Line No.1: 416 kW;
- IE1 motor efficiency: 88%;
- IE4 motor efficiency: 93%.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 137,892 kWh/year;
- Cost savings per year: 255,927,408 VND/year;
- Project investment cost: 980,000,000 VND;
- Payback period: 3.63 years.

Conclusion: The solution is feasible both technically and economically.

Input data:

- Rated power of grinding system, nano Line No.2: 1.153kW;

- IE1 motor efficiency: 70%;
- IE3 motor efficiency: 85%.

Summary of results of calculating economic efficiency of solutions:

- Energy saved per year: 153,140 kWh/year;
- Cost savings per year: 284,227,074 VND/year;
- Project investment cost: 1,250,000,000 VND;
- Payback period: 4.4 years.

Conclusion: The solution is feasible both technically and economically.

2.3 EE Project prioritisation

The key solutions selected for the investment study proposal after the audit are presented in the Level A list (table 2.2). To achieve the goal of transforming the factory into an energy-saving factory, the proposed solutions must go through several critical stages.

The process begins with the audit report, which provides an overview of the factory's energy-saving potential. Following this, the pre-feasibility stage is conducted to identify and select the two to three most important solutions. The feasibility phase then evaluates these options to determine the most viable solution for investment. Once a decision is made, the process moves to the bidding or competitive quotation stage, followed by bid evaluation or procurement.

The installation and commissioning phase require close supervision by the plant to ensure that key design decisions made during the feasibility and tendering phases are correctly implemented. After the solution is installed and operational, a comprehensive assessment must be conducted to collect and document new energy performance data. This final step ensures that the solution not only functions as expected but also delivers the anticipated energy savings.

2.4 Enterprises feedback

- *Proposal of Pre-feasibility implementation:*

After discussion with representatives of various departments in the Factory, along with suggestions from Mr. Rahul - Project Specialist, the following proposals for Pre-feasibility were identified:

- Utilizing residual heat to heat the air supply to the fluidized bed furnace
- Install inverter to control fan system in fast drying oven area at line No.2
- Non-electric LPG vaporizer replacement
- Replace the spray drying tower in Line No.1
- Energy Management System according to ISO 50001 standard application

o *Conclusions of final meeting with factory:*

After the presentation and discussion, the factory agreed with the results of the energy audit and all proposed energy-saving solutions. The factory has identified five solutions of particular interest and proposes that they be further studied in the Pre-Feasibility Study (Pre-FS) phase of the project. The factory hopes that the DE3 Project Board will review, select, and approve the solutions for Pre-FS support. Additionally, the factory has committed to supporting the project in the subsequent steps to ensure the successful implementation of energy-saving measures.

3 EE Projects identified

Table 3.1. Gross list (level B)

Gross list							
Project no.	Name of Project	Energy form	Investment Cost [$]	Saving			Simple Payback [Years]
				Energy [kWh]	CO_2 [ton]	Financial [EUR]	
I. Energy-saving solutions that require low investment costs							
1	Re-adjust the operating mode of the air compressors	Electricity	0	16,908	-	1,119	-
2	Fix compressed air leaks	Recommended					
3	Insulation for fluidized bed furnace's doors	Coal	1,069	23,310	2.03	215	4.97
4	Improve water quality for wet dust scrubber to reuse dust and water in exhaust gas	Recommended					
5	Install a time relay to turn on/off the raw slurry tank's stirring motor	Electricity	2,139	208,915	-	13,821	0.15
6	Measures to improve operational and energy management procedures	Recommended					
7	Replace fluorescent bulbs with LED lights	Electricity	1,568	10,435	-	690	2.27
8	Increase CosPhi for Transformer Station (more efficiency)	Electricity	1,426	9,711	-	642	2.22
II. Energy-saving solutions that require high investment costs							
9	Refurbishment of pneumatic piping from branch circuit pattern to closed-loop circuit pattern	Electricity	17,822	129,462	-	5,995	2.97
10	Utilize residual heat to raise the temperature of the slurry before entering the spray drying tower	Coal	42,773	1,045,520	91.02	9,647	4.43
11	Utilizing residual heat to pre-heat the air supply to the fluidized bed furnace	Coal	28,515	1,186,640	103.30	10,949	2.60
12	Install harmonic filters for transformers	Recommended					
13	Rooftop solar panel installation	Electricity	463,376	1,071,000	-	68,714	6.74
14	Replace old air dryer with high efficiency air dryer	Electricity	15,206	41,796	-	2,765	5.50
15	Install inverter to control fan system in fast Horizontal dryer of 2nd line	Electricity	21,387	109,105	-	7,218	2.96

Gross list							
Project no.	Name of Project	Energy form	Investment Cost [$]	Saving			Simple Payback [Years]
				Energy [kWh]	CO2 [ton]	Financial [EUR]	
16	Replace non-electric LPG vaporizer	Electricity	142,577	684,288	-	45,270	3.15
17	Utilize waste heat to generate hot water	Electricity	53,466	1,710,600	-	113,166	0.47
18	Replace tile grinder motor with IE4 motor of Production line No.1	Electricity	34,931	137,892	-	9,122	3.83
19	Replace tile grinder motor with IE4 motor of Production line No.2	Electricity	44,555	153,140	-	10,131	4.40
20	Replace existing batch ball mill with continuous vertical mill	Recommended					
21	Replacement of 1st line's spray drying tower	Recommended					
22	Apply Energy Management System according to ISO 50001 standard	Electricity	89,111	115,591	-	37,857	2.35

4 Selected EE Projects for further supports

Table 4.1. Selected project (level A mapping)

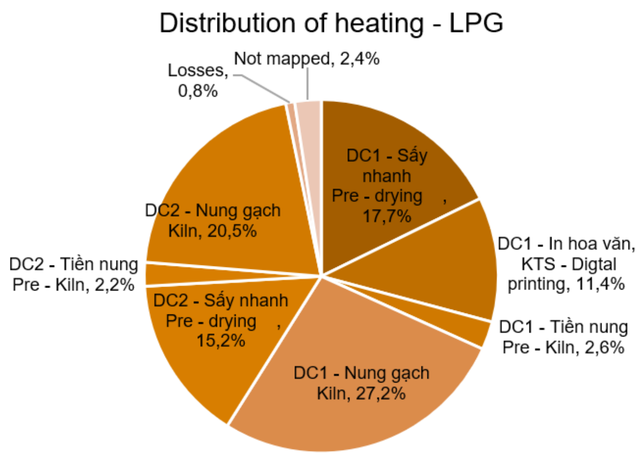
Project information		
Project: Installing an inverter for the fast-drying kiln fan system in production line 2	**Project no. 1**	**Date: Expected in 2025 - 2026**
Enterprise: Porcelain and Ceramic Company	**Name of EAC company: Vietnam Technology Solutions Joint Stock Company**	**Lead Auditor: Hoa Thai Thanh**

Project description

Current situation

At the factory, multiple heating processes operate simultaneously and are interconnected to ensure product quality throughout the production line. The **Energy Mapping** tool visualizes heat sources, providing a clearer overview of energy sources, systems, equipment, and energy consumption processes within the production line. This allows energy managers to monitor and optimize energy use, proposing improvements such as equipment upgrades, process optimization, operational enhancements, and the adoption of energy-saving technologies.

During the energy audit, the consulting team combined system analysis using the Energy Mapping tool with expert experience. Energy Mapping helps identify the largest energy-consuming areas, enabling the plant to focus its improvement efforts. This tool is crucial for businesses to manage and use energy more efficiently while systematically promoting energy-saving activities.



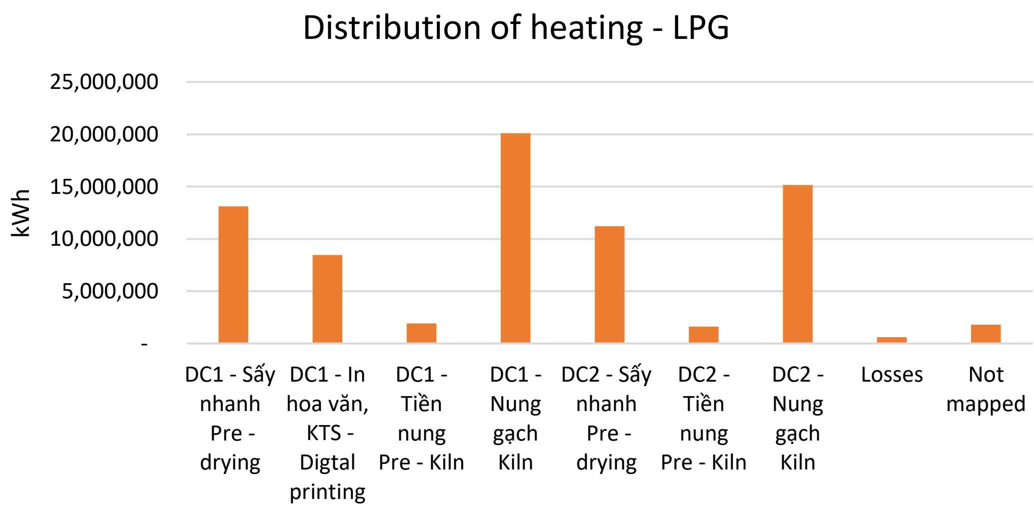


Figure IV.1. Identify heat distribution between processes

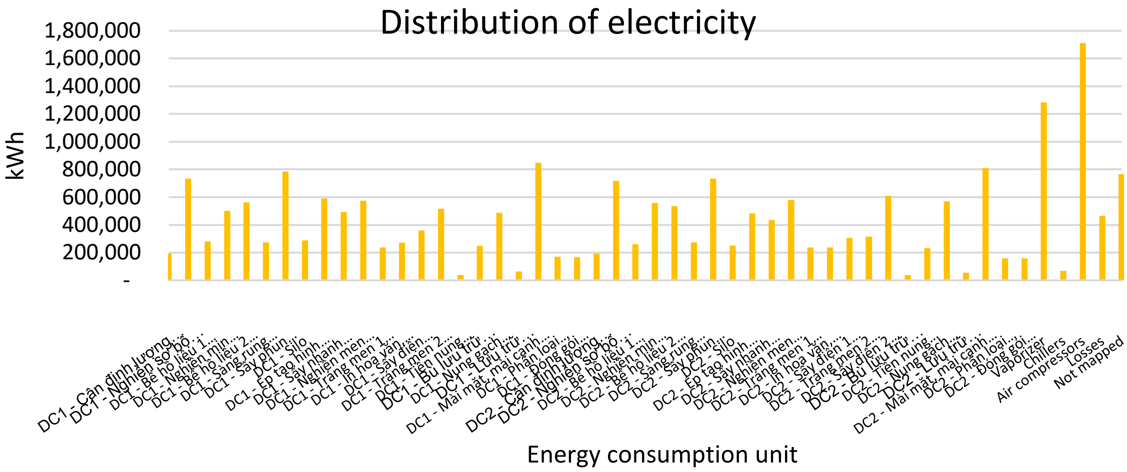


Figure IV.2. Energy consumption distribution chart by stage

Within the production line, after the raw clay mixture is pressed into green bricks using a hydraulic press, they must go through drying and firing stages. After forming, the green bricks are transferred to a 5-layer fast drying kiln (Production Line 2) or a 7-layer fast drying kiln (Production Line 1). During this process, the bricks are completely dried, removing any remaining moisture. A small portion of defective bricks—such as those with cracks, deformations, or other quality issues—are discarded and not reused to ensure the quality of the final product. The remaining bricks proceed to Glazing Stage 1. This drying stage significantly impacts the quality of subsequent production processes.

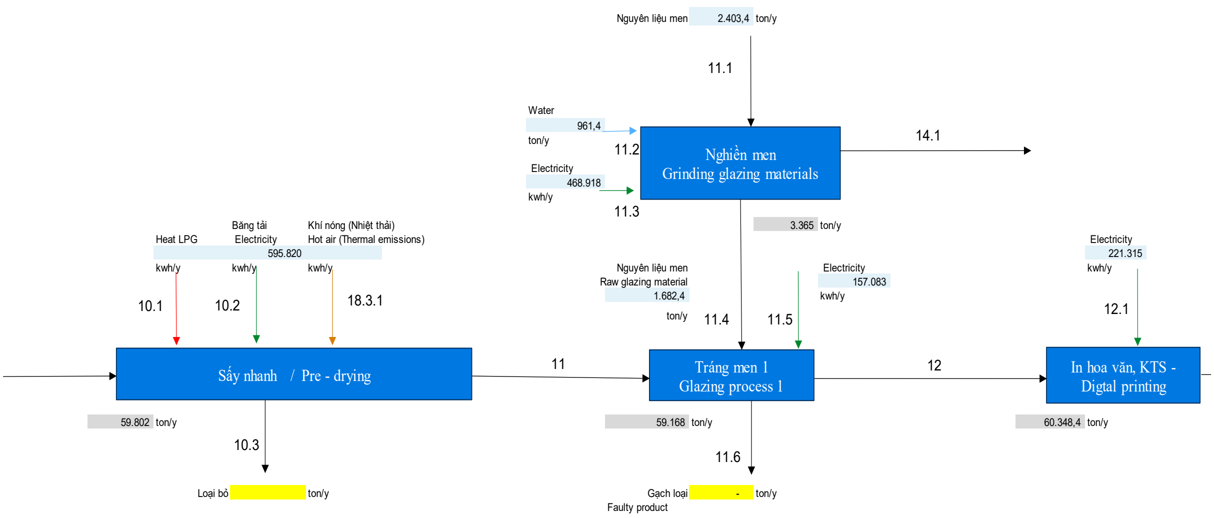


Figure IV.3. Flowchart of quick drying, glazing and pattern printing process

The exhaust and circulation fans in the fast drying kiln of Production Line 2 currently operate with direct start motors. Airflow is regulated using dampers, while the motors continuously run at their rated speed. As a result, the motors operate underloaded with a low power factor, leading to excessive reactive power consumption. This inefficient operation results in high energy consumption and significant energy waste. Therefore, there remains considerable energy-saving potential in this area of Production Line 2, particularly when compared to the more efficient system in Production Line 1.

Proposed project

The fast drying kilns currently utilize waste heat from the firing kiln, supplemented by LPG burners when waste heat is insufficient. After the prescribed drying period, the green bricks are transported to the glazing and digital printing stages. The fast drying kiln removes residual moisture from the bricks after shaping and before firing. Proper drying is crucial to prevent cracking, deformation, or damage during the firing process.

The consulting team has conducted measurements of the power and heat supply for the fast drying system, and the collected data is summarized in the following tables:

Table IV.1. Evaluation and comments on the results of fast drying system testing

No	Equipment	Prated (kW)	Measurement results	Evaluation
1	Total power of 5-layer drying kiln (line 2)	188.5	P_{avg} = 112.01 kW P_{max}= 114.59 kW P_{min} = 109.21 kW Cosφ = 0.74 ∑U-THD % = 3.60% ∑I-THD % = 8.60%	Motor operates at rapidly and continuously changing load levels. Low power factor. Total voltage and current harmonics within allowable range.
2	Total power of 7-layer drying kiln (line 1)	215	P_{avg} = 99.03 kW P_{max}= 99.76 kW P_{min} = 98.28 kW Cosφ = 0.88 ∑U-THD % = 7.04% ∑I-THD % = 47.67%	Motor operating at variable load. Average power factor. Total voltage harmonics and current harmonics within allowable range.

The results show that although Production Line 1 uses a 7-layer drying kiln with more fans and a higher total rated power, its actual power consumption is lower (99.03 kW). Meanwhile, Production Line 2, which has a 5-layer drying kiln with lower production output and fewer fans with a lower total rated power, consumes more electricity (112.01 kW on average). The key difference lies in the fan control technology used in the drying kilns.

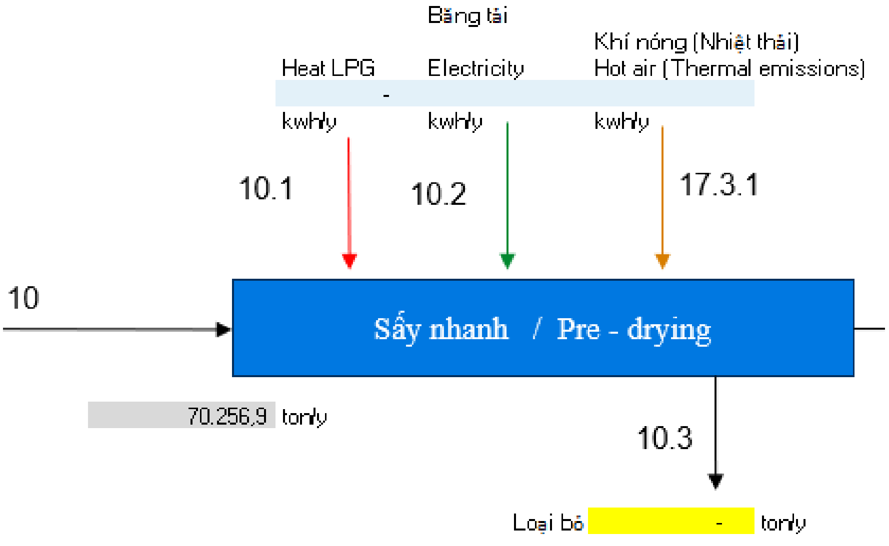


Figure IV.4. Fast drying stage in energy diagram

Current operating conditions:

- The fast drying kilns are equipped with LPG burners, but they are rarely used because the waste heat from the firing kiln is sufficient for drying. The main drying zone maintains a temperature of 180 – 230°C;
- The average drying cycle time is about 30 minutes.

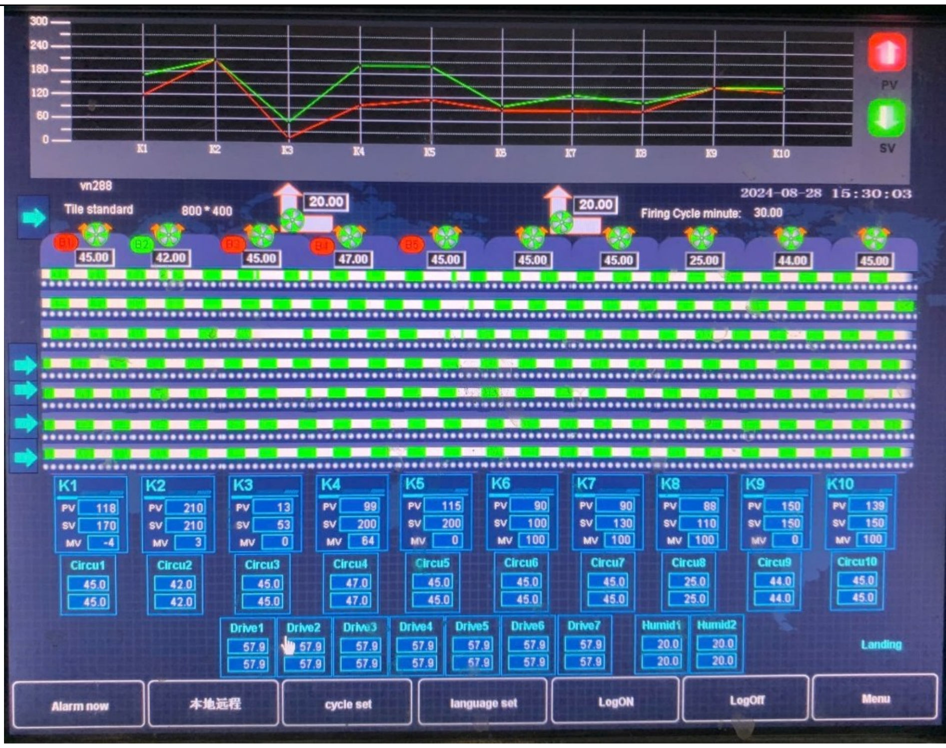


Figure IV.5. Control panel of 7-layer fast drying kiln area of line 1

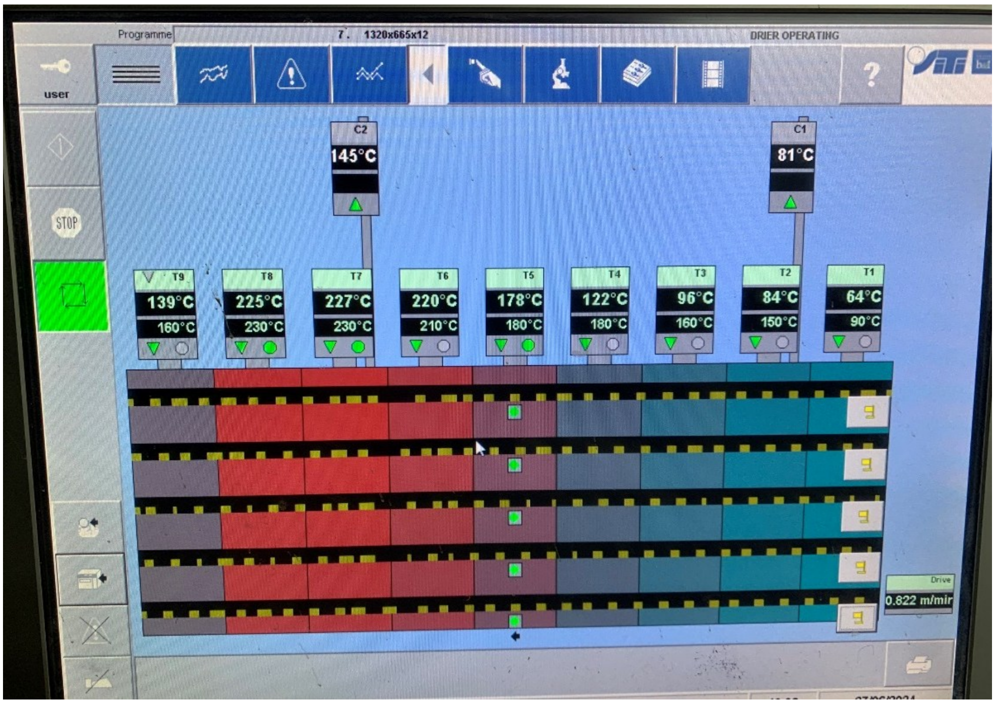


Figure IV.6. Control panel of 5-level fast drying kiln area of line 2

Technology:

- Production Line 1: The 7-layer drying kiln includes two 15 kW exhaust fans and ten 18.5 kW circulation fans, which are controlled by inverters. The frequency is optimally set for the drying process, maximizing energy efficiency;
- Production Line 2: The 5-layer drying kiln includes two 11 kW exhaust fans and nine 18.5 kW circulation fans, operating with direct start and running at full power without energy optimization.

Based on analysis and measurements, the consulting team has proposed the solution: "Installing inverters for the fan system in the fast drying kiln of production line 2."

While this solution theoretically has strong energy-saving potential—as demonstrated by the comparison between the two production lines—there are challenges to consider, given that the production line is fully automated and interlinked. Therefore, further research is needed to address the following concerns:

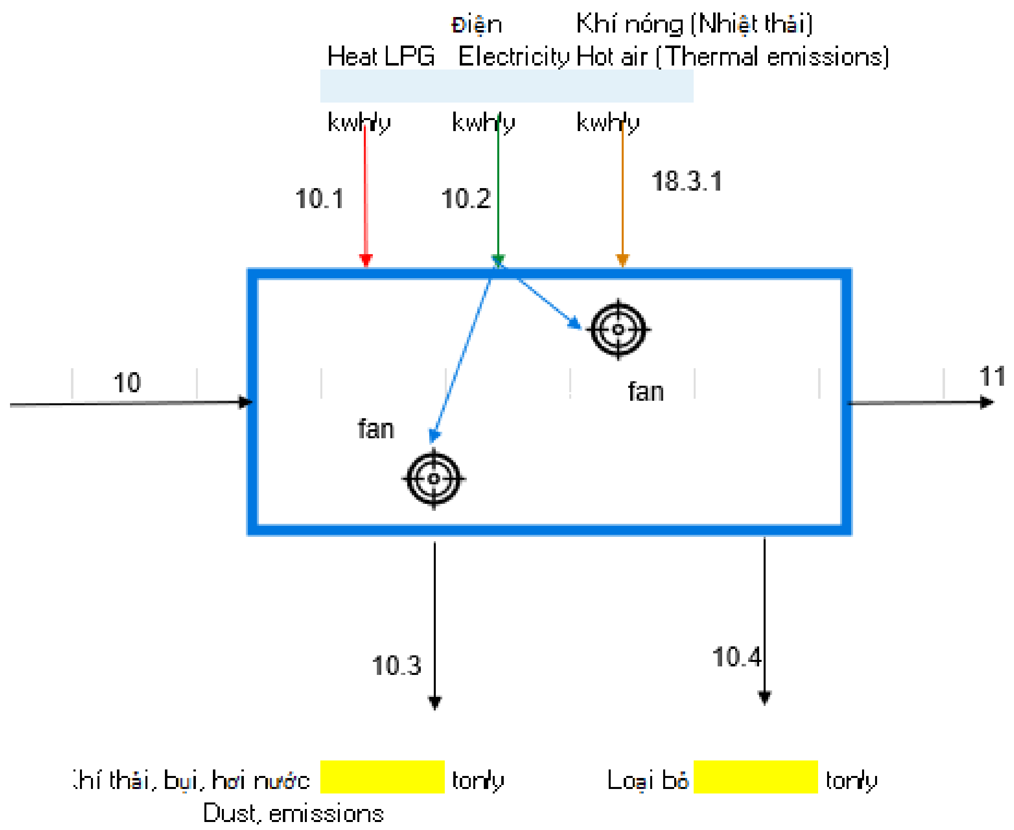
- Will installing inverters impact the production line's operation and productivity?
- Will it affect product quality?
- If there are any negative impacts, what corrective measures can be implemented?
- If inverter installation is feasible, what are the selection criteria for the inverters? Are additional auxiliary components needed?
- What are the possible approaches for installing inverters and modifying the production line?

Addressing these uncertainties requires a team of experienced experts with deep expertise not only in inverters and automation control but also in ceramic tile production technology. Due to these challenges, although the factory has long been aware of and interested in such solutions and recognizes their strong energy-saving potential, it has not yet proceeded with investment.

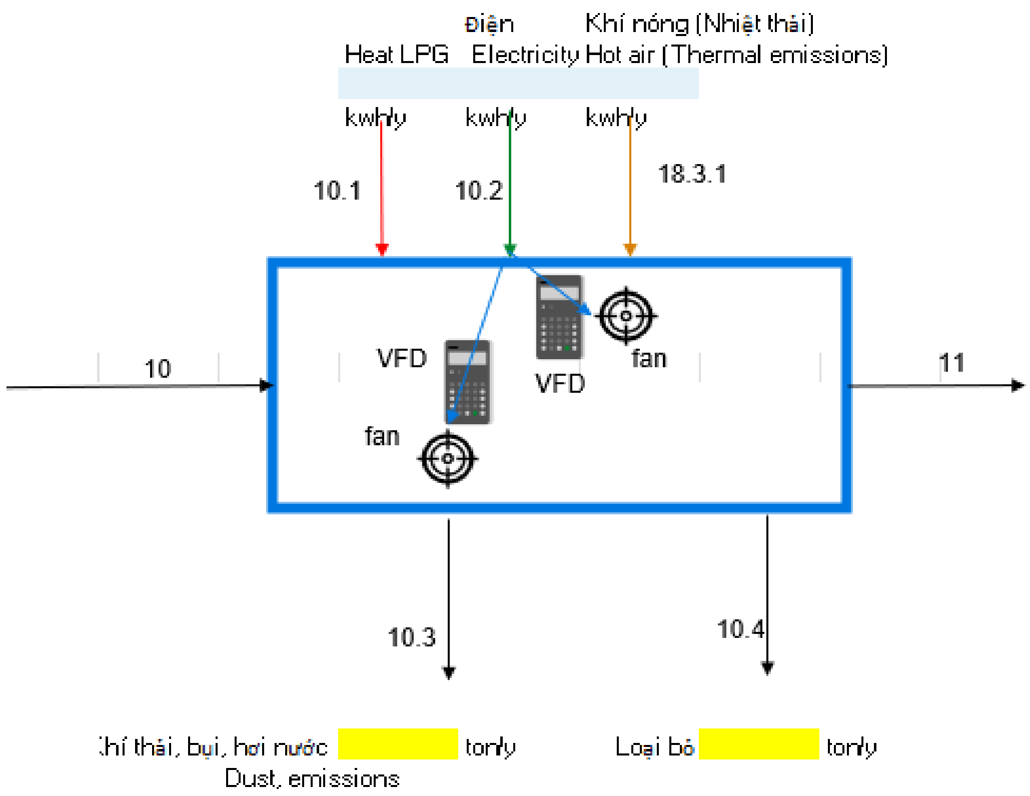
Through the energy audit, the factory has gained a clearer understanding of the proposed solutions and is now eager to submit the proposal: **"Installing inverters for the fan system in the fast drying kiln of production line 2"** to the DEPP3 PMB for support in conducting a Pre-Feasibility Study (Pre-FS).

Project illustration (PFD)

Before :



After :



Project Budget

- CAPEX costs for purchasing new inverters and accessories, installation
- OPEX costs including maintenance and operation, additional power consumption of inverters
- Staff training costs.

Total investment cost (estimated): Approximately 600 million VND

TIME SCHEDULE

No	Task	Month 1				Month 2				Month 3			
		W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
1	***Kick-off meeting, measurement plan and data collection***												
1.1	*Kick-off meeting, preparing detailed survey plan content*												
1.2	Conduct surveys and collect data												
1.2.1	*Survey and collect data on project site (Meteorological and hydrological data; Topography - geology)*												
1.2.2	*Survey, measure, collect data on the current operating status of existing two production line*												
1.2.3	*Survey and collect data of pre-drying kiln:*												

	- Measure fan power (kW), airflow (m^3/h), operating time (hours/day). *- Record electricity consumption (kWh/month).*												
1.2.4	*Collect some other data and information to serve the performance evaluation process and report preparation:* *- Assess tile moisture before and after drying.*												
1.3	*Discuss with the factory about the direction for Pre-fs solutions*												
2	***Collect additional data for the solution***												
2.1	Automation expert and engineer evaluate the feasibility of implementing the solution												
2.1.1	*Automation expert and engineer determine minimum airflow requirement for drying*												
2.1.2	*Assess inverter compatibility with existing PLC/SCADA of production line.* *Check environmental conditions (dust, temperature).*												
2.1.3	*- Design a test on one fan: install inverter, run trial, measure results.* *- Evaluate impact on kiln and production line.*												
2.2	Prepare technical options for solutions (in coordination with solution and inverter providers)												
3	***Preliminary calculation of the effectiveness of implementation options***												
3.1	Develop technical solutions												
3.1.1	*Develop technical solutions to implement the solution (in coordination with experts)*												
3.1.2	*Estimate CAPEX (inverter, installation, training). Estimate OPEX (maintenance, operation).*												
3.1.3	*Calculate electricity savings and payback period.*												
3.1.4	*Identify risks (insufficient drying, integration errors, equipment failure).* *Propose mitigation measures (sensors, testing).*												

3.2	Comparative calculation of the effectiveness, benefits and costs of technical solutions												
3.3	Present preliminary calculation results to the Factory, discuss and agree on the most feasible option to include in the Pre-Feasibility Study Report												
4	***Prepare pre-feasibility study report***												
4.1	Prepare pre-feasibility study report (Pursuant to Article 53 of Construction Law No. 50/2014/QH13 dated June 18, 2014 and Construction Law No. 10/VBHN-VPQH dated July 4, 2019)												
4.2	Meeting, clarifying Pre-FS report with relevant stakeholders												
4.3	Complete the report according to comments from relevant stakeholders.												

Saving

Energy (annual): 109,105 kWh/year	**Financial (annual): 202,498,449 VND**
CO2 (annual): 73.82 tons	**Simple Payback (years): 2.96**

Risk Analysis

a) Identifying Risk Factors

❖ ***Drying performance & synchronization with kiln***

- Risk: Reducing fan speed may result in insufficient hot air flow, leading to inadequate drying of the tiles before entering the kiln. This could cause tile cracking, deformation, or extended firing times, affecting overall production efficiency.
- Likelihood: Medium (if hot air demand is not accurately calculated).
- Impact: High (affecting tile quality and kiln efficiency).

❖ ***Process automation & system integration risks***

- Risk: Inverter speed adjustments may be incompatible with the existing PLC/SCADA control system, causing signal interruptions between the drying kiln and other units (e.g., pressing, kiln).
- Likelihood: Low to Medium (depending on inverter integration level).
- Impact: High (may cause system failure or downtime).

❖ ***Technical installation risks***

- Risk: Incorrect wiring or misconfigured inverters may cause fan failure, leading to process interruptions.
- Likelihood: Low (if experienced technicians are involved).
- Impact: Medium to High (depending on downtime required for troubleshooting).

❖ ***Inverter reliability risks***

- Risk: Inverter failures due to exposure to dust, high temperatures, or poor-quality equipment could result in fan shutdowns and production disruptions.
- Likelihood: Low to Medium (depending on brand and maintenance).

- Impact: High (production stoppage).

❖ ***Human factor risks***

- Risk: Operators lacking inverter knowledge may incorrectly set parameters (e.g., fan speed too high or too low), negatively affecting drying and kiln operations.
- Likelihood: Medium (if training is insufficient).
- Impact: Medium (can be quickly corrected if detected early).

b) Evaluating risk tolerance

- Financial capacity: Assessing whether the company can bear risks if the expected benefits are not achieved.
- Payback period: Evaluating whether the return on investment timeframe is acceptable.
- Seeking preferential financing: Since the solution saves energy and reduces environmental impact, it may be eligible for low-interest loans or incentives to ease financial burdens.

c) Developing risk mitigation plan

- Market research: Analyze different equipment suppliers to select the best option at a reasonable cost.
- Pilot testing before full investment: Conduct a trial with a small servo press before deciding to upgrade the entire system.
- Early employee training: Start training employees during the preparation phase to minimize production downtime.

❖ ***Ensuring proper drying performance & kiln synchronization***

- Accurate air demand calculation: Determine or measure the minimum hot air flow rate (m^3/h) and required moisture levels before tiles enter the kiln. Configure the minimum fan speed on the inverter to avoid exceeding this threshold.
- Install humidity sensors in the drying kiln for real-time automatic fan speed adjustment.

❖ ***Seamless integration with automation system***

- Verify inverter compatibility with the existing PLC/SCADA system before installation (e.g., Modbus, Profibus support).
- Test interlocking functions between the drying and firing kilns during the trial phase to ensure signal continuity.

❖ ***Reducing technical installation risks***

- Hire experienced engineers specializing in ceramic tile production and INVERTER systems to handle installation and programming.
- Run the system in manual mode first before switching to full automation, conducting step-by-step testing.

❖ ***Enhancing inverter reliability***

- Select inverters with at least IP54 or IP65 rating (for dust and heat resistance) from reputable brands.
- Install protective electrical enclosures and schedule regular maintenance (every 3-6 months) to prevent failures.

❖ ***Operator training & knowledge enhancement***

- Conduct hands-on training sessions on inverter operation and troubleshooting before project implementation.
- Prepare quick-reference user guides for operators to consult as needed.

d) Monitoring & Evaluation

After installation, the drying kiln's performance and overall production line efficiency should be continuously monitored and compared with initial projections. Adjustments can be made if necessary.

Non-Energy benefits

a) Economic benefits

- Lower maintenance costs for motors and fans: Direct-on-line starting causes mechanical and thermal stress on motors, reducing their lifespan. An inverter with soft-starting extends the motor and fan's lifespan, reducing maintenance or replacement frequency.
- Improved drying process control: The ability to adjust drying by zone within the kiln enhances product quality and reduces defective tiles.
- Competitive advantage: Lower production costs make ceramic tile pricing more competitive in the market.

b) Environmental benefits:

- Reduction in greenhouse gas emissions: This contributes to Vietnam's **Net Zero 2050** goal.
- Support for cleaner production: Energy optimization aligns with green manufacturing standards, helping the plant achieve ISO 14001 certification or meet international customer requirements.

c) Operational and product quality improvements:

- Better drying process control: The inverter allows precise control of hot airflow based on tile moisture levels, ensuring uniform drying and reducing defects (e.g., cracks or deformations due to uneven drying).
- Noise reduction: Fans running at lower speeds generate less noise, improving working conditions for employees.

d) Compliance and corporate reputation:

- Regulatory compliance: This solution helps the plant fulfill its energy-saving obligations under Vietnam's Law on Energy Efficiency and Conservation (2010), particularly for large energy-consuming facilities.
- Enhanced corporate image: Adopting modern, eco-friendly technology boosts credibility with partners, customers, and regulatory bodies.

e) Flexibility and future expansion:

- Seamless integration with automation systems: The INVERTER can be easily integrated with PLC or SCADA systems, creating a foundation for future production line upgrades.
- Adaptability to production changes: If production expands or processes change, the INVERTER can be reprogrammed to meet new requirements without replacing the entire fan system.

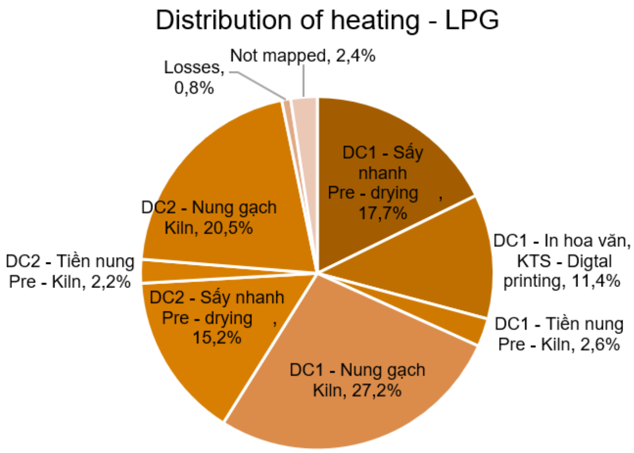
Table 4.2: *Selected project no.2*

Project information		
Project: Utilizing waste heat for LPG vaporization	**Project no. 2**	**Date: Expected in 2025 - 2026**
Enterprise: Porcelain and ceramic company	**Name of EAC company: Vietnam Technology Solutions Joint Stock Company**	**Lead Auditor: Hoa Thai Thanh**
Project description		

Current situation

At the factory, multiple heating processes operate simultaneously and are interconnected to ensure product quality throughout the production line. The **Energy Mapping** tool visualizes heat sources, providing a clearer overview of energy sources, systems, equipment, and energy consumption processes within the production line. This allows energy managers to monitor and optimize energy use, proposing improvements such as equipment upgrades, process optimization, operational enhancements, and the adoption of energy-saving technologies.

During the energy audit, the consulting team combined system analysis using the Energy Mapping tool with expert experience. Energy Mapping helps identify the largest energy-consuming areas, enabling the plant to focus its improvement efforts. This tool is crucial for businesses to manage and use energy more efficiently while systematically promoting energy-saving activities.



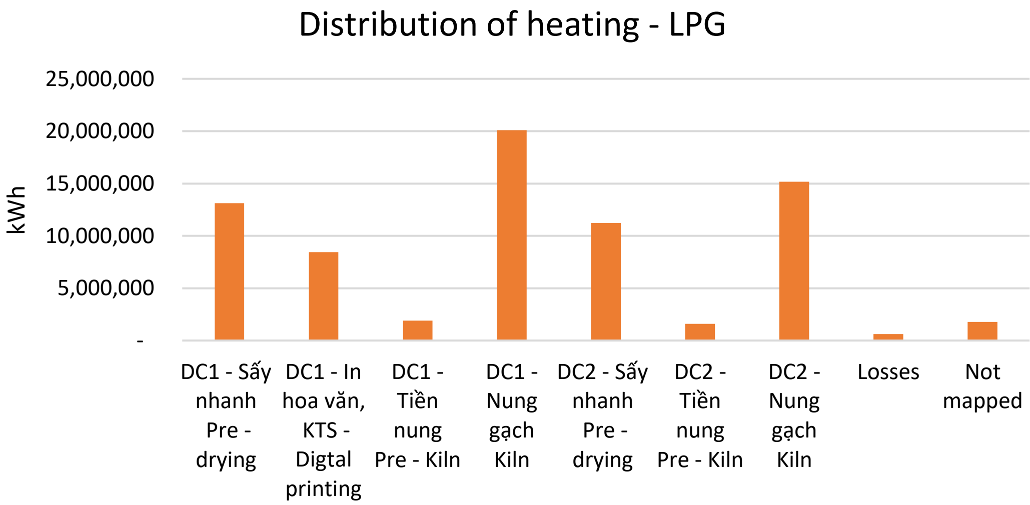


Figure IV.7. Identify heat distribution between processes

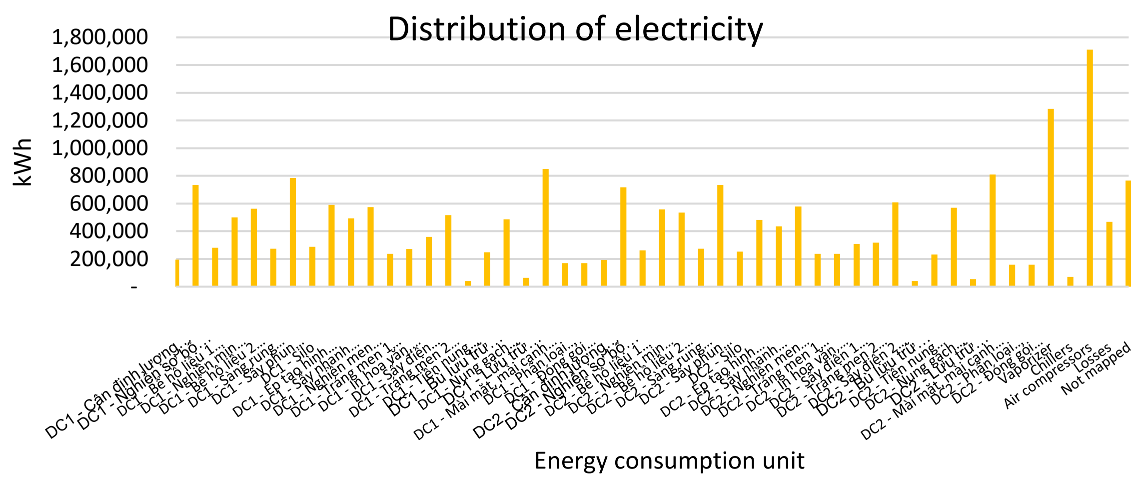


Figure IV.8. Energy consumption distribution chart by stage

In the energy structure supplied to the production lines, LPG accounts for a significant proportion of usage.

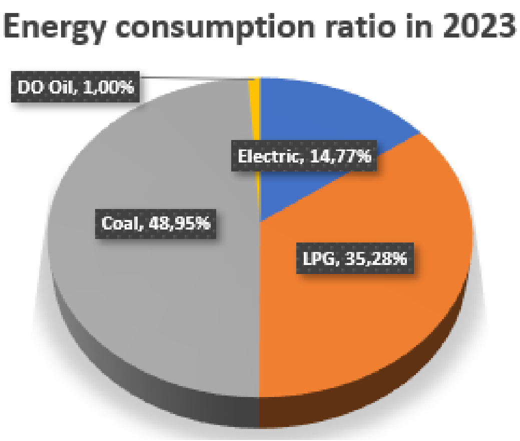


Figure IV.9. Energy consumption ratio in 2023

LPG accounts for a relatively large proportion of the Company's total energy consumption structure. LPG consumption fluctuates depending on the production plan, maintenance and repair of the Company's production system

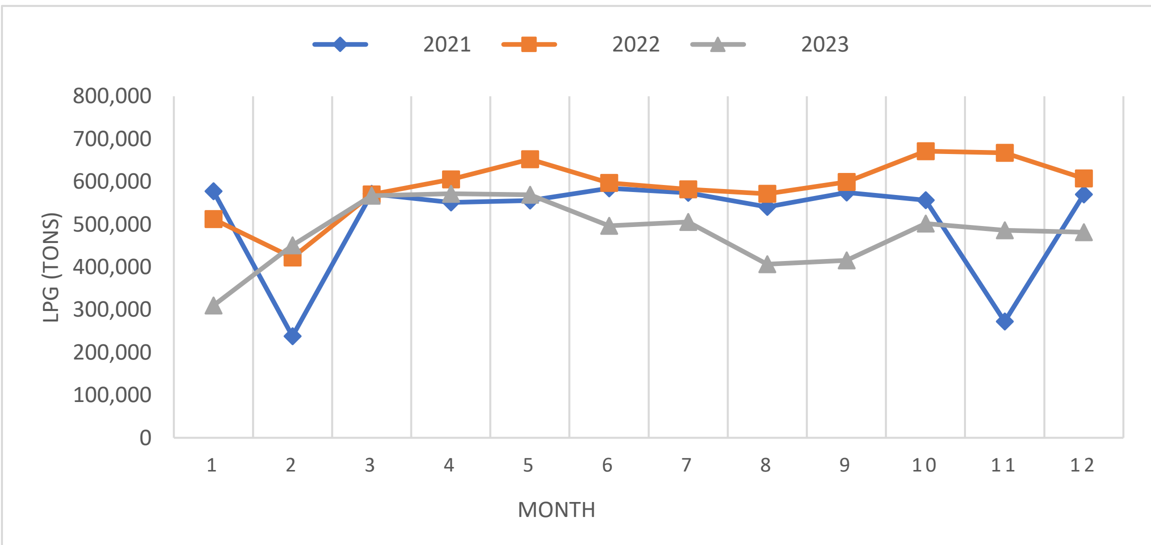


Figure IV.10. Chart showing LPG consumption in the period 2021 - 2023

LPG is purchased by the Company from an outside unit and stored in a tank within the Company's premises. Then, through the LPG vaporization system, it is transformed from liquid to vapor and supplied to the systems that need it;

LPG is mainly supplied to drying and furnace systems.

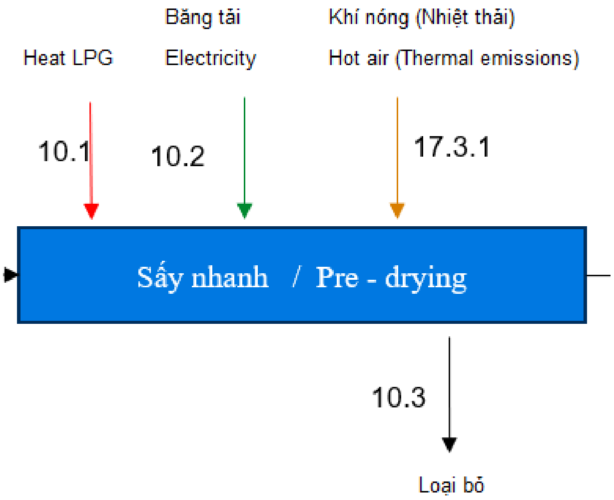


Figure IV.11. Rapid drying process using LPG

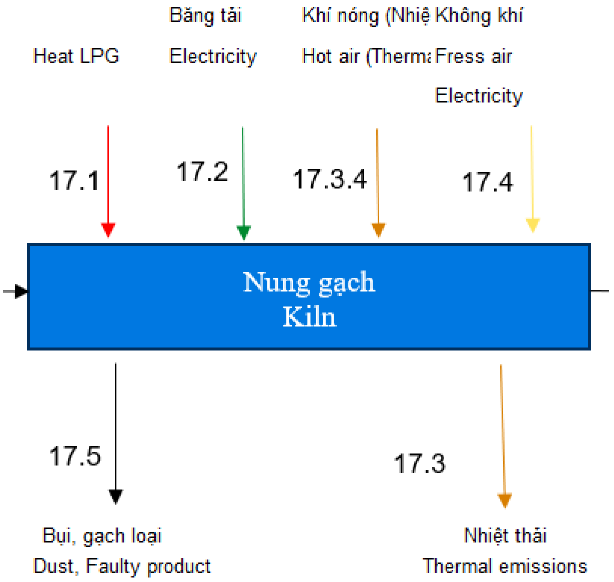


Figure IV.12. Tile firing process using LPG

The Company's LPG supply system is always maintained, serviced and monitored to promptly detect risks of leakage and explosion. The LPG supply system is equipped with an LPG vaporizer to provide stable and continuous LPG vapor to the usage areas. LPG vaporization system uses resistor to vaporize LPG, the load level varies depending on the needs of the Company's LPG using areas/systems.

Figure IV.13. The Company's LPG supply system

Some notable points that can be identified from Energy mapping analysis are as follows:

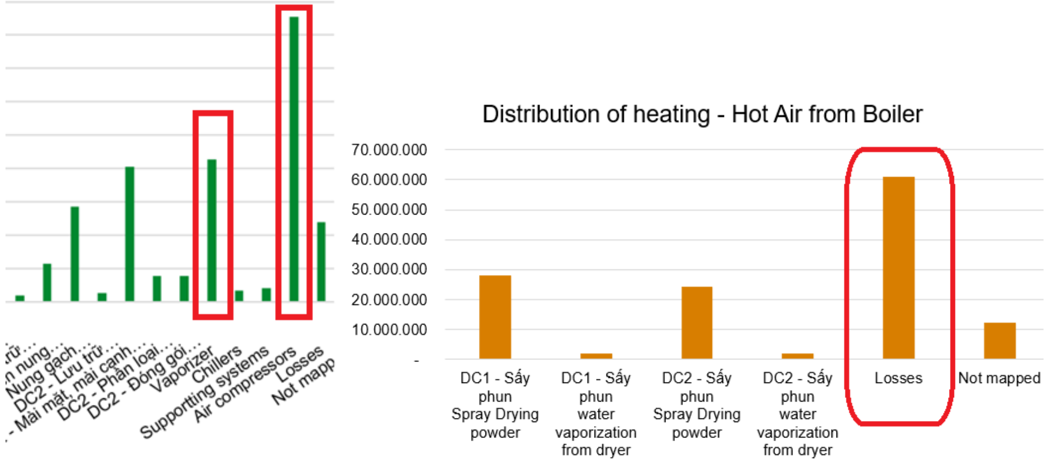


Figure IV.14. Identifying energy saving potential from mapping

Regarding the electrical loads, the total consumption of the air compressor station and the LPG vaporizer accounts for a high proportion compared to other stages in the line. This shows that measures are needed to reduce the electrical consumption of these loads.

For processes that require the use of hot heat from a coal-fired fluidized bed furnace, the calculation results show that the amount of heat absorbed by textile clay powder and evaporated water in the spray drying tower accounts for only a small proportion. A large part of the heat is not fully utilized, lost through exhaust pipes, through thermal radiation, through coal slag, etc. This is also an area that needs attention to fully utilize the useful heat and increase the overall efficiency of the system.

In the factory, there are many processes that require heating, but there are also processes that require product – cooling purpose, and there are many different sources of waste heat, so there is potential for optimization by heat recovery. The tool helps to map the heat sources, making the energy sources, systems, equipment and energy consumption processes in the production line more visual. From there, Energy Managers can control and optimize, propose improvement measures such as upgrading equipment, optimizing processes, improving operations, and using saving technology.

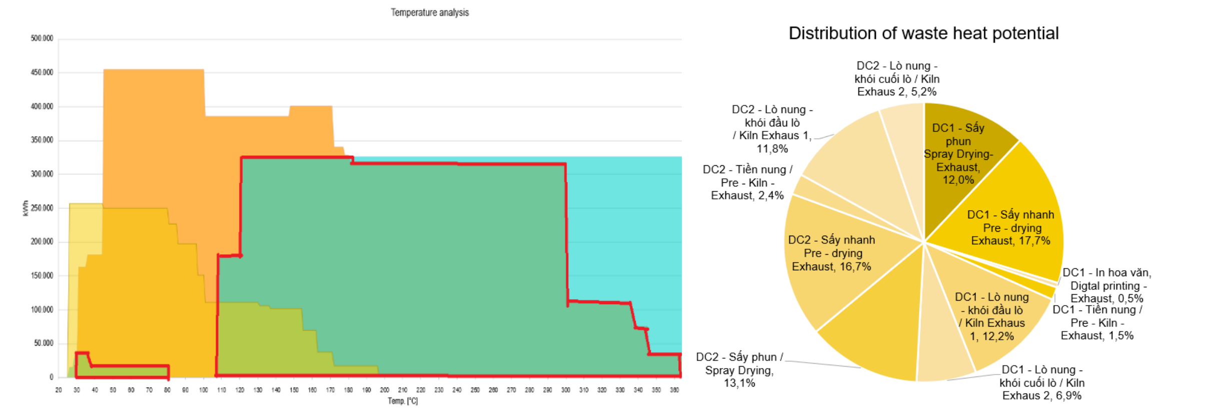


Figure IV.15. Identification of waste heat recovery potential and inter-process thermal optimization (red circled area)

Table IV.2. Evaluation and comments on the results of the LPG vaporizer test

NO.	Device code	Power (kW)	Parameter measurement results	Evaluation
1	Vaporizer	60	P_{avg} = 33.30 kW P_{max} = 67.25 kW P_{min} = 0 kW Cos φ = 0.92 $\sum U_{-THD}$ % = 4.59% $\sum I_{-THD}$ % = 4.64%	The evaporator system operates on/off to maintain a constant temperature all year round. High power factor. Total voltage harmonics and current harmonics within acceptable limits.

Through analysis in the temperature distribution graph of Energy mapping, we see that in the temperature range below 25-80 degrees C and 105-210 degrees C, we can take advantage of heat from waste sources to reduce cooling energy such as LPG vaporizer.

Proposed project:

This proposed project aims to utilize waste heat sources to generate hot water, which will then be used to vaporize LPG, thereby reducing electricity consumption. The solution involves collecting waste heat from the furnace area, air compressor station, and hydraulic press to heat water, which is then stored in an insulated tank. The heated water will be used to raise the temperature of LPG from 30°C to 70°C, reducing the need for electrical heating. After vaporization, the LPG gas will be supplied to the furnace burners, while the cooled water is collected in a cold water tank and recirculated to absorb waste heat again.

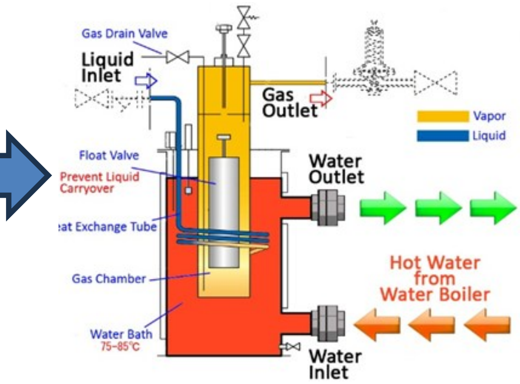


Figure IV.16. Electric LPG vaporizer

Figure IV.17. Residual heat vaporizer

The key advantages of this LPG vaporization method using residual heat include its high efficiency, as it saves energy compared to conventional electric resistance heating. Additionally, it enhances safety by minimizing fire and explosion risks associated with other vaporization methods. The operating costs of a hot water-based LPG vaporization system are relatively low, making it a cost-effective solution. Furthermore, this method helps reduce CO_2 emissions by recovering and utilizing excess heat, contributing to environmental sustainability.

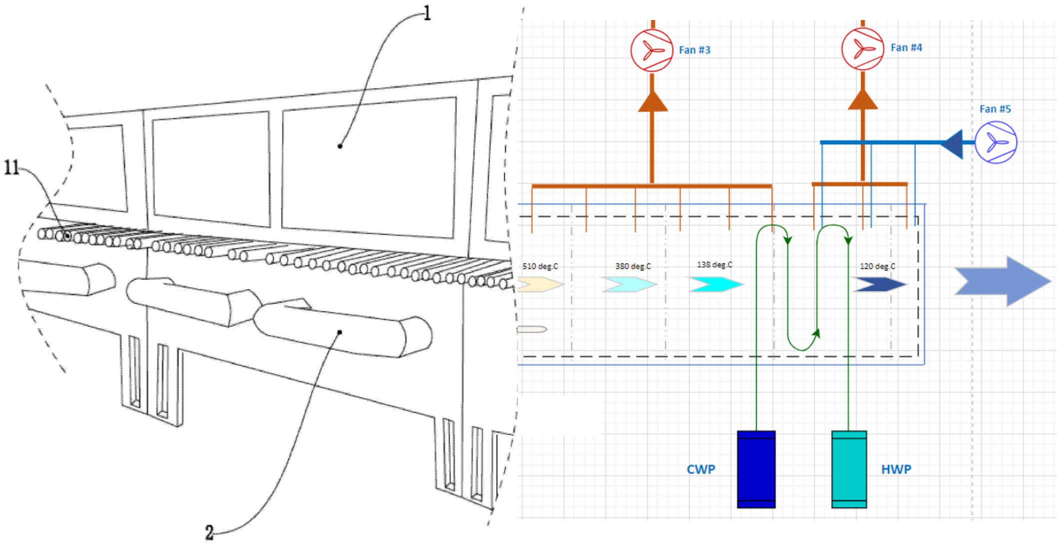


Figure IV.18. Furnace modification to utilize residual heat to heat the water

A key area for heat recovery is the end chamber of the kiln, which currently uses fans to cool the air and extract hot air from fired tiles before discharging it into the exhaust chimney. The proposal includes modifying the kiln walls by installing stainless steel water pipes under the rollers to capture residual heat from this chamber. This approach not only facilitates hot water collection but also lowers the chamber temperature, reducing the operational load of the cooling and exhaust fans.

The proposed diagram on the next page illustrates how hot water will be generated from various waste heat sources around the factory, replacing the existing electric LPG vaporizer and improving overall energy efficiency:

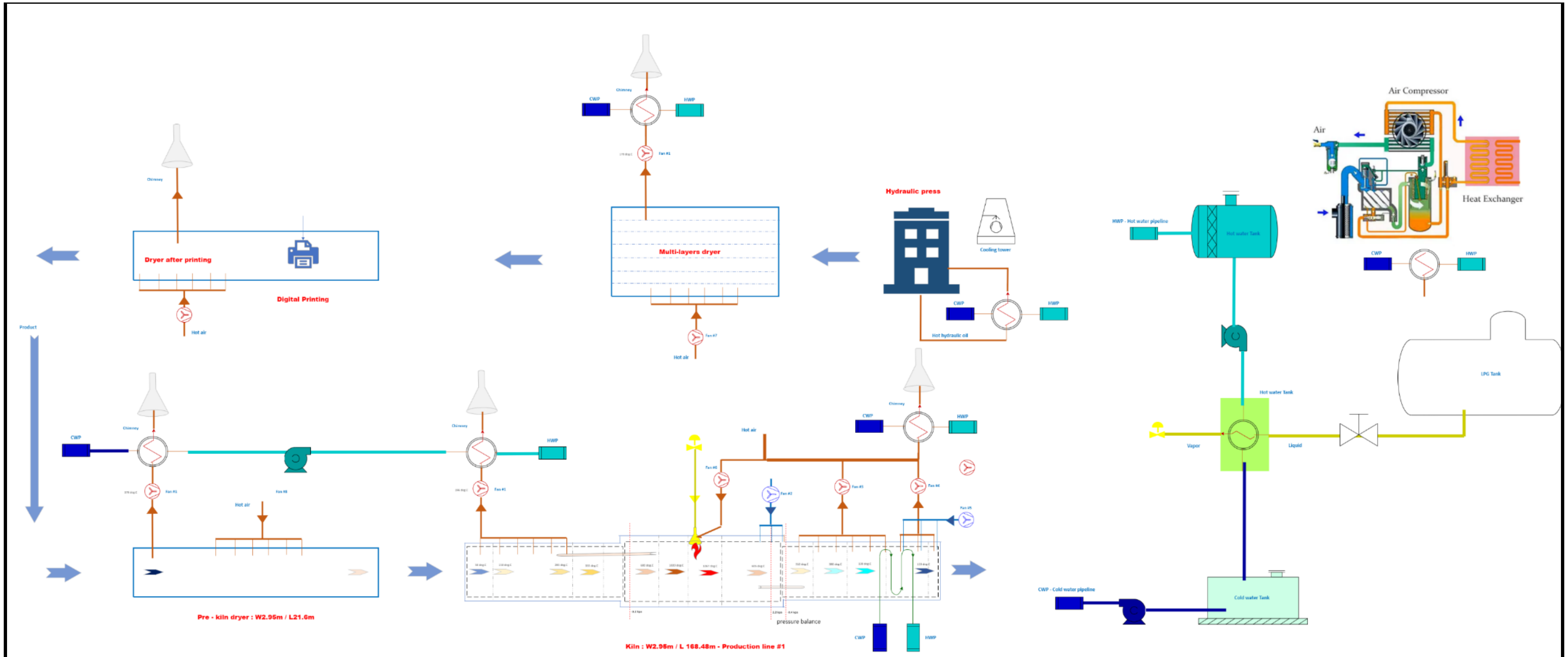
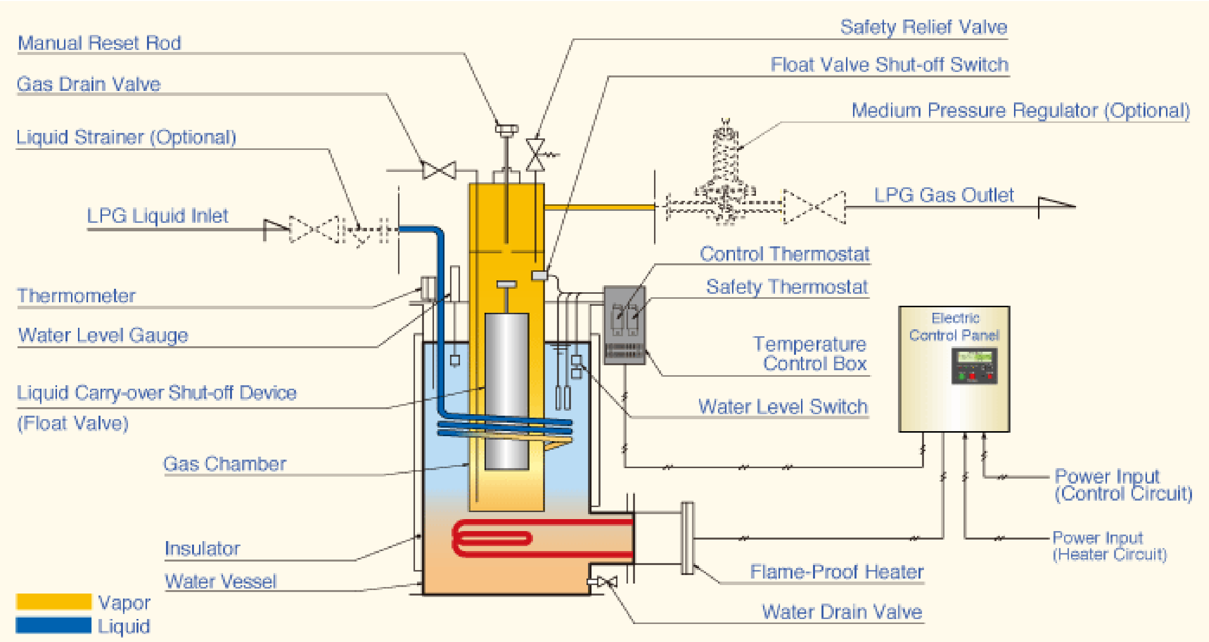


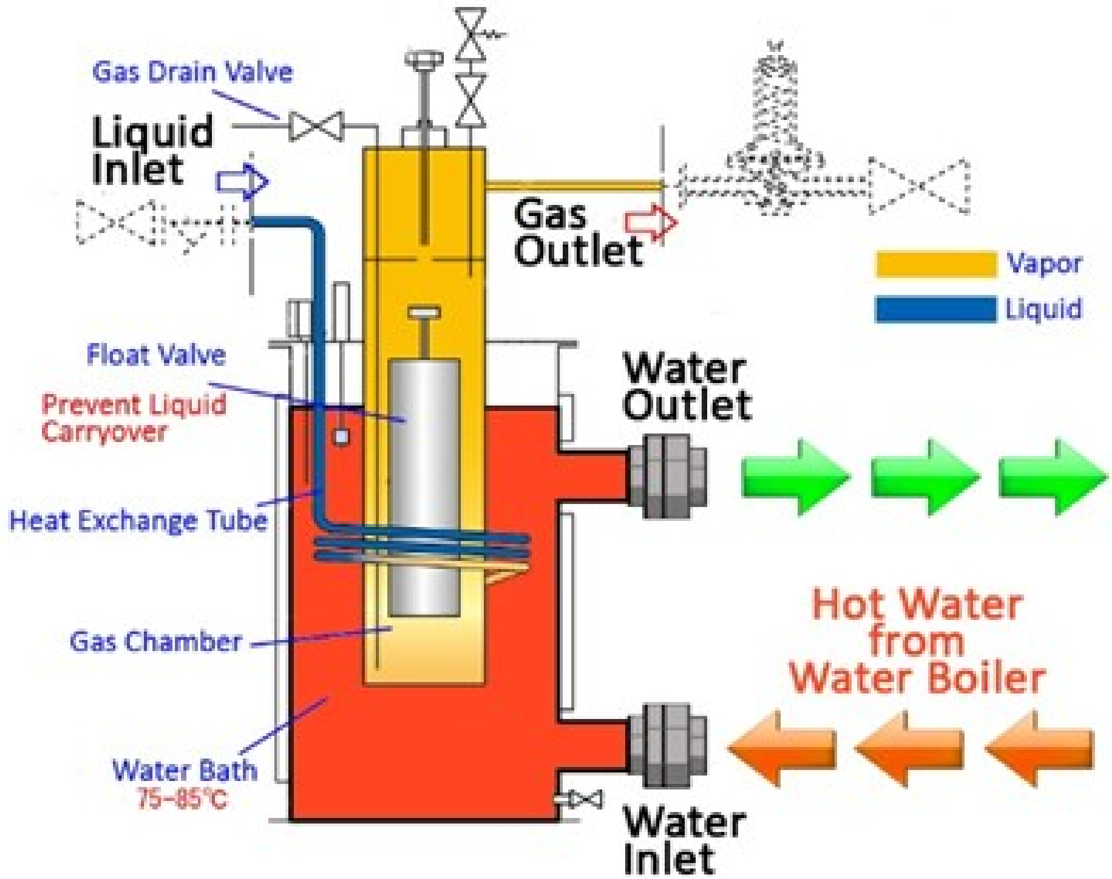
Figure IV.19. Diagram of utilizing waste heat sources to heat water for vaporizing LPG

Project illustration (PFD)

Before:



After :



Project Budget

- CAPEX costs: Procurement of the LPG vaporizer, heat exchangers, hot water pumps, accessories, and installation.
- OPEX costs: Maintenance, operation, and electricity consumption of the water pump.
- Training costs: Employee training expenses.

Total investment cost (estimated): Approximately 4 billion VND

TIME SCHEDULE

No	Task	Month 1				Month 2				Month 3			
		W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
1	***Kick-off meeting, measurement plan and data collection***												
1.1	*Kick-off meeting, preparing detailed survey plan content*												
1.2	Conduct surveys and collect data												
1.2.1	*Survey and collect data on project site (Meteorological and hydrological data; Topography - geology)*												
1.2.2	*Survey, measure, collect data on the current operating status of existing electric LPG vaporizers and evaluate the possibility of replacing them with hot water-based ones*												
1.2.3	*Survey and collect data on areas with waste heat sources on the current production line and evaluate the possibility of reusing them for hot water heating*												
1.2.4	*Collect some other data and information to serve the performance evaluation process and report preparation.*												
1.3	*Discuss with the factory about the direction for Pre-fs solutions*												
2	***Collect additional data for the solution***												
2.1	Survey and discuss with suppliers about waste heat utilization solution for hot water heating and replacement of non-electric LPG vaporizer												
2.1.1	*Survey, search and discuss with suppliers of solutions to utilize waste heat in the chain to heat hot water*												
2.1.2	*Survey, search and discuss with suppliers of hot water LPG vaporizers*												

2.1.3	*Survey, search and discuss with suppliers of hot water circulation pump systems from the utilized heat source to the LPG vaporizers*												
2.2	Prepare technical options for solutions (in coordination with solution providers)												
3	***Preliminary calculation of the effectiveness of implementation options***												
3.1	Develop technical solutions												
3.1.1	*Develop technical solutions to implement the solution (in coordination with experts)*												
3.1.2	*Calculate the basic technical parameters of the non-electric LPG vaporizer*												
3.1.3	*Develop technical solutions to utilize waste heat sources in the furnace area, spray drying tower, air compressor, etc. to heat hot water*												
3.1.4	*Calculate the basic technical parameters of the hot water circulation system from the utilized heat source to the LPG vaporizers*												
3.2	Comparative calculation of the effectiveness, benefits and costs of technical solutions												
3.3	Present preliminary calculation results to the Factory, discuss and agree on the most feasible option to include in the Pre-Feasibility Study Report												
4	***Prepare pre-feasibility study report***												
4.1	Prepare pre-feasibility study report (Pursuant to Article 53 of Construction Law No. 50/2014/QH13 dated June 18, 2014 and Construction Law No. 10/VBHN-VPQH dated July 4, 2019)												
4.2	Meeting, clarifying Pre-FS report with relevant stakeholders												
4.3	Complete the report according to comments from relevant stakeholders.												

Saving	
Energy (annual): 684,288 kWh	**Financial (annual): 1,270,038,528 VND**
CO2 (annual): 252.07 tons	**Simple Payback (years): 3.15**

Risk Analysis

a) Identifying risk factors

❖ ***Risk of affecting kiln performance***

- The heat recovery system may alter exhaust gas temperature or flow rate, impacting the firing process, leading to cracked, deformed, or substandard bricks. Unstable temperatures can reduce brick durability.
- Probability: Medium, if not designed correctly.
- Impact: High, direct impact on product quality.

❖ ***Fouling and blockage***

- Exhaust gases and hot air from the kiln's cooling zone contain brick dust, which can accumulate on heat exchangers, reducing heat transfer efficiency. According to Energy Efficiency in Brick Kilns, fouling can decrease efficiency by 10-20% without regular maintenance.
- Probability: High, especially with air from the cooling zone.
- Impact: Medium, causing maintenance disruptions.

❖ ***Operational safety risks***

- High temperatures (200-500°C) and system pressure pose fire and explosion hazards, especially if thermal oil or gas leaks occur. Waste Heat Utilization in Kiln Industries highlights combustion risks as a major concern in thermal systems.
- Probability: Low, if designed correctly, but high impact if it occurs.
- Impact: High, affecting human safety and property.

❖ ***Interlock disruption***

- In an automated system, failures in the heat exchanger (e.g., clogging, breakdowns) can affect interconnected components, such as cooling fans, burners, or brick conveyor lines. Research indicates that interlock disruptions can cause line shutdowns and production losses.
- Probability: Medium, without a backup system.
- Impact: High, affecting productivity.

❖ ***Technical risks during installation***

- Risk: Incorrect connection or configuration if the LPG vaporizer is installed incorrectly, causing the line to stop, interrupting the brick firing process and the entire line.
- Probability: Low (if performed by an experienced technical team).
- Impact: Medium-High (depending on repair time).

❖ ***Human factor risks***

- Risk: Operators may lack training on how to properly monitor and maintain the heat recovery system, leading to inefficiencies or breakdowns.
- Likelihood: Medium (if training is insufficient).
- Impact: Medium (reduced energy savings and potential downtime).

b) Evaluating risk tolerance

- Financial capacity of the enterprise: Assess the financial capacity to bear risks in case the expected benefits are not achieved.
- Payback period: Consider whether the payback period is acceptable.

- Seeking preferential capital sources: As the solution helps save energy and reduce environmental impact, preferential loan sources can be used to reduce the project's financial burden.

c) Developing risk mitigation plan

- Market research: Analyze different machinery suppliers to select the best equipment at a reasonable price.
- Testing before large investment: Conduct tests with a small servo press before deciding to upgrade the entire system.
- Early employee training: Start training employees from the preparation stage to minimize production downtime.

❖ ***Correct design***

- Use corrosion-resistant materials such as 316L stainless steel for the heat exchanger, especially with exhaust gases containing SO_2 and HCl.
- Install a pre-filter to reduce dust from the cooling zone air, ensuring no impact on the kiln.

❖ ***Regular maintenance***

- Schedule regular cleaning for the heat exchanger, using self-cleaning systems like soot blowers to prevent fouling, according to Energy Savings in Tunnel Kilns.
- Regularly inspect valves, pumps, and pipes to ensure no leaks.

❖ ***Monitoring and control***

- Install temperature, pressure, and flow sensors to monitor system performance, ensuring no impact on kiln temperature or brick cooling process. According to Ceramic World, automatic control systems help reduce disruption risks.
- Use PLC/SCADA to integrate with the automatic system, ensuring safe interlocking.

❖ ***Safety checks***

- Equip safety valves, CO_2 or powder fire extinguishing systems, and oil leak sensors to reduce fire and explosion risks.
- Test the system before operation to ensure no impact on the production line.

❖ ***Initial testing***

- Run the system on a part of the production line (e.g., recovery from the kiln's end zone) to assess the impact on brick cooling, making adjustments before full deployment.

❖ ***Reduce technical risks during installation***

- Hire a team of experienced technical experts in the ceramic brick and LPG vaporization industries to perform installation and programming.
- Test the system in manual mode before switching to automatic, checking each step.

❖ ***Employee training***

- Organize practical training courses on system operation and troubleshooting before deployment.
- Prepare concise instruction manuals for employees to refer to when needed.

d) Monitoring & Evaluation

- After upgrading and installing, monitor the performance of the kiln, LPG supply system, and the entire production line, and compare with initial predicted indicators to make timely adjustments if necessary.

Non-Energy benefits

a) Economic benefits

- Lower operating costs: In addition to electricity savings, the solution indirectly reduces operational costs, including maintenance expenses, by lowering exhaust gas and discharged air temperatures, minimizing equipment wear.
- Extended equipment lifespan: Reduced temperatures decrease wear and corrosion, cutting replacement and repair costs by an estimated 10-20%, as per Energy Efficiency in Brick Kilns.
- Long-term investment benefits: The system can achieve payback within 2-5 years, depending on initial investment costs.
- Enhanced competitiveness: Lower production costs make ceramic products more competitive in the market.

b) Environmental benefits:

- Lower greenhouse gas emissions: Electricity savings reduce CO_2 emissions, especially if electricity is sourced from fossil fuels, contributing to Vietnam's Net Zero 2050 goals.
- Supports cleaner production: Energy optimization aligns with green manufacturing standards, making it easier for the factory to obtain environmental certifications (ISO 14001) or meet international customer requirements.
- Resource utilization: Reusing waste heat instead of discharging it into the environment minimizes environmental impact and supports sustainable development goals, in line with Waste Heat Recovery in Kilns.

c) Operational and product quality improvements:

- More stable processes: Hot water from the system provides consistent heat for LPG vaporization, reducing grid electricity fluctuations, improving combustion efficiency and product quality, as per Tunnel Kiln Operation and Maintenance.
- Reduced dependence on the power grid: Less strain on the electricity system, especially during peak hours or in power-shortage regions, enhances operational reliability.
- Improved working environment: Lower exhaust gas and air discharge temperatures improve workplace conditions for employees, while reduced cooling fan noise contributes to a quieter environment.

d) Compliance and corporate reputation:

- Regulatory compliance: This solution helps the plant fulfill its energy-saving obligations under Vietnam’s Law on Energy Efficiency and Conservation (2010), particularly for large energy-consuming facilities.
- Enhanced corporate image: Adopting modern, eco-friendly technology boosts credibility with partners, customers, and regulatory bodies.

e) Flexibility and future expansion:

- Scalability: The system can be expanded to recover more waste heat from additional sources, further reducing energy consumption.
- Adaptability to process changes: The waste heat recovery system can be adjusted to meet future production requirements without major modifications.

5 Appendix

Table 5.1. Financial efficiency analysis of rooftop solar power system installation

No.	Parameter	Unit	Value
I	**Base data**		
1.1	Total expected installed capacity	kWp	1,000
1.2	Average annual solar power generation at Company location	kWh/kWp/ year	1,071
1.3	Total cost of installation 1kWp	VND	13,000,000
1.4	Total cost of installation of the entire system	VND	13,000,000,000
1.5	Cost of maintenance, upkeep and cleaning of solar panels (periodic cleaning 4 times/year)	VND	60,000,000
II	**Energy saving potential**		
2.1	Amount of electricity generated by the system	kWh/year	1,071,000
2.2	Average electricity cost	VND/kWh	1,856
2.3	Total annual cost reduction	VND	1,927,776,000
2.4	Simple payback period	Year	6.74
2.5	Internal Rate of Return IRR	%	13.69%
2.6	Net present value NPV (in 20 years, discounted at 12%/year)	VND	1,399,414,152
III	**Environment**		
3.1	TOE Conversion	TOE/year	220.23
3.2	CO_2 emissions	tons of CO2 / year	1,147.67

Table 5.2. Reset the operating mode of air compressors

No	Parameter	Unit	Value
1	AC 110kW front flow	m^3/ min	10.6
2	AC 110kW Load Time Ratio	%	47.25%
3	AC 75kW flow before	m^3/ min	11.96
4	Time ratio with load AC 75kW	%	98.75%
5	Time of use during the year	Day	310
6	Time of use during the day	Hour	24
7	Total compressed air flow required for workshop 1	m^3/year	7,507,934
8	AC flow 110kW after background running	m^3/year	4,731,840
9	AC flow rate 75kW after adjustment	m^3/year	2,776,094
10	AC flow 75kW in 1 minute	m^3/ min	6.22
11	Energy saving ability	%	70%
12	AC 75kW capacity saved	kWh/year	663,413
13	AC capacity 110kW after background running	kWh/year	646,505
14	Electricity saved in 1 year	kWh/year	16,908
15	Electricity price for 1 year	VND	1,856
16	Cost savings in 1 year	VND	31,381,248

Table 5.3. Renovating air compressor pipeline from branch circuit to loop circuit

No.	Parameter	Unit	AC 4	AC 3	AC 2
I	**Energy saving potential**				
1.1	Operating pressure before solution implementation	bar	6.9	7	7.1
1.2	Operating pressure after solution implementation	bar	6.7	6.8	6.9
1.3	Power consumption before pressure drop	kWh/year	2,897,138	4,152,719	4,425,821
1.4	Power consumption after pressure reduction	kWh/year	2,849,836	4,084,916	4,355,980
1.5	Utilization factor	%	70%	70%	70%
1.6	Energy saving 1 year	kWh/year	33,111	47,462	48,889
1.7	Average electricity price	VND/kWh	1,856	1,856	1,856
1.8	Cost savings for 1 year	VND/year	43,018,331	61,662,760	63,516,199
1.9	Investment cost of pipeline renovation circuit	VND	500,000,000		
1.10	Payback period	Year	2.97		
II	**Environment**				
2.1	TOE Conversion	TOE/year	19.98		
2.2	CO_2 emissions	tons of CO2 / year	87.59		

Table 5.4. Replacing old air dryers with high efficiency air dryers

No	Parameter	Unit	Old type air dryer	PCM Air Dryer
1	**Base data**			
1.1	Number of air dryers in operation	Piece	4	1
1.2	Actual average power	kW	2.4	3.15
1.3	Total operating capacity	kW	9.6	3.15
1.4	Hours of operation per day	Hour	24	24
1.5	Number of operating days per year	Day	300	300
1.6	Power consumption of old type air dryer	kWh/year	69,120	22,680
2	**Energy saving potential**			
2.1	Electricity saved per year	kWh/year		46,440
2.2	Concurrent usage factor	%		90%
2.3	Energy savings 1 year	kWh/year		41,796
2.4	Average electricity price	VND/kWh		1,856
2.5	Amount of money saved	VND/year		77,573,376
2.6	Total investment and installation costs	VND		426,600,000
2.7	Simple payback period	Year		5.50
3	**Environment**			
3.1	TOE Conversion	TOE/year		6.45
3.2	Emission mitigation	tons of CO2 / year		28.28

Table 5.5. Insulation for fluidized bed furnace operating doors

No	Parameters	Unit	Value
Operating parameters			
1	Temperature difference between kiln door and ambient temperature	30^oC	215
2	Heat loss	kcal/(m ^{2} h)	4,528
3		kJ/(m ^{2} s)	5.26
4	Heat exchange area of the kiln door	m ^{2}	0.42
5	Number of kiln doors	unit	2
6	Total heat loss of the furnace door	kJ/s	4,416
7	Average operating hours per day	hour	24
8	Average number of operating days per year	day	330
9	Solution performance	%	80%
10	Amount of heat saved in 1 year	kJ/year	100,734,249
11	Calorific value of coal	kJ/kg	30,250
13	Fuel savings in 1 year	ton	3.33
14	Price of coal	VND/ton	1,812,000
15	Cost savings	VND/year	6,034,065
16	Investment costs	VND	30,000,000
17	Payback period	year	4.97
Environment			
18	TOE Conversion	TOE/year	2.33
19	CO_2 emissions	tons of CO2 / year	9.59

Table 5.6. Utilizing residual heat to heat the air supply to the fluidized bed furnace

No	Parameter	Unit	Value
I	**Operating information**		
1.1	Average operating hours per day	hour	24
1.2	Average number of operating days per year	day	310
1.3	Utilization factor	%	90
II	**Current status information**		
2.1	Air flow into the furnace	m3 / hour	17,097.3
2.2	Specific gravity of exhaust gas	kg/ m3	1.15
2.3	Mass of air supplied to the furnace	kg/s	5.46
2.4	Current average air temperature	^{o}C	25
III	**Solution information**		
3.1	Air temperature after heat recovery unit	^{o}C	70
3.2	Specific heat of air	kJ/kg.K	0.779
3.3	Amount of heat saved	kJ/s	191
3.4	Fuel calorific value	kJ/kg	30,250.00
3.5	Fuel savings	kg/year	169,521
IV	**Energy saving calculation**		
4.1	Fuel savings in 1 year	kg/year	169,521
4.2	Fuel prices	VND/kg	1,812
4.3	Money saved in 1 year	VND/year	307,171,624
4.4	Investment costs	VND	800,000,000
4.5	Payback period	Year	2.60
V	**Environment**		
5.1	Energy saving standard	TOE/year	101,712.5
5.2	CO_2 reduction	Tons of CO2 / year	488.22

Table 5.7. Installing time relay for stirring motor

No	Parameters	Unit	Data
I	**Base data**		
1.1	Total capacity of 2-line agitator	kW	117
1.2	1 day operation time	Hour	24
1.3	1 year operation time	Day	310
1.4	Concurrent usage factor	%	80%
1.5	Total annual operating capacity	kWh	696,384
II	**Solution information**		
2.1	Energy saving potential	%	30
2.2	Energy saving electricity	kWh	208,915
2.3	Electricity cost	VND/kWh\	1,856
2.4	Cost savings	VND/year	387,746,611
2.5	Investment costs	VND	60,000,000
2.6	Payback period	Year	0.15
III	**Environment**		
3.1	TOE Conversion	TOE/year	32.24
3.2	Emission mitigation	tons of CO2 / year	601.68

Table 5.8. Using residual heat to raise the temperature of the material

No	Parameter	Unit	Value
I	**Operating information**		
1.1	Average operating hours per day	hour	24
1.2	Average number of operating days per year	day	310
1.3	Utilization factor	%	90
II	**Current status information**		
2.1	Current powder temperature	^{o}C	44
2.2	Total mass of raw powder	Ton	130,163
2.3	Specific heat of the material	kJ/kg.K	0.90
III	**Solution information**		
3.1	Temperature of the data after implementing the solution	^{o}C	60
3.2	Amount of heat saved	kJ/s	1,874
3.3	Fuel calorific value	kJ/kg	30,250
IV	**Energy saving calculation**		
4.1	Fuel savings in 1 year	kg/year	149,363
4.2	Fuel prices	VND/kg	1,812
4.3	Money saved in 1 year	VND/year	270,645,910
4.4	Investment costs	VND	1,200,000,000
4.5	Payback period	Year	4.43
V	**Environment**		
5.1	Energy saving standard	TOE/year	89,617.9
5.2	CO_2 reduction	Tons of CO2 / year	430.17

Table 5.9. Installing the control inverter for the fan system in the Line No.2 quick drying kiln area

No.	Parameters	Formula	Unit	Data
I	**Base data**			
1.1	Rated capacity of the system	A	kW	188.5
1.2	System operating capacity	B	kW	112.01
1.3	Motor frequency without inverter	C	Hz	50
1.4	Hours of operation/day	D	Hour	8
1.5	Number of operating days/year	E	Day	360
1.6	Total electricity consumption in the year	F= B*D*E	kWh/year	322,589
II	**Energy saving potential**			
2.1	Average frequency of motor power supply when inverter is installed	G	Hz	35
2.2	Power used when installing inverter	I=B*(G^3/B^3)	kW	64.66
2.3	Power saving	J= BI	kW	47.35
2.4	Power saving time ratio	K	%	80%
2.5	Energy saved when using inverter	L=D*E*J*K	kWh/year	109.105
2.6	Average electricity cost	M	VND/kWh	1,856
2.7	Total annual savings	N=L*M	VND/year	202,498,449
2.8	Total investment and installation costs	O	VND	600,000,000
2.9	Payback period	P=O/N	year	2.96
III	**Environment**			
3.1	TOE Conversion	Q=L*0.0001543	TOE/year	16.83
3.2	CO_2 emissions	R=L*0.0006766	tons of CO2 / year	73.82

Table 5.10. Use of residual heat of LPG vaporization furnace

No	Parameters	Formula	Unit	Value
I	**Base data**			
1.1	Amount of LPG used per day	A	kg	17,465
1.2	Converted LPG usage	B=A/24	kg/hour	727.71
1.3	Number of operating hours per day	C	hour	24
1.4	Number of operating days per year	D	day	310
1.5	Electricity consumed in a year	K=I+J	kWh/year	684,288
1.6	Average electricity price	L	VND/kWh	1,856
1.7	Cost of electricity used for heating in 1 year	M=K*L	VND/year	1,270,038,528
1.8	Total investment and installation costs	O	VND	4,000,000,000
1.9	Simple payback period	P=O/N	Year	3.15
II	**Environment**			
2.1	TOE Conversion	Q=K*0.0001543	TOE/year	57.54
2.2	Emission mitigation	R=K*0.0006766	tons of CO2 / year	252.07

Table 5.11. Replace low efficiency Line No.1 nano grinding motor with high efficiency IE4 motor

No	Parameter	Unit	Old motor	New motor
I	**Base data**			
1.1	Rated power	kW	416.0	
1.2	Power required	kW	416.0	416.0
1.3	Operating power factor		0.90	
1.4	Rated power factor		0.79	0.90
1.5	Rated performance	%	0.88	0.93
1.6	Average daily operations	Hour	24	24
1.7	Number of operating days in a year	Day	330	330
1.8	Number of operating hours in 1 year	Hour	7,920	7,920
1.9	Apparent load power consumption	kVA	462.22	462.22
1.10	Iron loss in motor	kW	13.87	9.39
1.11	Copper loss in motor	kW	34.86	21.92
1.12	Total loss	kW	48.72	31.31
II	**Energy saving potential**			
2.1	Power saving	kW		17.41
2.2	Energy saving	kWh		137,892
2.3	Average electricity price	VND/kWh	1,856	1,856
2.4	Amount of savings	VND/year		255,927,408
2.5	Total investment cost	VND		980,000,000
2.6	Payback period	Year		3.83
III	**Environment**			
3.1	TOE Conversion	TOE/year		21.28
3.2	CO_2 emissions	tons of CO2 / year		112.44

Table 5.12. Replace low efficiency Line No.2 nano grinding motor with high efficiency IE4 motor

No	Parameter	Unit	Old motor	New motor
I	**Base data**			
1.1	Rated power	kW	462.0	
1.2	Power required	kW	462.0	462.0
1.3	Operating power factor		0.90	
1.4	Rated power factor		0.79	0.90
1.5	Rated performance	%	0.88	0.93
1.6	Average daily operations	Hour	24	24
1.7	Number of operating days in a year	Day	330	330
1.8	Number of operating hours in 1 year	Hour	7,920	7,920
1.9	Apparent load power consumption	kVA	513.33	513.33
1.10	Iron loss in motor	kW	15.40	10.43
1.11	Copper loss in motor	kW	38.71	24.34
1.12	Total loss	kW	54.11	34.77
II	**Energy saving potential**			
2.1	Power saving	kW		19.34
2.2	Energy saving	kWh		153,140
2.3	Average electricity price	VND/kWh	1,856	1,856
2.4	Amount of savings	VND/year		284,227,074
2.5	Total investment cost	VND		1,250,000,000
2.6	Payback period	Year		4.40
III	**Environment**			
3.1	TOE Conversion	TOE/year		23.63
3.2	CO_2 emissions	tons of CO2 / year		124.87