The Danish Energy Agency

# Anonymous Audit Report

## from a power generation company

**Vietnam Technology Solutions JSC., November, 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 summary 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 | Purchased auxiliary electricity | kWh | 29,841,990 | 4,605 | 0.52 |
| 2 | Coal | tons | 1,653,607 | 873,672 | 99.47 |
| 3 | DO Oil | tons | 24 | 23 | 0.003 |
| | **Total** | | | **878,299** | **100** |
| **2022** | | | | | |
| 1 | Purchased auxiliary electricity | kWh | 34,767,048 | 5,365 | 0.75 |
| 2 | Coal | tons | 1,340,967 | 708,491 | 99.24 |
| 3 | DO Oil | tons | 40 | 38 | 0.005 |
| | **Total** | | | **713,893** | **100** |
| **2023** | | | | | |
| 1 | Purchased auxiliary electricity | kWh | 31,412,134 | 4,847 | 0.57 |
| 2 | Coal | tons | 1,596,589 | 843,547 | 99.42 |
| 3 | DO Oil | tons | 40 | 38 | 0.004 |
| | **Total** | | | **848,431** | **100** |

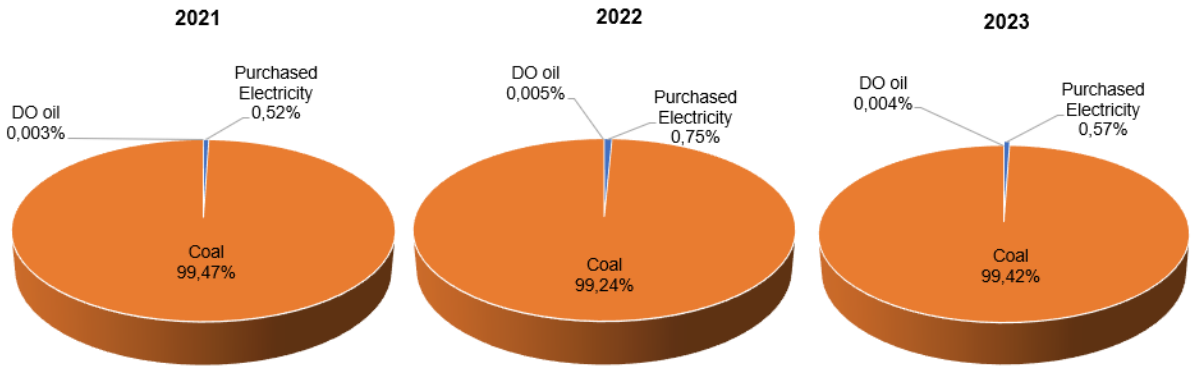



*Figure 1.1. Energy Consumption proportions (2021–2023)*

Actual performance of Thermal Power Plant and units:

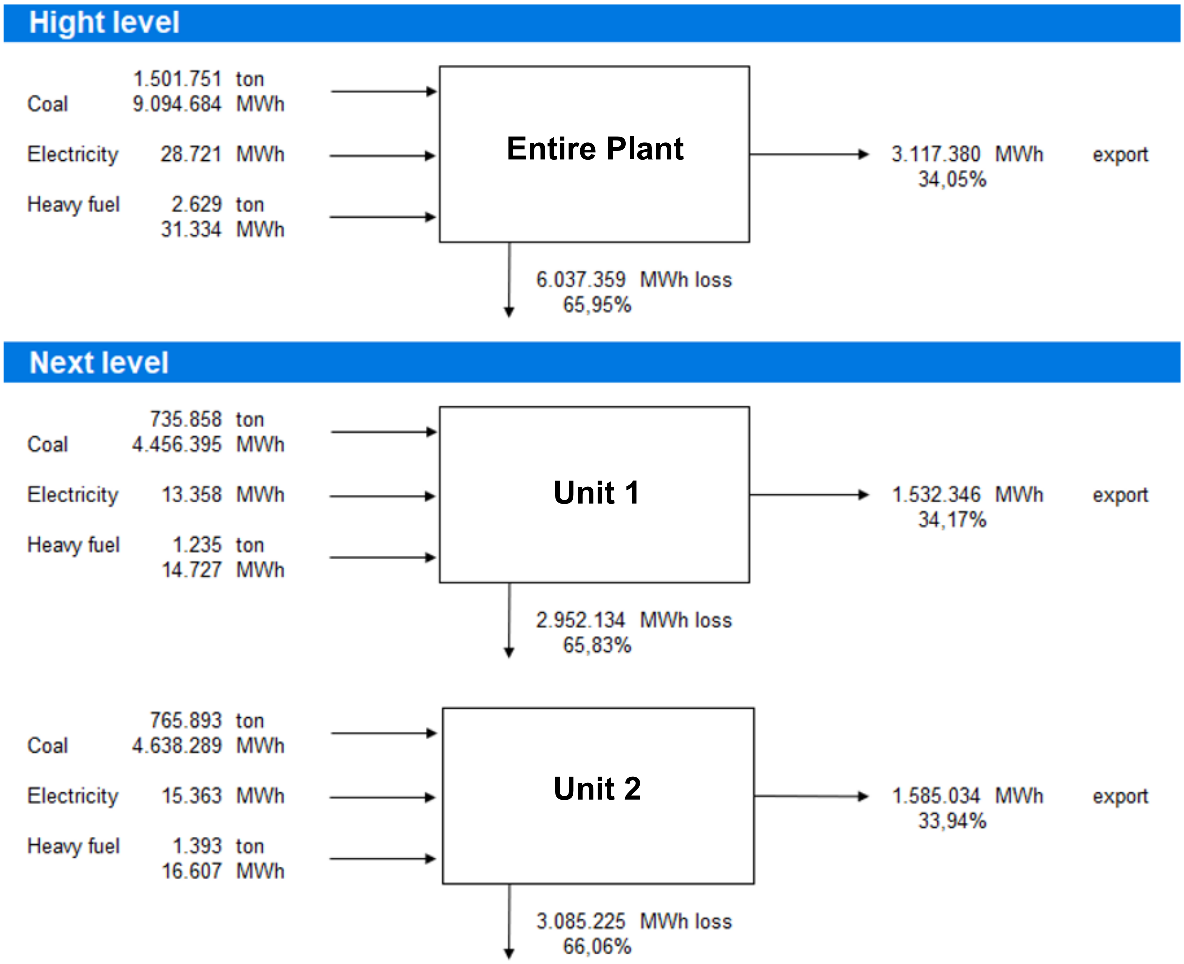



*Figure 1.2. Actual performance of the plant and units*

### Energy saving potential

After conducting a survey and assessment of the current energy usage and management at the company, the audit team identified several potential energy-saving opportunities. Detailed analysis and calculations reveal the following energy-saving potential:

- Annual energy savings potential: approximately 37,078,333 kWh/year and 1,461.75 tons of coal/year;
- Estimated cost savings: approximately 1,927,701.25 EUR/year;
- Required investment: approximately 6,448,895.31 EUR.

# 1 About the enterprise

## 1.1 Description of the company

- Sector: Power Generation
- Main raw materials: Anthracite Coal 5A.1
  - Consumption: 1,596,589 ton/year
- Main Product: Commercial Electricity
  - 2021: 3,450,070,600 kWh
  - 2022: 2,738,565,990 kWh
  - 2023: 3,305.499,310 kWh
- Annual energy total consumption Electricity, coal, LPG, DO
  - Purchased auxiliary electricity: 31,412,134 kWh (equivalent to 4,847 TOE; 31,412 MWh)
  - Coal: 1,596,589 tons (equivalent to 10,377 TOE; 9,669,031 MWh)
  - DO: 40 tons (equivalent to 3 TOE; 477 MWh)
- Annual greenhouse gas emissions: 3,309,800 tons of $CO_2$

## 1.2 Description of the process

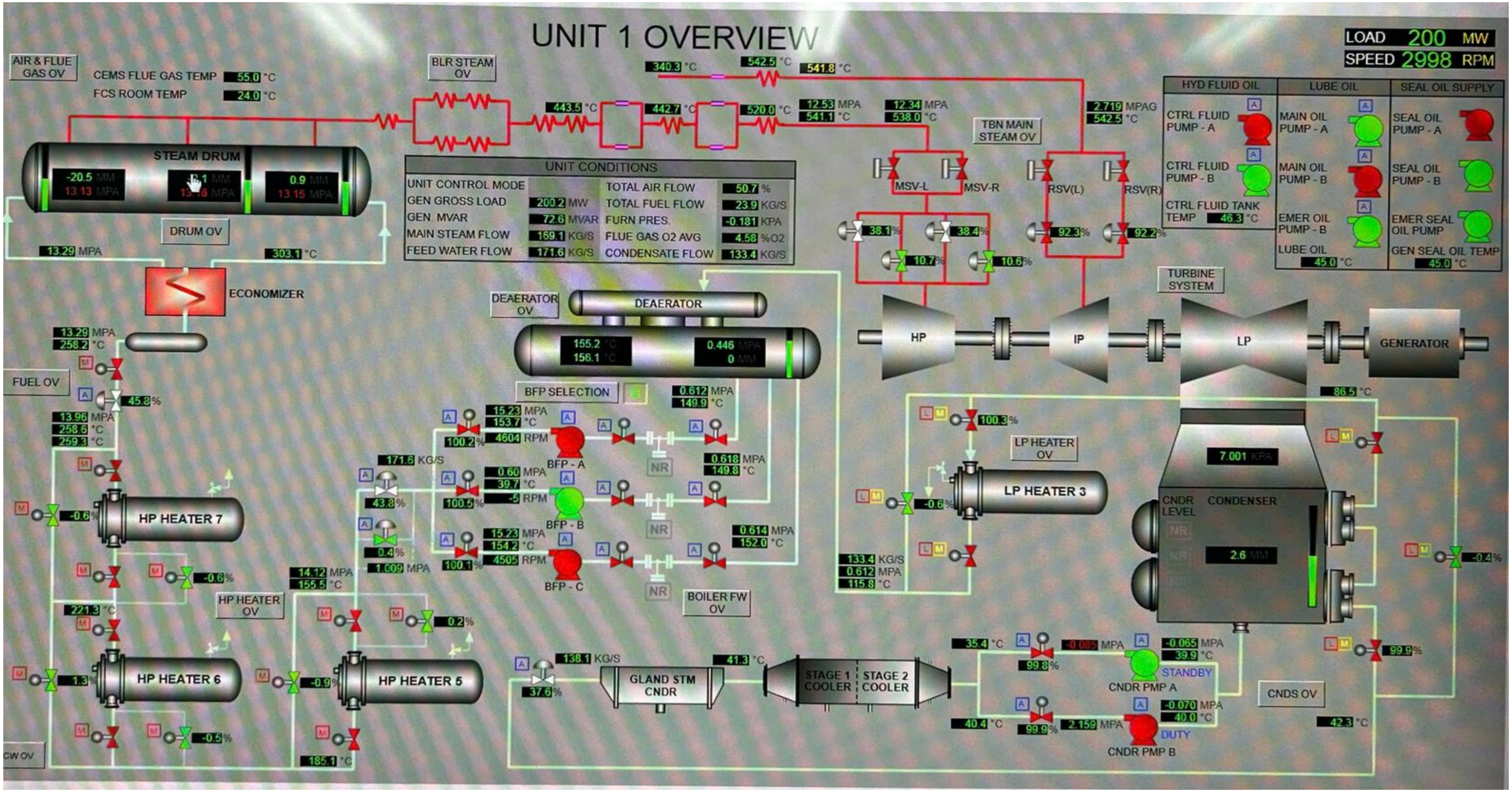
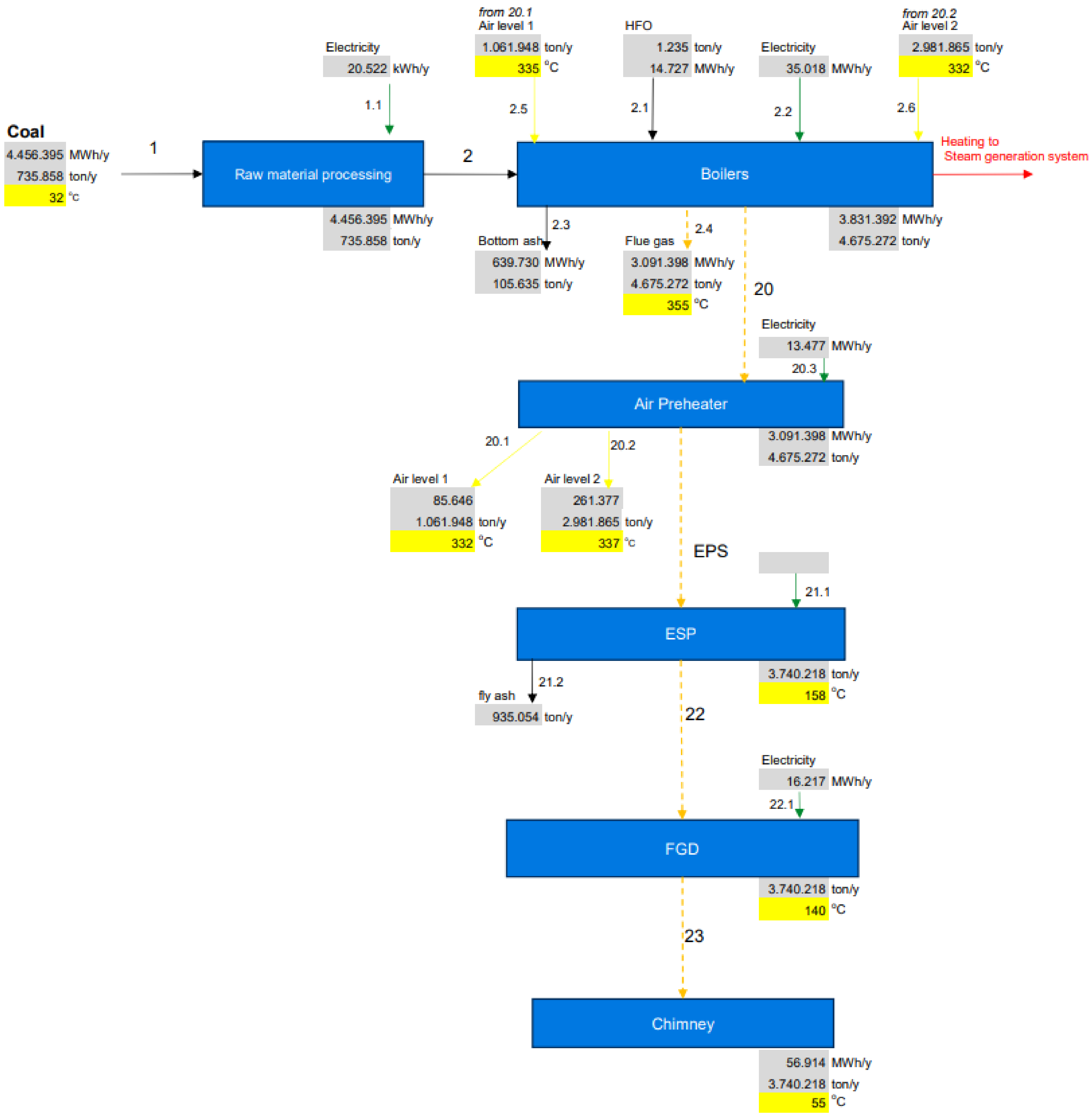



*Figure 1.3. Process Flow Diagram*


Coal
4.456.395 MWh/y
735.858 ton/y
32 °c
1
Raw material processing
Electricity
20.522 kWh/y
1.1
4.456.395 MWh/y
735.858 ton/y
2
from 20.1
Air level 1
1.061.948 ton/y
335 °C
2.5
HFO
1.235 ton/y
14.727 MWh/y
2.1
Electricity
35.018 MWh/y
2.2
from 20.2
Air level 2
2.981.865 ton/y
332 °C
2.6
Boilers
Heating to
Steam generation system
3.831.392 MWh/y
4.675.272 ton/y
2.3
Bottom ash
639.730 MWh/y
105.635 ton/y
2.4
Flue gas
3.091.398 MWh/y
4.675.272 ton/y
355 °C
20
Electricity
13.477 MWh/y
20.3
Air Preheater
3.091.398 MWh/y
4.675.272 ton/y
20.1
20.2
Air level 1
85.646
1.061.948 ton/y
332 °C
Air level 2
261.377
2.981.865 ton/y
337 °c
EPS
21.1
ESP
3.740.218 ton/y
158 °C
21.2
fly ash
935.054 ton/y
22
Electricity
16.217 MWh/y
22.1
FGD
3.740.218 ton/y
140 °C
23
Chimney
56.914 MWh/y
3.740.218 ton/y
55 °C

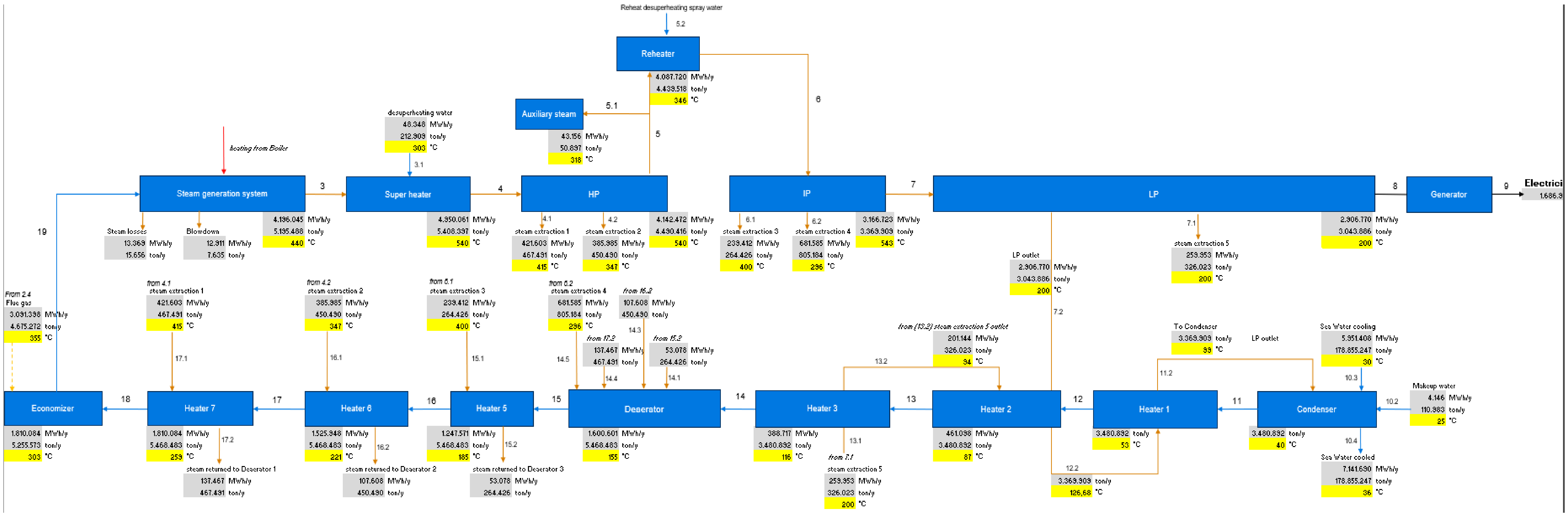
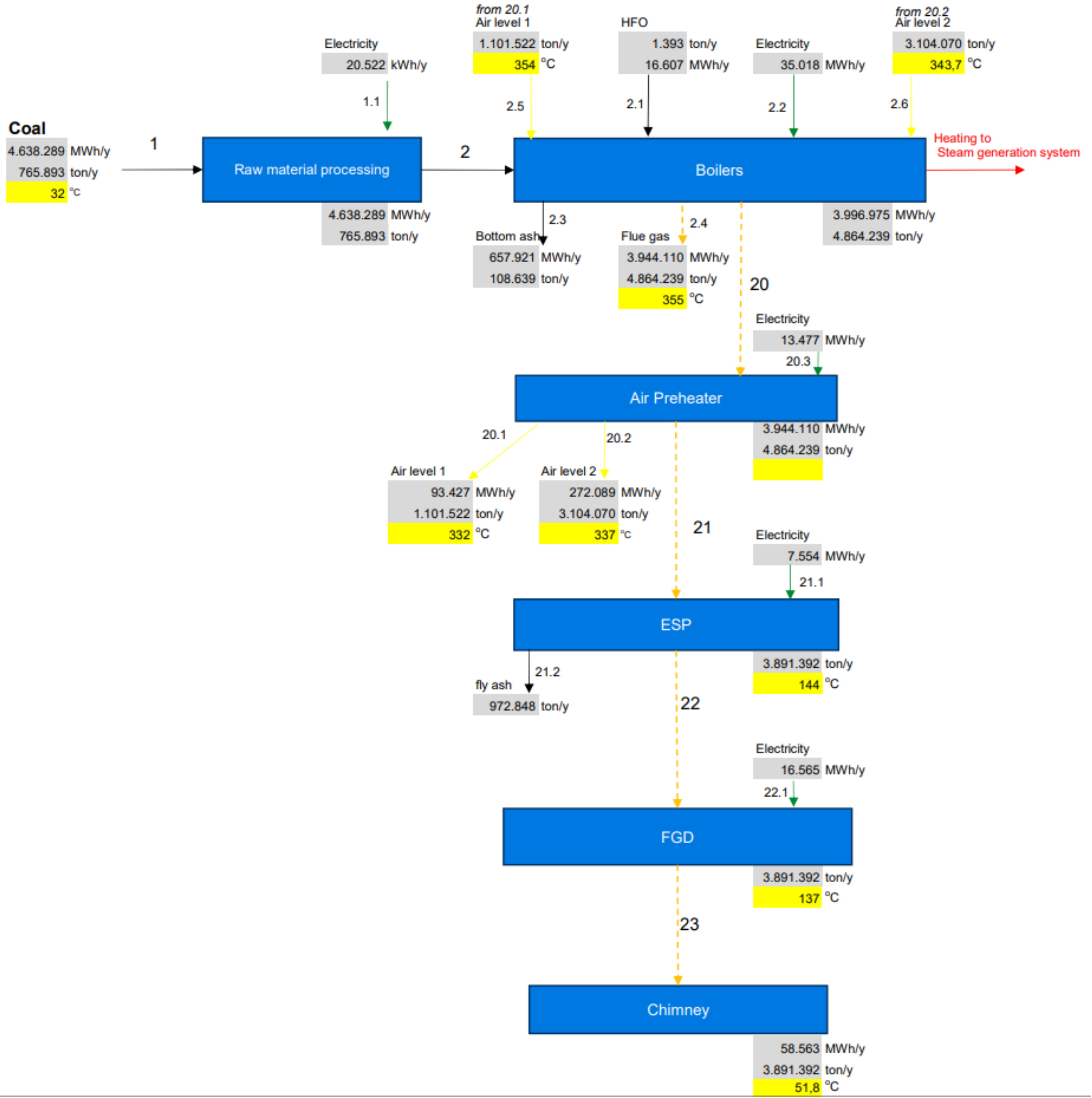



*Figure 1.4. Process Flow Diagram of Unit 1 (U1)*



Coal
4.638.289 MWh/y
765.893 ton/y
32 °C
1
Electricity
20.522 kWh/y
1.1
Raw material processing
4.638.289 MWh/y
765.893 ton/y
2
from 20.1
Air level 1
1.101.522 ton/y
354 °C
2.5
HFO
1.393 ton/y
16.607 MWh/y
2.1
Electricity
35.018 MWh/y
2.2
from 20.2
Air level 2
3.104.070 ton/y
343,7 °C
2.6
Boilers
Heating to
Steam generation system
3.996.975 MWh/y
4.864.239 ton/y
2.3
Bottom ash
657.921 MWh/y
108.639 ton/y
2.4
Flue gas
3.944.110 MWh/y
4.864.239 ton/y
355 °C
20
Electricity
13.477 MWh/y
20.3
Air Preheater
3.944.110 MWh/y
4.864.239 ton/y
20.1
Air level 1
93.427 MWh/y
1.101.522 ton/y
332 °C
20.2
Air level 2
272.089 MWh/y
3.104.070 ton/y
337 °C
21
Electricity
7.554 MWh/y
21.1
ESP
3.891.392 ton/y
144 °C
21.2
fly ash
972.848 ton/y
22
Electricity
16.565 MWh/y
22.1
FGD
3.891.392 ton/y
137 °C
23
Chimney
58.563 MWh/y
3.891.392 ton/y
51,8 °C

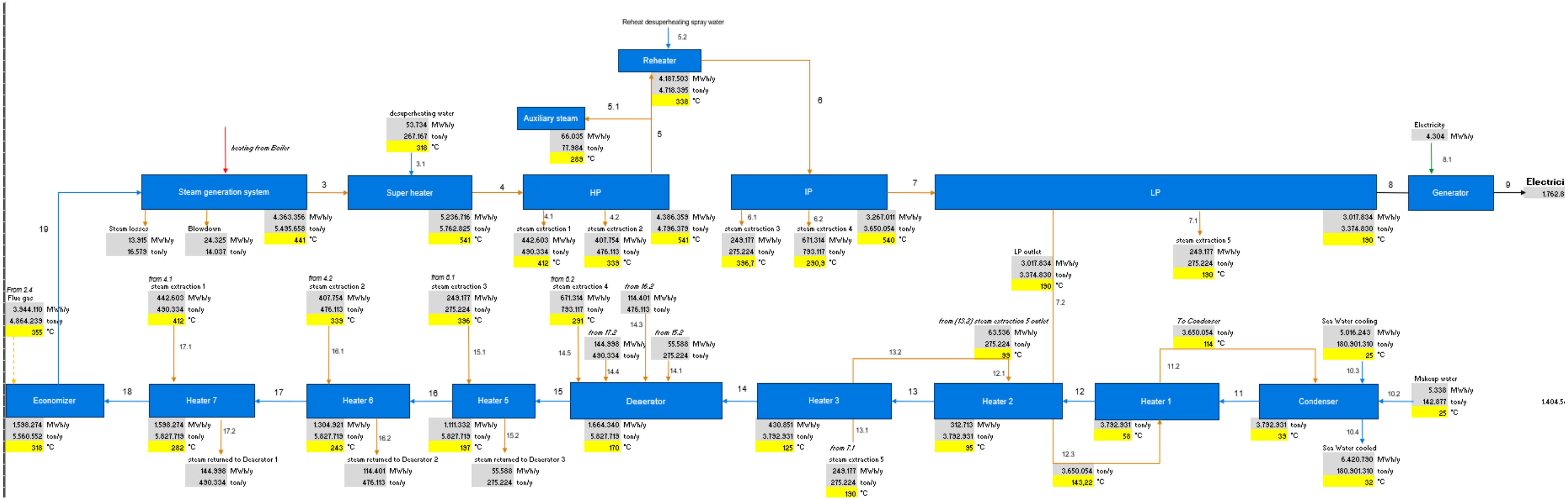



*Figure 1.5. Process Flow Diagram of Unit 2 (U2)*

**Description of stages in the technological process:**

Fuel Supply and Processing: Coal is transported to the plant by ship and unloaded at the Company’s port, from where it is conveyed to the storage yard via a conveyor belt system. The coal is stored in a covered warehouse that prevents weather impacts such as rain from increasing its moisture content. From the warehouse, coal is delivered to the coal hopper, then fed into two raw coal feeders (screw conveyors) and subsequently to the ball mills. The pulverized coal is then blown through coarse and fine separators before being distributed to 24 burners (12 front and 12 rear) for combustion in the boiler. Each burner is equipped with an HFO oil burner used during boiler start-up, shutdown, or low-load operation.

Combustion Process in the Boiler: The hot air supply and “W”-shaped downshot flame utilize concentrated pulverized coal burners with low-NOx EI-XCL technology (Enhanced Ignition – Centralized Control – Low NOx). These burners are designed to burn coal with a low volatile matter content. The saturated steam passes through the bare furnace superheater, then through the platen superheater, the division wall superheater, the first-stage superheater, the second-stage (pendant) superheater, and finally the third-stage superheater. Once the steam reaches the required temperature, it is directed to the high-pressure turbine.

Turbine and Generator: The superheated steam first enters the high-pressure turbine, where it rotates the blades at high speed, converting thermal energy into mechanical energy. As the steam expands in the high-pressure turbine, its temperature and pressure decrease significantly, reducing its work potential in the subsequent turbines. Therefore, the steam is reheated to increase its temperature before entering the intermediate- and low-pressure turbines. As the steam expands through the turbine stages, it gradually decreases in pressure, transferring energy to the rotating blades. The mechanical energy from the turbine is converted into electrical energy through a generator coupled to the turbine. When the turbine rotates, its shaft transmits this motion to the generator rotor, inducing alternating current in the stator windings. The rotational speed of the turbine and generator must be precisely controlled to ensure a stable electricity frequency of 50 Hz.

Condensation and Water Circulation: After passing through the turbine, the exhaust steam is cooled and condensed in the condenser using cooling water. The condensed water (condensate) is then reheated through feedwater heaters and recirculated back into the boiler system for steam generation, which helps conserve water and enhance the overall efficiency of the plant.

Flue Gas and Ash Handling: Pollution control systems such as Electrostatic Precipitators (ESP), Flue Gas Desulfurization (FGD), and other treatment devices are employed to remove pollutants from the flue gas before it is released into the atmosphere. Fly ash is transported to storage silos, where it can be utilized as a raw material in industries such as cement, concrete, lightweight brick production, or as filling material. Bottom ash is cooled using either water or dry cooling systems and then transported to disposal sites for further handling. The plant is equipped with an online continuous emission monitoring system (CEMS) to measure pollutant concentrations in the flue gas, enabling real-time adjustment of treatment processes and optimization of operational efficiency to ensure compliance with environmental standards and minimize impacts on the surrounding air quality.

### 1.3 Description of the utility systems

- Power supply system:

*Table 1.2. Transformer parameters*

| No. | Equipment name | Voltage level (kV) | Rated capacity (MVA) |
|---|---|---|---|
| 1 | Transformer T1 | 231±10x1.5%/21 | 353 |
| 2 | Transformer T2 | 231±10x1.5%/21 | 353 |
| 3 | Transformer T3 | 225±8x1.25/6.6/6.6 | 60/30/30 |
| 4 | TD91 | 21±2x2.5%/6.6 | 63/30/30 |
| 5 | TD92 | 21±2x2.5%/6.6 | 63/30/30 |

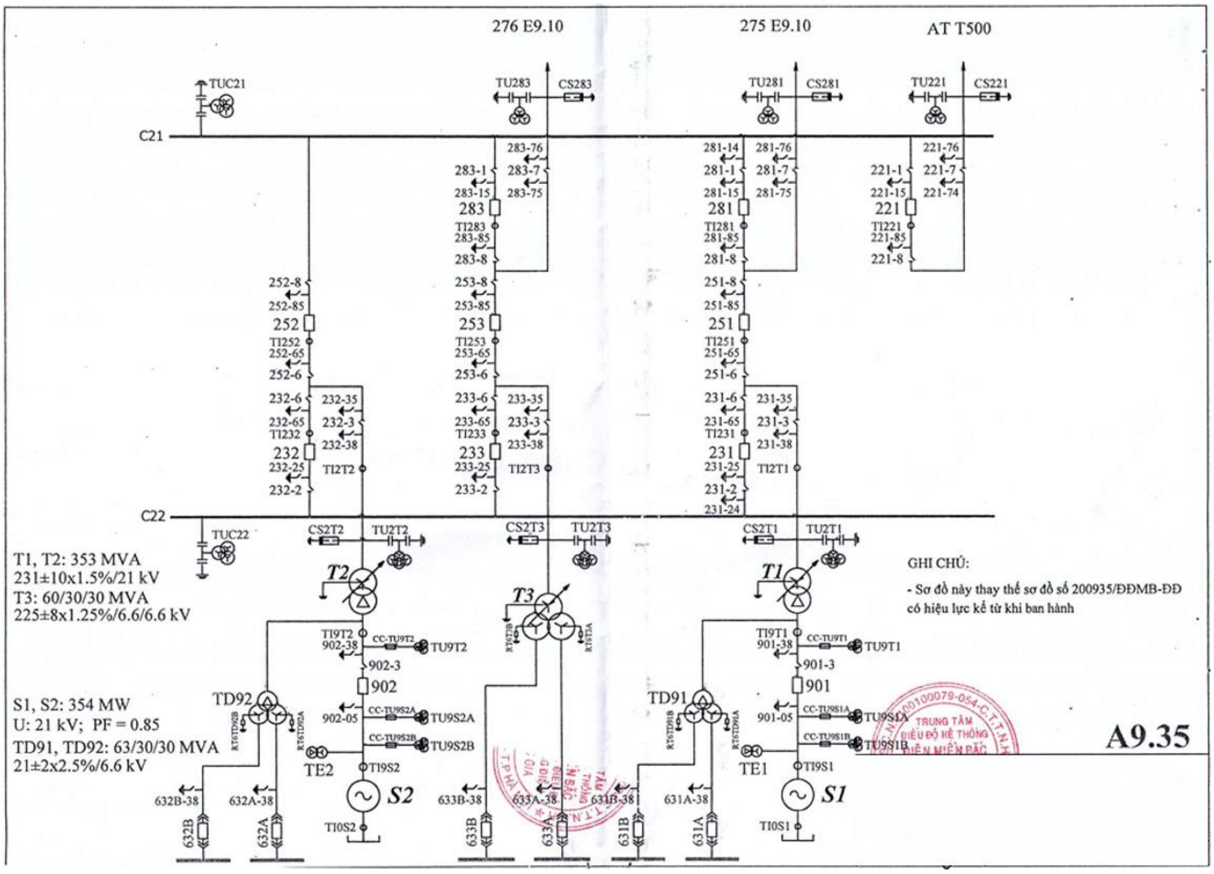



*Figure 1.6.Single-line electrical diagram of the Company*

- Fuel Supply System

After being received, the coal is transported to the storage area through a conveyor system before being fed into the pulverizer. The coal feed rate is adjusted by changing the speed of the feeder conveyor via the DCS or local control.

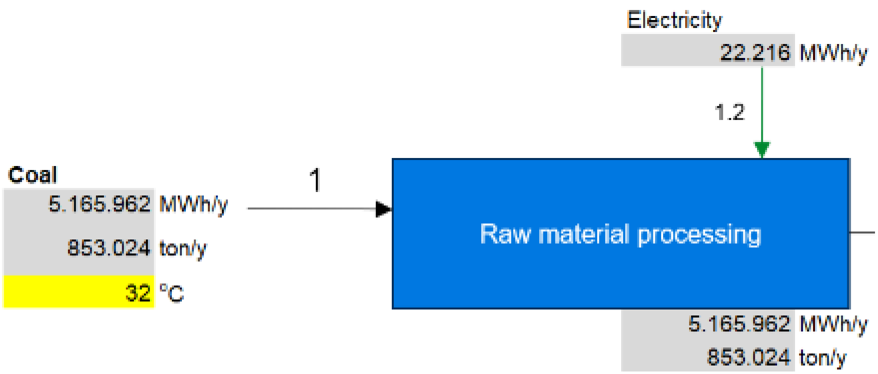



*Table 1.3. List of auxiliary boiler systems and equipment*

| No | Equipment Name | Quantity | Power (kW) | Operating Time (hours/year) |
|---|---|---|---|---|
| 1 | Mill | 4 | 1,494 | 8,760 |
| 2 | Raw coal feeder | 8 | 2.2 | 8,760 |

| No | Equipment Name | Quantity | Power (kW) | Operating Time (hours/year) |
|---|---|---|---|---|
| 3 | Mill oil cooling pump | 4 | 0.75 | 8,760 |
| 4 | Mill lubrication oil pump | 8 | 5.5 | 8,760 |

- Boiler System and Auxiliary Equipment:

The boiler system is the central and most critical component in coal-fired thermal power plants. It performs the following functions:

- Fuel Combustion: Completely burns coal in the furnace to release a large amount of heat.
- Energy Conversion: Transfers heat from the combustion process to liquid water, converting it into superheated steam.
- Turbine Operation: The superheated steam is then directly delivered to the steam turbine to rotate the turbine blades.

The Company uses the following types of boilers:

- The Company has two 300 MW units, each unit equipped with one boiler supplying steam to one turbine for power generation. The boiler is a natural circulation, single-drum type with a single furnace, balanced draft, single reheater, and dry bottom ash discharge.
- The boiler is designed to burn Vietnamese Anthracite coal, together with a ball mill grinding system. The hot air supply and the “W”-shaped flame combustion use dense-phase EI-XCL low-NOx pulverized coal burners (Enhanced Ignition – Centrally Controlled – Low NOx).

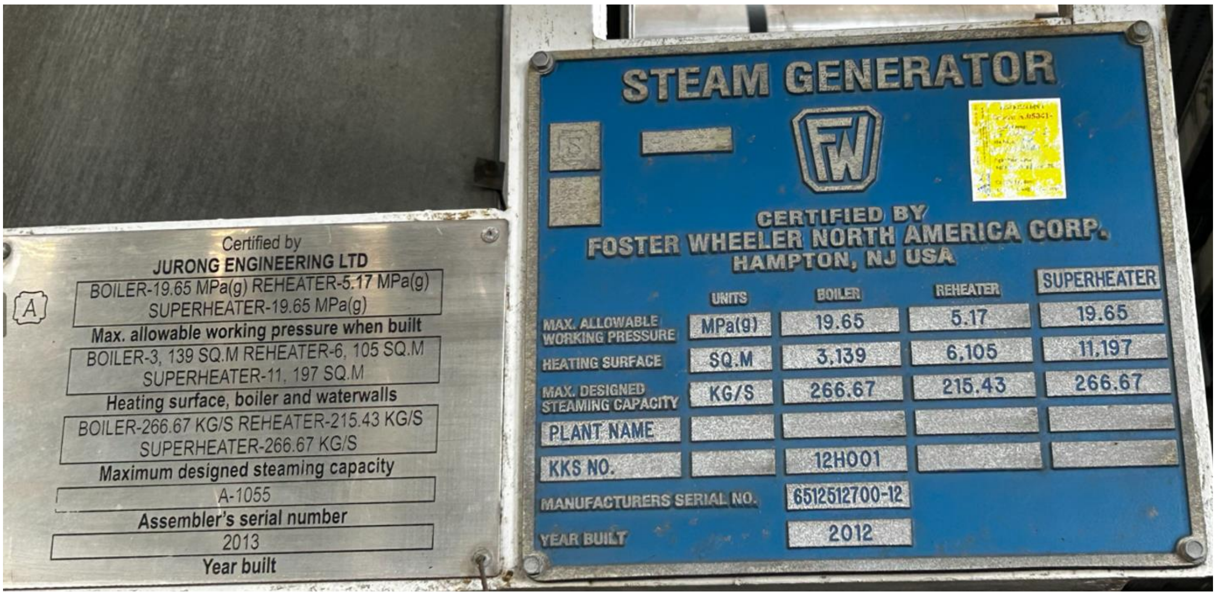



*Figure 1.7. Boiler specifications of the company*

**Air Preheater**

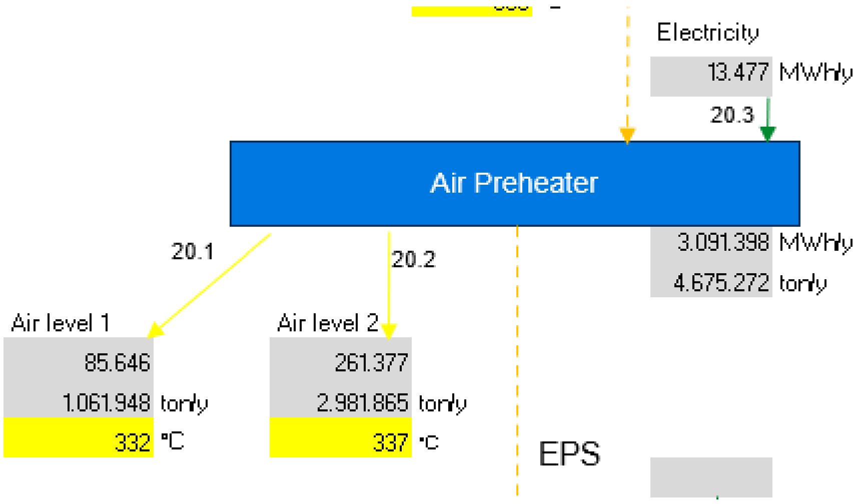



*Figure 1.8. Air preheater*

- Air is heated using flue gas before being supplied to the boiler;
- Electricity is consumed in this stage for equipment such as fans, etc.

*Table 1.4. Boiler Feedwater Softening System*

| No | Equipment Name | Quantity | Power (kW) | Operating Time (hours/year) |
|---|---|---|---|---|
| **Preliminary water treatment system** | | | | |
| 1 | Raw water pump | 2 | 22 | 3,840 |
| 2 | Dissolved gas–water mixture pump | 4 | 22 | 3,840 |
| 3 | Settled water pump | 2 | 45 | 3,840 |
| 4 | Clarified water transfer pump | 2 | 37 | 3,840 |
| **Demineralized water system** | | | | |
| 5 | Filtered water pump for demineralization | 2 | 11 | 3,840 |
| 6 | Service filtered water supply pump | 2 | 1,5 | 3,840 |
| 7 | Wastewater transfer pump | 2 | 11 | 3,840 |
| 8 | Sodium hypochlorite (NaOCl) dosing pump | 2 | 0.18 | 3,840 |
| 9 | Filtered water pump | 2 | 11 | 3,840 |
| 10 | Demineralized water booster pump | 2 | 15 | 3,840 |
| 11 | Regeneration water pump | 2 | 7.5 | 3,840 |

| No | Equipment Name | Quantity | Power (kW) | Operating Time (hours/year) |
|---|---|---|---|---|
| 12 | Neutralization tank pump | 2 | 15 | 3,840 |
| 13 | Hydrochloric acid (HCl) dosing pump | 2 | 2.2 | 3,840 |
| 14 | Sodium hydroxide (NaOH) dosing pump | 2 | 3.7 | 3,840 |

- Turbine and Generator System

The turbine of the coal-fired power plant is a condensing steam turbine manufactured by Fuji, Japan, consisting of three separate sections: High Pressure (HP), Intermediate Pressure (IP), and Low Pressure (LP). The function of the turbine is to convert steam into mechanical energy to drive the turbine for electricity generation.

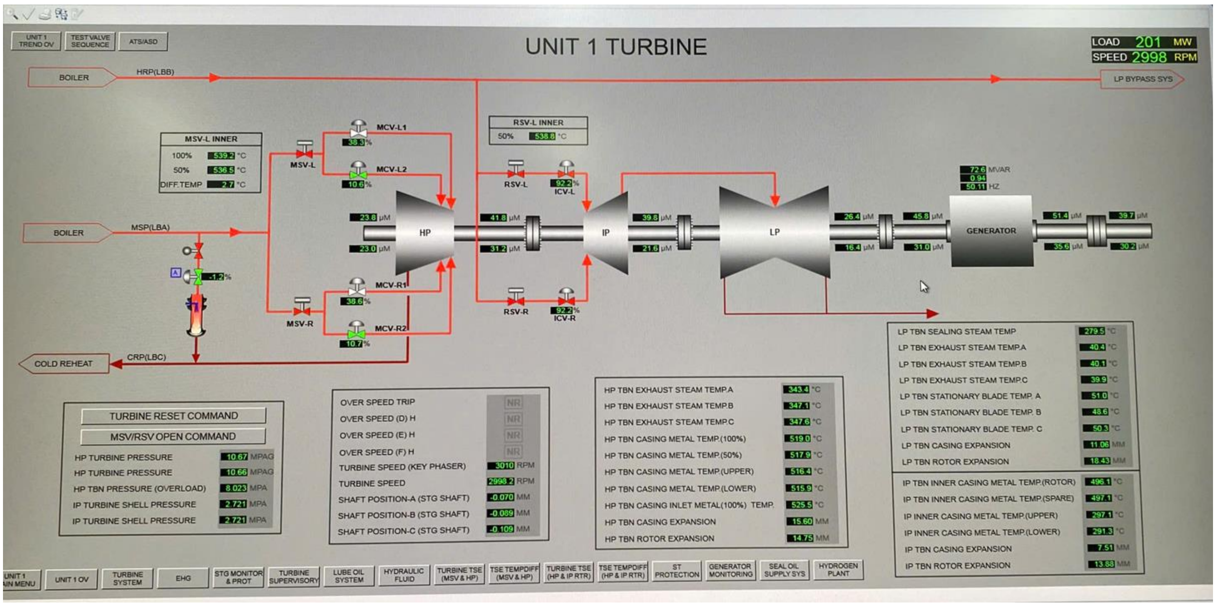



*Figure 1.9. Turbine system and auxiliary equipment*

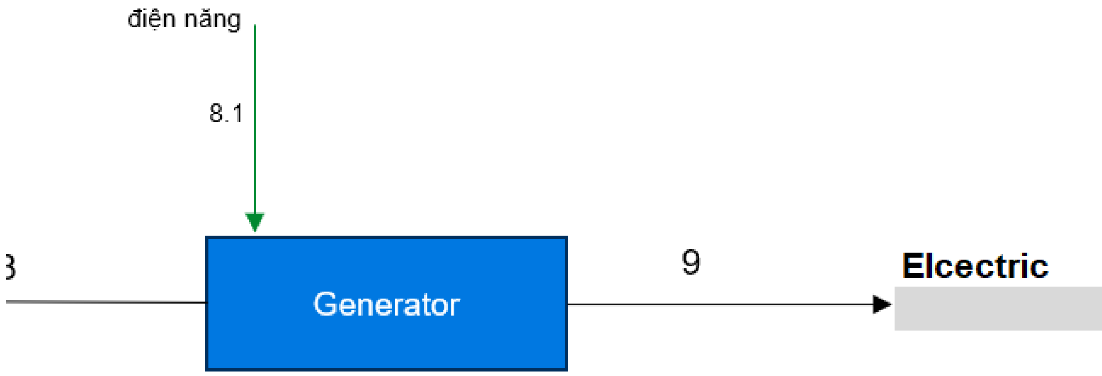



*Figure 1.10. Generator*

The generator at the power plant is manufactured by Fuji, with a capacity of 354.5 MVA, cooled by hydrogen gas. The generator output voltage is 21 kV, with a frequency of 50 Hz.

- Electricity consumption at the generator is used for excitation, cooling, lubrication oil pumps, etc.
  - Circulating water and condenser system

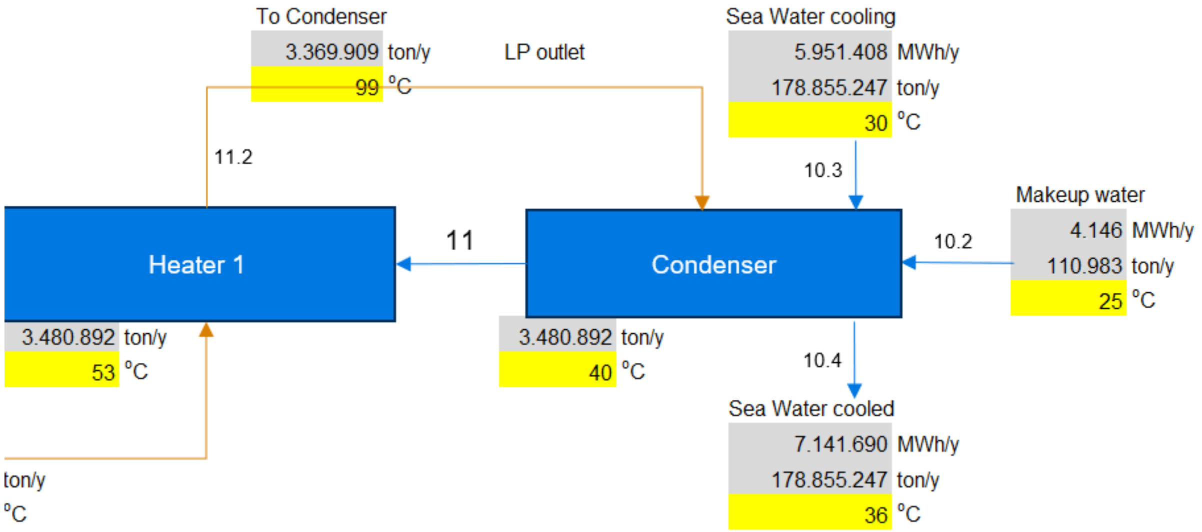



*Figure 1.11. Condenser*

The system includes two condenser pumps. The condenser pumps are responsible for pumping water from the condenser, where the pressure is usually quite low, through the economizers and feedwater heaters before entering the boiler. The two pumps operate alternately to ensure equipment longevity.

*Table 1.5. List of Condenser System Equipment*

| No. | Equipment Name | Quantity (Units) | Power (kW) | Operating Hours (hrs/year) |
|---|---|---|---|---|
| 1 | Condensate Pump A | 4 | 527 | 8,760 |
| 2 | Condensate Water Filter Pump | 4 | 18 | 8,760 |
| 3 | Feed Pump | 6 | 5,100 | 8,760 |

Seawater Circulating Pump System: The two units use four seawater circulating pumps for cooling and maintaining vacuum pressure in the condenser.

Closed-Loop Circulating Pump System: Includes two pumps responsible for supplying cooling water to the bearing lubrication oil system, various engine supports, and for cooling sealing oil, etc.

*Table 1.6. List of Circulating Water System Equipment*

| No. | Equipment Name | Quantity (Units) | Power (kW) | Operating Hours (hrs/year) |
|---|---|---|---|---|
| 1 | Closed-Circuit Cooling Water Pump | 4 | 306 | 8,760 |
| 2 | Sea Water Booster Pump | 4 | 170 | 8,760 |
| 3 | Circulating Pump | 4 | 1,600 | 8,760 |

- Flue Gas Treatment System

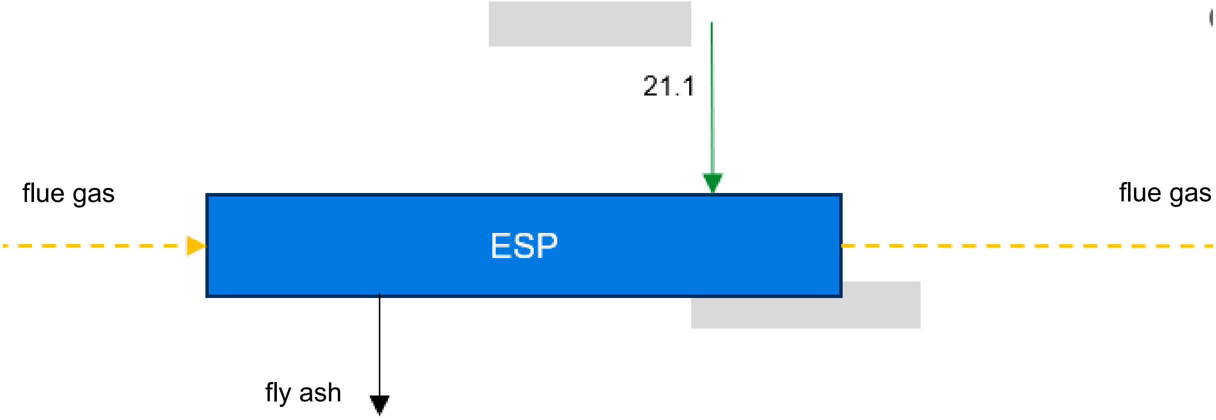



*Figure 1.12. Electrostatic Precipitator (ESP) System*

*Figure 1.13. The Company's Electrostatic Precipitator (ESP) System*

Table 1.17. List of Equipment in the ESP System

| No. | Equipment Name | Quantity (Units) | Power (kW) | Operating Hours (hrs/year) |
|---|---|---|---|---|
| 1 | Discharge Electrode Hammer | 32 | 0.37 | 8,760 |
| 2 | Collecting Electrode Hammer | 32 | 0.37 | 8,760 |
| 3 | Ceramic Heater Fan | 4 | 7.5 | 8,760 |
| 4 | Heater | 4 | 2 | 8,760 |
| 5 | Rectifier Transformer (Branch A) | 16 | - | 8,760 |

The electrostatic precipitator (ESP) system at the Company is supplied by KC Cottel (South Korea) with a dust removal efficiency of up to 99.79%, used to separate fly ash and dust from the flue gas before it is sent to the SOx and NOx treatment system.

Electricity is used in the system for dust filtration and for operating the dust rapping system and fans

*SOx and NOx Treatment System (FGD)*

After passing through the ESP, the flue gas is transported by draft fans to the Flue Gas Desulfurization (FGD) absorber tower, where SOx is removed with an efficiency exceeding 95%. The treated gas, free of dust, NOx, and SOx, exits through a 205-meter stack. Emissions are continuously monitored by the Continuous Emission Monitoring System (CEMS), with data sent to the Plantgate's main screen, the Department of Natural Resources and Environment, and Vietnam Electricity Group for online monitoring.

*Figure 1.14. SOx and NOx Treatment System of the Company*

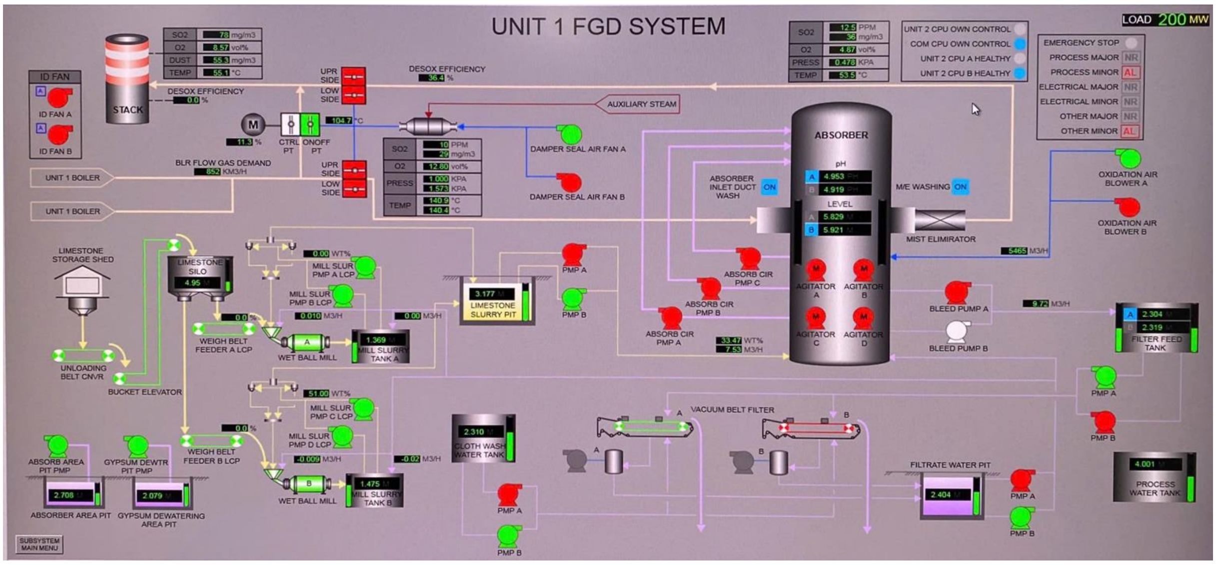



*Figure 1.15. FGD Control Panel*

The system is divided into three main subsystems:

- Absorber tower system;
- Lime slurry preparation system;
- Gypsum dewatering system.

*Table 1.18. List of Equipment in the FGD System*

| No | Equipment Name | Quantity (Units) | Power (kW) | Operating Hours (hrs/year) |
|---|---|---|---|---|
| 1 | Absorber Circulation Pump | 3 | 425/375/325 | 8,760 |
| 2 | Gas Damper Booster Fan | 4 | 45 | 8,760 |
| 3 | Absorber Mixer | 8 | 30 | 8,760 |

| No | Equipment Name | Quantity (Units) | Power (kW) | Operating Hours (hrs/year) |
|---|---|---|---|---|
| 4 | Oxidation Fan | 4 | 220 | 8,760 |
| 5 | Emergency Discharge Pump | 2 | 37 | 8,760 |
| 6 | Limestone Hopper Fan | 2 | 22 | 8,760 |
| 7 | Limestone Mill | 4 | 110 | 8,760 |
| 8 | Slurry Pump | 4 | 15 | 8,760 |
| 9 | Lime Slurry Feed Pump | 4 | 22 | 8,760 |
| 10 | Vacuum Pump | 4 | 90 | 8,760 |
| 11 | Production Water Pump | 4 | 55 | 8,760 |
| 12 | Dehumidification Water Pump | 4 | 30 | 8,760 |

- Compressed Air Supply System:

The Company uses 4 screw air compressors, including 2 units with 145 kW and 2 units with 90 kW, arranged in a centralized layout. The set pressure is 7–8.5 bar according to the demand of the Company's compressed air systems. The compressors operate in Load/Unload mode.

*Table 1.19. Statistics of Compressed Air System Equipment*

| No. | Air Compressor Name | Quantity (unit) | Capacity (kW) | Set Pressure (bar) | Operating Hours (h/day) |
|---|---|---|---|---|---|
| 1 | Maintenance Compressor A | 1 | 90 | 7-8.5 | 24 |
| 2 | Maintenance Compressor B | 1 | 90 | 7-8.5 | 24 |
| 3 | Control Compressor A | 1 | 145 | 7-8.5 | 24 |
| 4 | Control Compressor B | 1 | 145 | 7-8.5 | 24 |

# 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 the electrical system and load profile, collect data from the DCS.
- Fuel Supply and Processing System: Inspect equipment such as mills, screens, conveyors, etc., and collect data from the DCS.
- Boiler and Auxiliary Equipment System: Inspect the boiler system, measure energy consumption, and collect data from the DCS.
- Turbine and Generator System: Collect energy consumption data from the DCS.
- Circulating Water and Condenser System: Measure temperature, survey, and collect energy consumption data from the DCS.
- Flue Gas Treatment System: Collect operating and energy consumption data from the DCS;
- Compressed Air System: Measure electricity, survey pressure, flow, and air leakage.
- Lighting System: Measure illuminance and lighting efficiency.
- Other Systems: Conduct additional tests to ensure a comprehensive assessment.

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.

In addition, the current energy consumption of equipment in the process and production lines—such as mills, boilers, and turbines—is also assessed. The study also considers the energy consumption of auxiliary systems, water-cooling and compressed air systems, as well as other pumps and fans.

*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:

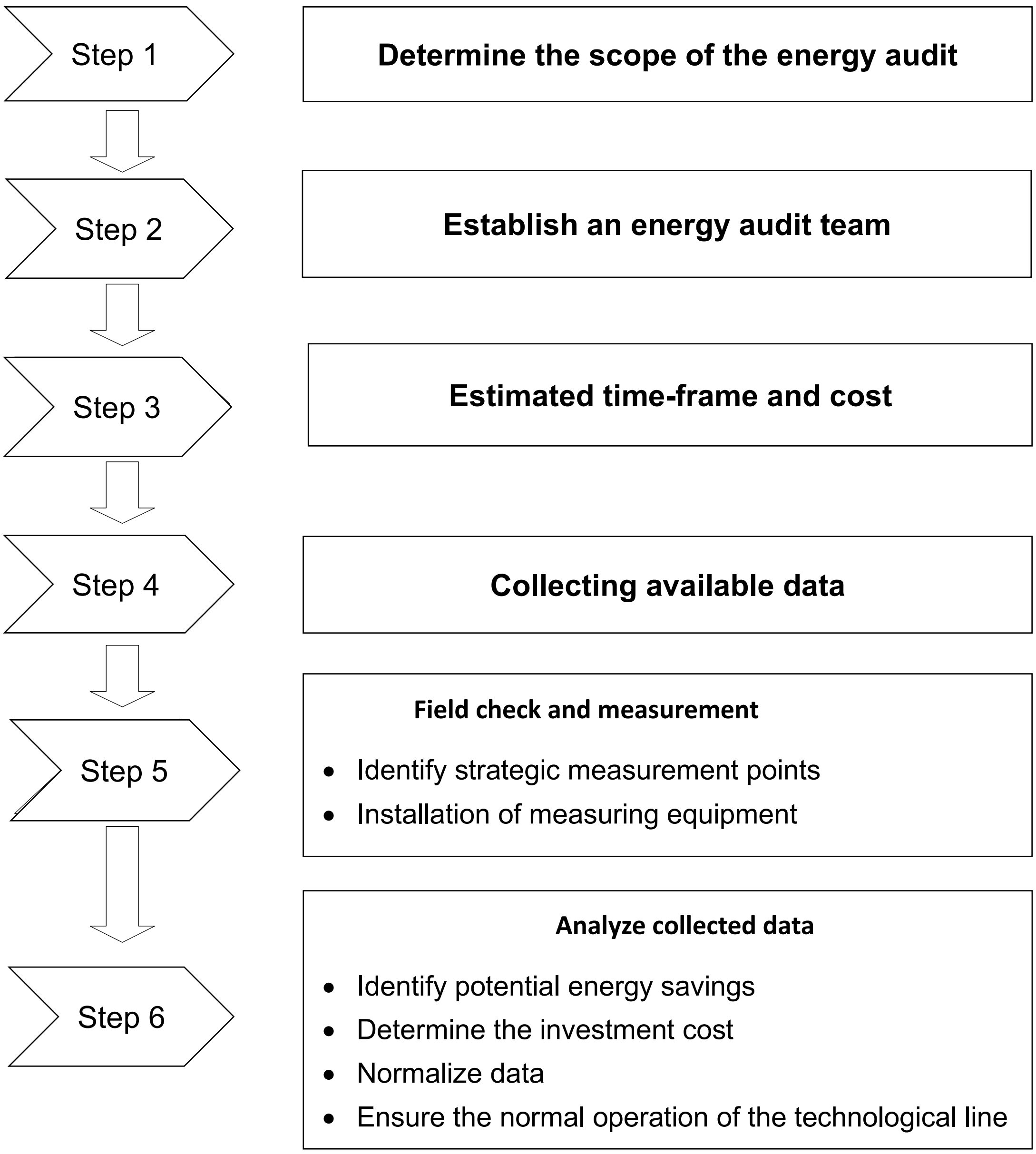



*Figure 2.1. Audit procedure sequence*

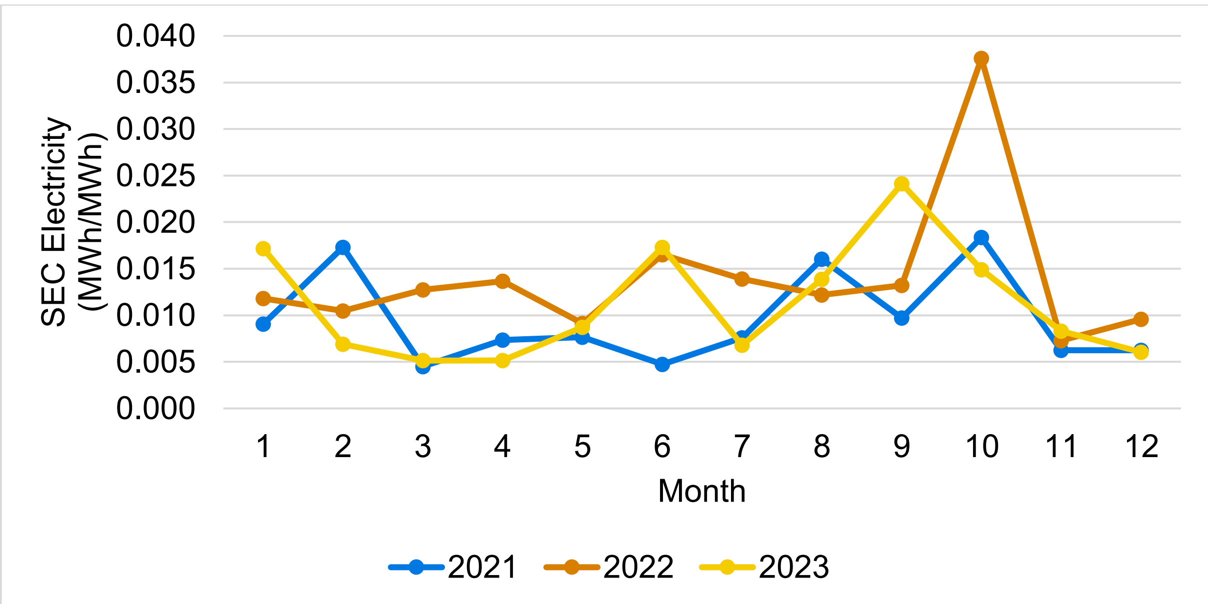


*Figure 2.2. Electricity consumption rate of the Company in the period 2021 - 2023*

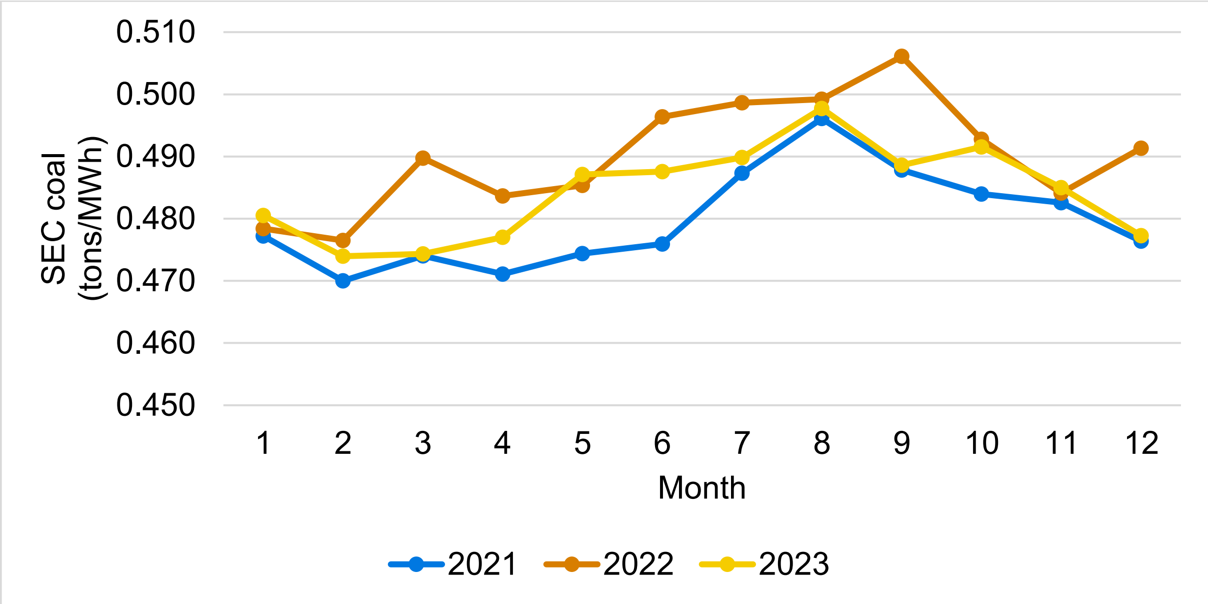



*Figure 2.3. Coal consumption rate of the company for the period 2021–2023*

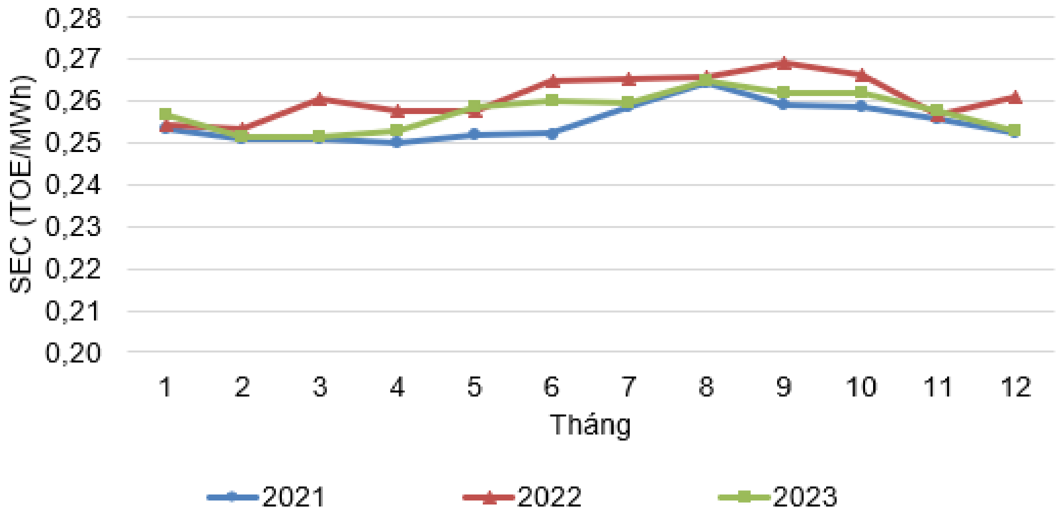



*Figure 2.4. Energy consumption rate of the Company in the period 2021 - 2023*

The company's energy consumption rate remained stable across the years and months within the period. Specifically:

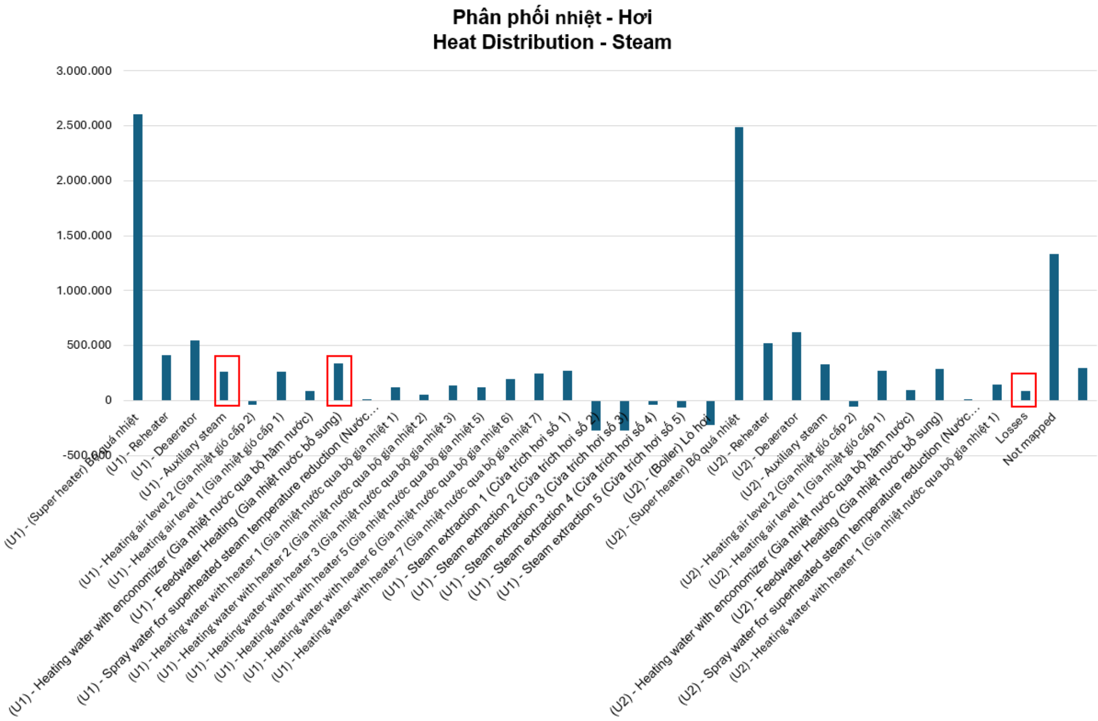
- In 2022, the average energy consumption rate increased by 2.4% compared to 2021;
- In 2023, the average energy consumption rate decreased by 1.54% compared to 2022.

The stability of the energy consumption rate during 2021–2023 is attributed to the company's consistent production demand, efficient operational management system, and well-calibrated, maintained, and periodically serviced equipment.

Identifying and implementing energy-saving measures is necessary to improve the current consumption rate. Additionally, any abnormal fluctuations in the SEC (Specific Energy Consumption) index indicate areas that require improvement in the company's management system.

To determine the energy-saving potential, the consulting team combined system analysis using the Energy Mapping Tool with expert assessment. Energy mapping helps identify areas with the highest energy consumption, enabling the plant to focus on key improvement opportunities. This method serves as an essential tool in energy management, supporting the systematic implementation of energy-saving initiatives and enhancing overall efficiency.

Key findings from the energy mapping analysis include:



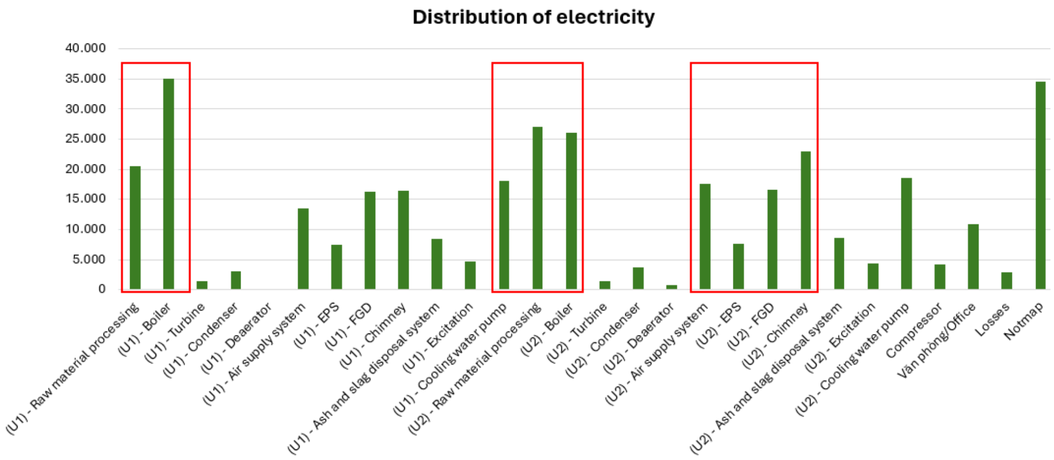




*Figure 2.5. Identifying energy saving potential from mapping*

For electrical loads, the total consumption of the boiler auxiliary systems, milling systems, circulating pump systems, and flue gas systems accounts for a high proportion compared to other stages in the production line. This indicates the need for measures to reduce electricity consumption of these loads.

For processes using thermal energy, calculations show that the heat consumption in the superheater is the highest; however, this steam is recirculated during production, so its impact is not significant. A considerable portion of thermal energy is still underutilized, such as self-used steam that is discharged directly into the environment after use, losses through flue gas, heat radiation, and coal ash. This is also an area that requires attention to fully utilize useful heat and improve the overall system efficiency.


*Figure 2.6. Identification of waste heat recovery potential and inter-process heat optimization (red-marked area)*

Through the system analysis methods described above, the consulting team has proposed a list of potential energy-saving measures (List level B) as presented in Chapter 3 of the report.

The energy-saving potential proposed by the consulting team is substantial. Implementing these measures will contribute to significant reductions in energy costs. According to the assessment, the proposed measures are highly feasible from both technical and economic perspectives. Based on the proposed list, the consulting team will coordinate with the Plant to select the measures for further investment study (List level A). Investment costs will be preliminarily estimated and calculated in detail during the investment phase.

*Table 2.1. Level A List – Energy Efficiency Measures for Investment*

| No. | Description | Area | Equipment | Energy Savings | Potential Savings (kWh) | Estimated Savings Cost (EUR) | Investment Cost (EUR) | Payback Period (years) | Summary of Energy Efficiency Potential |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Install INVERTER control for Repair Air Compressor A | Air Compressor | Inverter | Electricity saving | 37,189 | 1,837 | 6,588 | 3.59 | Repair Air Compressor A operates with long no-load time, running in Load/Unload mode |
| 2 | Renovation, repair, and insulation of heat loss points | Boiler | Insulation | Heat saving | 581 | 6,282 | 3,294 | 0.52 | Many insulation points are degraded, causing large heat losses |
| | Renovation, repair, and insulation of heat loss points | | | | 217 | 2,340 | 6,588 | 2.82 | |

| No. | Description | Area | Equipment | Energy Savings | Potential Savings (kWh) | Estimated Savings Cost (EUR) | Investment Cost (EUR) | Payback Period (years) | Summary of Energy Efficiency Potential |
|---|---|---|---|---|---|---|---|---|---|
| | (steam valve insulation) | | | | | | | | |
| 3 | Renovation of common piping connections for seawater circulation pumps of 2 units | Circulation Pump | Joints, piping | Electricity saving | 3,744,000 | 184,991 | 65,880 | 0.36 | Condenser cooling water flow is excessive in winter |
| 4 | Install INVERTER control for auxiliary fans in boiler area | Boiler | Inverter | Electricity saving | 12,638,683 | 624,477 | 1,317,600 | 2.11 | IDF, FDF, PAF are directly controlled, flow regulated by valves |

| No. | Description | Area | Equipment | Energy Savings | Potential Savings (kWh) | Estimated Savings Cost (EUR) | Investment Cost (EUR) | Payback Period (years) | Summary of Energy Efficiency Potential |
|---|---|---|---|---|---|---|---|---|---|
| 5 | Install INVERTER for seawater circulation pump system | Circulation Pump | Inverter | Electricity saving | 7,371,817 | 364,241 | 658,800 | 1.81 | Seawater circulation pumps are directly controlled, flow regulated by valves |

## 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. Regularly Repair Compressed Air Leaks*

1. **Current Equipment Condition**

During the testing and measurement period, the energy audit team inspected the entire production line and evaluated that the amount of compressed air leakage in the factory is relatively significant at connection points, rubber gaskets, etc.

When leakage occurs over a long period, it increases the compressor's operating time and power demand to compensate for the lost air volume. This leads to reduced compressor lifespan and higher maintenance costs for other components.

2. **Proposed Solution**

To prevent air compressor leakage, it is necessary to pay attention to the maintenance and inspection of parts prone to leakage such as:

- Joints, connectors, and air distribution pipelines;
- Compressor pressure control devices;
- Air inlet and exhaust valves.

In addition to repairing leakage points, the Company should promote communication and training programs to raise employee awareness of proper and efficient use of compressed air, avoiding unnecessary use that causes energy waste.

3. **Investment Cost and Financial Effectiveness**

Investment cost depends on the current condition of the plant.

4. **Feasibility Assessment**

The solution is technically and economically feasible.

### 2.2.2. *Retrofit the Compressed Air Piping System into a Ring-Type Layout Instead of a Branch-Type Layout*

1. **Current System Condition**

– The Company's compressed air distribution system is currently installed in a branch-type configuration.

– Pressure drops have been observed at the end points of the pipelines.

2. **Proposed Solution**

– The proposed solution is to redesign the compressed air pipeline network into a closed-loop (ring-type) layout to ensure a more balanced and efficient air distribution to consumption points, while maintaining stable pressure across the system. After implementing this solution, the air pressure should be adjusted to appropriate levels based on workshop demand.

3. **Investment Cost and Financial Effectiveness**

– Investment cost depends on the current condition of the plant.

4. **Feasibility Assessment**

– The solution is technically and economically feasible.

### 2.2.3. *Replace the Existing Air Dryer with a High-Efficiency Model*

1. **Current System Condition**

Based on collected data, the company is currently using a conventional refrigerant-type air dryer, and the compressor operates continuously.

2. **Proposed Solution**

The company should replace the existing air dryer with a high-efficiency Flex Series model from SFXFlow.

The Flex Series operates effectively by using a special material called *Phase Change Material (PCM)*. This material alternates between solid and liquid states to remove moisture from compressed air while consuming minimal energy, especially under moderate ambient temperature conditions or when the compressor is not running at full capacity.

### 2.2.4. *Installation of a Inverter for Repair Air Compressor A*

1. **Current Equipment Condition**

- The compressor operates in Load–Unload mode. The Unload operating time accounts for 2%–65.5% of the total operating time. When running in Unload mode (Unload > 15%), the motor continues to run without generating compressed air, causing significant energy waste.

2. **Proposed Solution**

- Install a INVERTER for the motor of Repair Air Compressor A to adjust the motor speed according to actual load demand, thereby reducing electricity consumption during unloaded operation.

3. **Energy Consumption Before and After**

- Before INVERTER installation: ~57,213 kWh/year during unloaded operation
- After INVERTER installation: Saves 37,189 kWh/year (~65% of non-useful load)

4. **Expected Savings**

- Electricity savings: 37,189 kWh/year
- Cost savings: 55,782,979 VND/year
- $CO_2$ emission reduction: 25.16 tons/year
- TOE savings: 5.74 TOE/year.

5. **Investment Cost and Financial Effectiveness**

- Investment cost: 200 million VND
- Simple payback period: 3.59 years
- IRR: 12.2%
- NPV after 5 years (discount rate 12%): 1.085 million VND

6. **Feasibility Assessment**

- Technical: Feasible with minor control system modifications.
- Economic: Feasible and should be prioritized for early implementation.

#### *2.2.5. Insulation Renovation and Repair for Heat Loss Points*

1. **Current System Condition**

- Most high-temperature areas and surfaces are well-insulated; however, after long-term operation, the insulation layer has degraded, causing heat loss in some areas.
- Many large-sized valves are not insulated, with surface temperatures ranging from 100–141°C.

2. **Proposed Solution**

- To prevent heat loss and avoid unnecessary cost increases, the Company should consider insulating all high-temperature surfaces.

### 3. Energy Consumption Before and After

- Average annual heat loss: 791,052,023 kJ
- Annual fuel savings: 35.76 tons of coal/year

### 4. Expected Savings

- Coal savings: 35.76 tons/year
- Cost savings: 71,044,811 VND/year
- $CO_2$ emission reduction: 88.33 tons/year
- TOE savings: 21.46 TOE/year.

### 5. Investment Cost and Financial Effectiveness

- Investment cost: 200 million VND
- Simple payback period: 2.82 years
- IRR: 12.2%
- NPV after 5 years (12% discount rate): 56,100,644 VND.

### 6. Feasibility Assessment

The solution is technically and economically feasible.

*2.2.6. Replacement of Low-Efficiency Fly Ash Silo Aeration Fan Motor with High-Efficiency IE4 Motor*

### 1. Current System Condition

- Most motors used at Thermal Power Plant 1 are high-efficiency motors (IE2 or IE3), helping optimize internal electricity consumption.
- However, the fly ash silo aeration fan still uses a standard IE1 motor with low efficiency (0.79), resulting in unnecessary energy losses. With continuous operation throughout the year (aligned with turbine operating hours), electricity losses from this low-efficiency motor are significant.

### 2. Proposed Solution

- Replace the low-efficiency fly ash silo aeration fan motor with a high-efficiency **IE4 motor.**

### 3. Energy Consumption Before and After

- Annual electricity loss of old IE1 motor: 383,164 kWh/year

- Annual electricity loss of new IE4 motor: 164,402 kWh/year;

### 4. Expected Savings

- Electricity savings: 218,762 kWh/year
- Cost savings: 328,143,601 VND/year
- $CO_2$ emission reduction: 148.01 tons/year
- TOE savings: 33.76 TOE/year

### 5. Investment Cost and Financial Effectiveness

- Investment cost: 1.280 billion VND
- Simple payback period: 3.9 years

### 6. Feasibility Assessment

- The solution is technically and economically feasible.

## *2.2.7. Waste Heat Recovery from Flash Steam and Boiler Blowdown for Other Required Processes*

### 1. Current System Condition

- Boiler blowdown water has a high temperature, typically from 150–200°C, and steam traps discharge condensate and air from the steam system at 70–100°C, containing a significant amount of thermal energy.
- This steam can be recovered and used to supply low-pressure steam for processes requiring thermal energy or for heating auxiliary equipment.

### 2. Proposed Solution

- Recover and utilize waste heat from flash steam and boiler blowdown to preheat boiler feedwater.

### 3. Energy Consumption Before and After Implementation

- Boiler feedwater temperature before implementation: 30°C
- Boiler feedwater temperature after implementation: 52.76°C
- Total coal consumption before implementation: 9,094,684 tons/year
- Total coal consumption after implementation: 9,094,491 tons/year

### 4. Expected Savings

- Coal savings: 193 tons/year
- Coal cost savings: 383,407,392 VND/year
- $CO_2$ emission reduction: 476.68 tons/year

– TOE savings: 115.79 TOE/year.

**5. Investment Cost and Financial Effectiveness**

– Investment cost: 1 billion VND
– Simple payback period: 1.61 years
– IRR: 26.51%
– NPV after 5 years (12% discount rate): 382,097,841 VND.

**6. Feasibility Assessment**

– The solution is feasible both technically and economically.

*2.2.8. Waste Heat Recovery from Auxiliary Steam to Preheat Make-up Water*

***1. Current System Condition***

– Steam traps discharge condensate and air from the steam system at **70–100°C**, containing significant thermal energy. Discharging this heat into the environment leads to waste of the condensate's thermal content.

**2. Proposed Solution**

– Recover waste heat from the auxiliary steam system to heat make-up water using a heat exchanger or a heat pump.

**3. Energy Consumption Before and After Implementation**

– Boiler feedwater temperature before implementation: 30°C
– Boiler feedwater temperature after implementation: 53.68°C
– Total coal consumption before implementation: 9,094,684 tons/year
– Total coal consumption after implementation: 9,093,546 tons/year

**4. Expected Energy Savings**

– Coal savings: 1,137 tons/year
– Coal cost savings: 2,259,817,166 VND/year
– $CO_2$ emission reduction: 2,809.56 tons/year
– TOE savings: 682.48 TOE/year.

**5. Investment Cost and Financial Effectiveness**

– Investment cost: 4 billion VND
– Simple payback period: 1.77 years
– IRR: 48.73%
– NPV after 5 years (12% discount rate): 4,146,135,143 VND

**6. Feasibility Assessment**

- The solution is technically and economically feasible**.**

*2.2.9. Installation of Variable Frequency Drives (INVERTERs) for Seawater Booster Pumps*

**1. Current System Condition**

- Seawater booster pumps operate in direct-on-line (DOL) mode, with flow regulated manually using valves.
- The valve opening angle is typically maintained at around 50%, increasing pipeline resistance and causing unnecessary electrical energy losses.

**2. Proposed Solution**

- Install INVERTERs for seawater booster pumps 1A and 2A to adjust pump speed according to actual load demand, ensuring optimal operation.

**3. Energy Consumption Before and After**

- Total annual electricity consumption of both pumps: 1,997,280 kWh/year
- Expected electricity consumption after installing INVERTERs: 685,067 kWh/year.

**4. Expected Savings**

- Electricity savings: 852,938 kWh/year
- Electricity cost savings: 1,279,407,636 VND/year
- $CO_2$ emission reduction: 577.10 tons/year
- TOE savings: 131.61 TOE/year

**5. Investment Cost and Financial Effectiveness**

- Investment cost: 2 billion VND
- Simple payback period: 1.56 years
- IRR: 12.2%
- NPV after 5 years (12% discount rate): 5,930,144,769 VND.

**6. Feasibility Assessment**

- The solution is technically and economically feasible.

*2.2.10. Installation of Deep-Seawater Intake Pipes for Cooling.*

**1. Current System Condition**

- The plant's current seawater cooling system draws water from a depth of 2–5 meters, i.e., near the surface. In summer, seawater temperature at this depth is significantly higher than in winter, with a temperature difference of 5–6°C. This temperature difference increases the required cooling water flow in summer—up to 50% higher compared to winter. Extracting seawater from greater depths would provide cooler water year-round, helping reduce the required seawater flow and saving electricity used by the seawater circulation pumps while maintaining efficient unit operation..

**2. Proposed Solution**

- Install a siphon pipeline to extract seawater from deeper, cooler layers, especially during summer.

**3. Investment Cost and Financial Effectiveness**

- Dependent on the actual scale of the system.

**4. Feasibility Assessment**

- Further research and refinement are required before considering future investment.

*2.2.11. Study on Using Blended Coal with Higher Calorific Value and Volatile Matter Compared to the Design Coal*

***1. Current System Condition***

- Thermal Power Plant 1 consists of 2 units, with a total installed capacity of 600 MW (2 × 300 MW). The boilers use pulverized coal (PC) combustion technology—natural circulation, subcritical parameters, designed to burn anthracite coal 5A.1. Annual coal consumption is approximately 1.5 million tons. Anthracite 5A.1 is high-quality coal but more difficult to ignite compared to other coal types, requiring additional HFO (heavy fuel oil) during boiler start-up or low-load operation.
- Coal calorific value: 22,121 kJ/kg.

**2. Proposed Solution**

- The consulting team proposes studying the possibility of blending anthracite 5A.1 with one or more coal types that have higher calorific value, higher volatile matter, and better ignition characteristics.
- This solution would improve combustion, enhance boiler efficiency, reduce coal and HFO consumption, and lower greenhouse gas emissions.
- Coal types considered for blending include:
  - Sub-bituminous coal
  - Bituminous coal

- Imported coal (Australia, Indonesia)
- Other domestic fine coals (6a, 6b, 7)

– The table below presents a preliminary comparison between anthracite 5A.1 and selected blending coals based on technical and economic criteria such as advantages/disadvantages, boiler performance, emissions, cost, and technical feasibility.

*Table 2.8. Preliminary Comparison of Blending Options with Anthracite 5A.1*

| Criteria | Sub-bituminous Coal | Bituminous Coal | Imported Coal (Indonesia/ Australia) | Domestic Fine Coal (6a, 6b, 7) |
|---|---|---|---|---|
| **Calorific Value (MJ/kg)** | 20–25 | 25–30 | 18–28 | 15–23 |
| **Volatile Matter (%)** | 20–35 | 20–35 | 15–38 | 10–25 |
| **Advantages** | Easy to ignite, stable flame | High combustion efficiency, low ash | Easy to ignite, low cost, suitable calorific value | Locally available, low cost |
| **Disadvantages** | High moisture, high ash content | High cost, potential slagging | Variable quality, requires impurity control | Low stability, higher maintenance cost |
| **Boiler Efficiency Improvement** | ⭐⭐⭐ | ⭐⭐⭐⭐ | ⭐⭐⭐ | ⭐⭐ |
| **Coal Consumption Reduction** | ⭐⭐ | ⭐⭐⭐⭐ | ⭐⭐⭐ | ⭐ |
| **Emission Reduction ($CO_2$, $NO_x$)** | ⭐⭐ | ⭐⭐⭐⭐ | ⭐⭐⭐ | ⭐⭐ |
| **Fuel Cost Optimization** | ⭐⭐ | ⭐⭐ | ⭐⭐⭐⭐ | ⭐⭐⭐ |

| Criteria | Sub-bituminous Coal | Bituminous Coal | Imported Coal (Indonesia/ Australia) | Domestic Fine Coal (6a, 6b, 7) |
|---|---|---|---|---|
| **Compatibility with Anthracite-Fired Boilers** | ★★ | ★★★★ | ★★★ | ★★ |
| **Technical Feasibility (at low blending ratios)** | High | High | High | Medium – requires strict combustion control |
| **Commercial Feasibility** | Medium – dependent on imports | High cost | High – abundant supply | High – locally available |

- To implement this measure, detailed technical studies are required, including combustion characteristic modeling of blended coal, trials with various blending ratios, and evaluation of the performance and effectiveness of each option.

3. **Investment Cost and Financial Effectiveness**

- A detailed implementation plan is required to determine total investment cost and financial effectiveness.

4. **Feasibility Assessment**

- The solution is fully feasible and has been applied in many large coal-fired power plants worldwide, including in Vietnam (such as Vung Ang, Vinh Tan, Duyen Hai, etc.).

### *2.2.12. Retrofit Common Piping Connection for the Seawater Circulation Pump System of Two Units*

1. **Current System Condition**

- Currently, the two units are using four seawater circulation pumps to cool the condenser. These pumps regulate flow using valves, with valve opening angles typically 50–55%. However, when cooling demand decreases or seawater temperature drops in winter, the power consumption and cooling water flow remain unchanged.

2. **Proposed Solution**

  - To address this issue, a solution to interconnect the piping systems between the two seawater circulation pump systems is proposed. This connection will enable a reduction in the number of pumps operating when cooling demand is low, while ensuring mutual backup capability in the event of pump failure..

**3. Energy Consumption Before and After**

- Total annual electricity consumption of 4 seawater circulation pumps: 45,552,000 kWh/year. Electricity consumption after turning off 1 pump during 4 winter months: 41,808,000 kWh/year.

**4. Expected Savings**

- Electricity savings: 3,744,000 kWh/year
- Cost savings: 5,616,000,000 VND/year
- $CO_2$ emission reduction: 2,533.19 tons/year
- TOE savings: 577.70 TOE/year.

**5. Investment Cost and Financial Effectiveness**

- Investment cost: 2,000 million VND
- Simple payback period: 0.36 years
- IRR: 12.2%
- NPV after 5 years (12% discount rate): 18,244,423,152 VND

**6. Feasibility Assessment**

- The solution is technically and economically feasible.

*2.2.13. Installation of Variable Frequency Drives (INVERTERs) for Auxiliary Fans in the Boiler Area*

**1. Current System Condition**

- Auxiliary fans are operating at loads ranging from 24–90% rated capacity, while flow rate is regulated by adjusting the valve opening angle (approximately 34–54%)

**2. Proposed Solution**

- Install INVERTERs to control fan speed and fully open fan dampers to minimize energy losses.

**3. Energy Consumption Before and After**

- Before INVERTER installation: ~24,046,200 kWh/year
- After INVERTER installation: ~8,247,847 kWh/year.

**4. Expected Savings**

- Electricity savings: 12,638,683 kWh/year
- Cost savings: 18,958,024,080 VND/year

- $CO_2$ emission reduction: 9,126 tons/year
- TOE savings: 1,950 TOE/year

**5. Investment Cost and Financial Effectiveness**

- Investment cost: 40,000 million VND
- Simple payback period: 2.11 years
- IRR: 12.2%
- NPV after 5 years (12% discount rate): 28,339,434,047 VND.

**6. Feasibility Assessment**

- The solution is technically and economically feasible.

### *2.2.14. Installation of Variable Frequency Drives (INVERTERs) for Seawater Circulation Pumps*

**1. Current System Condition**

- The seawater circulation pumps operate in direct-on-line mode, with flow controlled manually by valves.
- Valve opening angles typically remain low (55–56%), increasing pipeline resistance and causing unnecessary energy losses.

**2. Proposed Solution**

- Install INVERTERs to control pump speed and fully open the pump guide vanes to reduce energy losses.

**3. Energy Consumption Before and After**

- Before INVERTER installation: ~23,240,280 kWh/year
- After INVERTER installation: ~11,899,023 kWh/year.

**4. Expected Savings**

- Electricity savings: **7,371,817 kWh/year**
- Cost savings: **11,057,725,224 VND/year**
- $CO_2$ emission reduction: **4,988 tons/year**
- TOE savings: **1,137 TOE/year**.

**5. Investment Cost and Financial Effectiveness**

- Investment cost: 20,000 million VND
- Simple payback period: 1.81 years
- IRR: 12.2%
- NPV after 5 years (12% discount rate): 19,860,624,740 VND.

**6. Feasibility Assessment**

– The solution is technically and economically feasible.

*2.2.15. Replacement of the Existing Ball Mills with Vertical Coal Mills*

**1. Current Condition**

– The current coal pulverizing system of the plant uses horizontal ball tube mills with two inlets and two outlets (Double Inlet Double Outlet – DIDO). Although this technology has been in stable operation for many years, it still presents limitations in grinding efficiency and high electricity consumption.

**2. Proposed Solution**

– Replace the horizontal ball mills with modern vertical coal mills, which offer higher grinding efficiency, optimized maintenance structure, and reduced electricity consumption and operating costs.

**3. Energy Consumption Before and After**

– Before replacement: ~36,742,944 kWh/year
– After replacement: ~24,528,000 kWh/year.

**4. Expected Savings**

– Electricity savings: 12,214,944 kWh/year
– Cost savings: 18,322,416,000 VND/year
– $CO_2$ emission reduction: 8,265 tons/year
– TOE savings: 1,885 TOE/year.

**5. Investment Cost and Financial Effectiveness**

– Investment cost: 125,000 million VND
– Simple payback period: 6.82 years.

**6. Feasibility Assessment**

– Further research and refinement are required to consider future investment.

## 2.3 Prioritization of Energy Efficiency Projects

The main solutions selected for further investment study after conducting the energy audit are presented in the Level A List (Tables 4.1 and 4.2). To achieve the goal of transforming the plant into an energy-efficient facility, the proposed solutions must go through several key stages.

The process begins with the energy audit report, which provides an overview of the plant's energy-saving potential. This is followed by the feasibility stage aimed at identifying and selecting the two to three most important solutions. The feasibility stage will then evaluate these options to determine the solution with the highest viability for investment. Once an investment decision is made, the process moves to the tendering or competitive quotation stage, followed by the evaluation of bids or procurement documents.

The installation and commissioning phase must be closely supervised by the plant to ensure that critical design decisions made during the feasibility and tendering stages are implemented correctly. After the solution is installed and put into operation, a comprehensive assessment is required to collect and record updated data on energy performance. This final step ensures that the solution not only operates as expected but also delivers the projected level of energy savings.

## 2.4 Feedback from the Enterprise

- *Proposal for conducting the Feasibility Study (FS):*

After discussions with representatives of the plant's departments and based on the recommendations of Mr. Peter Kristensen – Project Expert, the following proposals were identified for inclusion in the feasibility study stage:

- Retrofit common piping connection for the seawater circulation pump system of two units.
- Installation of variable frequency drives (INVERTERs) for the seawater circulation pump system.

- *Conclusion of the final meeting with the plant:*

Following the presentation and discussion, the plant agreed with the results of the energy audit and all proposed energy-saving solutions. The plant identified five solutions of particular interest and proposed that these be examined in more detail during the project's Feasibility Study (FS) phase. The plant expects the DE3 Project Management Unit to review, select, and approve these solutions to support the FS stage. In addition, the plant committed to cooperating and supporting the upcoming steps to ensure the successful implementation of the energy-saving solutions.

# 3 EE Projects identified

*Table 3.1. Gross list (level B)*

| No. | Name of Project | Energy form | Investment Cost (EUR) | Saving | | | Payback Period (years) |
|---|---|---|---|---|---|---|---|
| | | | | Energy (kWh) | $CO_2$ Reduction ($tCO_2$/year) | Cost Savings (EUR) | |
| **I. Energy Efficiency Solutions Requiring Low Investment Costs** | | | | | | | |
| 1 | Repair compressed air leakage points | Electricity | Recommened | | | | |
| 2 | Install compressed air piping from branch layout to ring layout | Electricity | Recommened | | | | |
| 3 | Replace old air dryer with high-efficiency air dryer | Electricity | Recommened | | | | |
| 4 | Install VSD for Air Compressor A (Maintenance Dept.) | Electricity | 6,588 | 37,189 | 25.16 | 1,837 | 3.59 |
| 5 | Retrofit, repair, and insulate heat-loss points (insulation at heat-loss points) | Coal | 3,294 | 581 | 237.11 | 6,282 | 0.52 |
| | Retrofit, repair, and insulate heat-loss points (steam valve insulation) | Coal | 6,588 | 217 | 88.33 | 2,340 | 2.82 |
| 6 | Replace low-efficiency IE1 fly-ash silo aeration fan motor with high-efficiency IE4 motor | Electricity | 42,163 | 218,762 | 148.01 | 10,809 | 3.9 |
| 7 | Recover waste heat from auxiliary steam to preheat make-up water | Coal | 131,760 | 6,886 | 2,809.56 | 74,438 | 1.77 |
| 8 | Recover waste heat from flash steam and blowdown | Coal | 32,940 | 1,169 | 476.68 | 12,629 | 2.61 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | water for other processes | | | | | | |
| **I. Energy Efficiency Solutions Requiring High Investment Costs** | | | | | | | |
| 9 | Install VSD for seawater booster pumps | Electricity | 65,880 | 852,938 | 379.67 | 42,144 | 1.56 |
| 10 | Install deep-sea water intake pipeline for cooling | Electricity | Khuyến nghị | | | | |
| 11 | Study blending coal with higher heating value and volatile matter than design coal | Coal | Khuyến nghị | | | | |
| 12 | Retrofit common piping connection for seawater circulating pump system of two units | Electricity | 65,880 | 3,744,000 | 2,533.19 | 184,991 | 0.36 |
| 13 | Install VSD for auxiliary fans in boiler area | Electricity | 1,317,600 | 12,638,683 | 9,126.39 | 624,477 | 2.11 |
| 14 | Install VSD for seawater circulating pump system | Electricity | 658,800 | 7,371,817 | 4,987.77 | 364,241 | 1.81 |
| 15 | Replace existing ball mills with vertical mills | Electricity | 4,117,500 | 12,214,944 | 8,264.63 | 603,540 | 6.82 |

# 4 Selected EE Projects for further supports

*Table 4.1. Selected project (level A mapping)*

| Project information | | |
|---|---|---|
| **Tên dự án: Lắp biến tần cho bơm hệ thống bơm tuần hoàn nước biển** | **Project no. 1** | **Date: Expected in 2025 - 2026** |
| **Enterprise: Power Generation Company** | **Name of EAC company: Vietnam Technology Solutions Joint Stock Company** | **Lead Auditor: Duong Chi Cong** |

**Project description**

**Current Status:**

At the plant, many heating processes occur simultaneously and are closely interconnected to ensure product quality throughout the entire production line. The Energy Mapping tool helps visualize heat sources, providing a clearer overview of the energy sources, systems, equipment, and processes that consume energy within the production chain. This enables energy managers to monitor and optimize energy use, thereby proposing improvements such as equipment upgrades, process optimization, operational enhancements, and the application of energy-efficient technologies.

During the energy audit, the consulting team combined system analysis using the Energy Mapping tool with professional expertise. This tool helps identify the areas with the highest energy consumption, allowing the plant to focus on priority improvement actions. It serves as an important tool that helps enterprises manage and use energy more efficiently, while promoting systematic implementation of energy-saving measures.

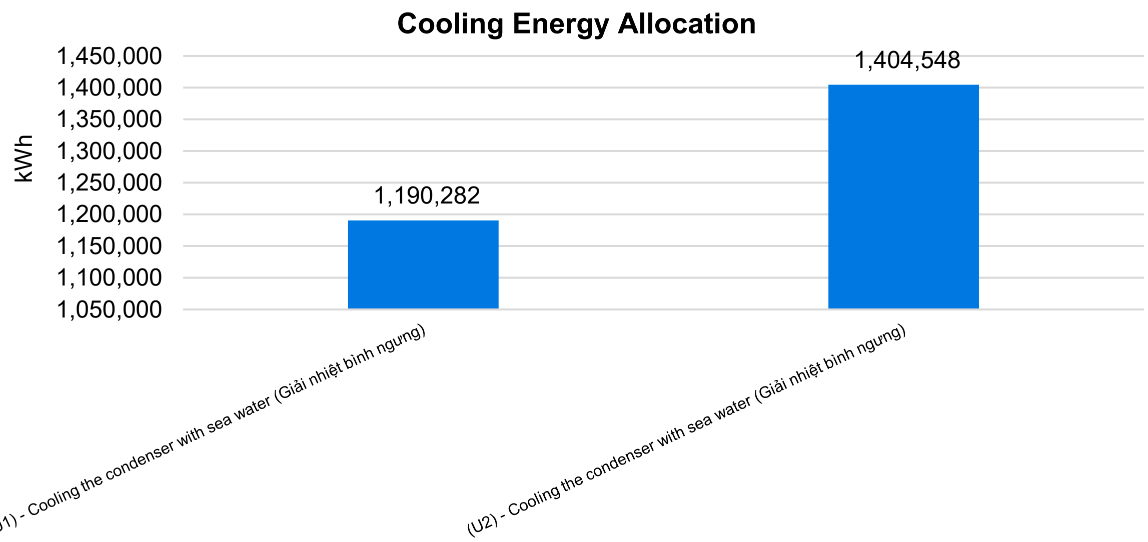



*Figure 4.1. Cooling Water Consumption Distribution Chart*

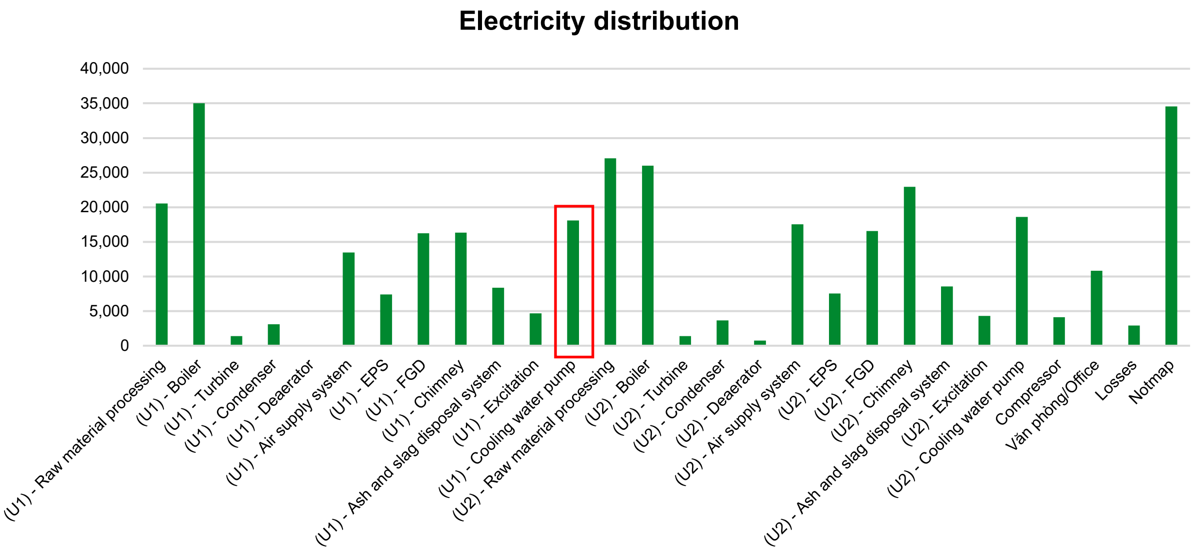
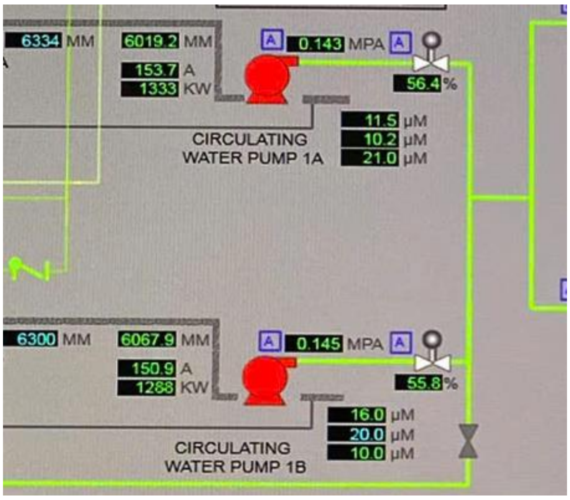



*Figure 4.2. Energy Consumption Distribution Chart by Process*

The company uses a seawater circulating pump system to cool the condenser, thereby maintaining a closed thermodynamic cycle and ensuring the power generation efficiency of the turbine. After completing the cooling process, the heated seawater is discharged into the environment through a cooling water discharge channel, designed to ensure that the discharge temperature always complies with applicable environmental standards. The seawater circulating pump system also accounts for a significant proportion of the plant's total electricity consumption, which is why the energy audit team focused on identifying potential energy-saving solutions for this system.



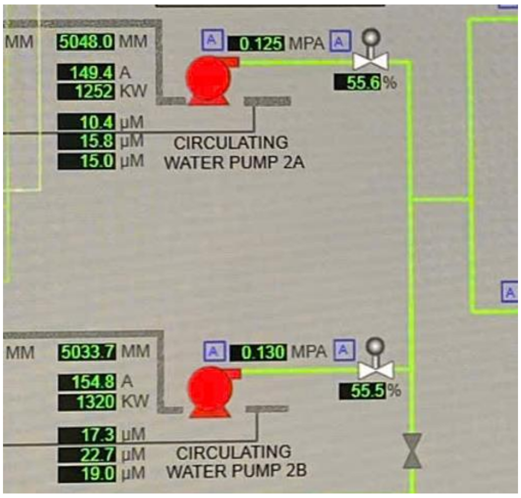




*Figure 4.3. Control Screen of the Seawater Circulating Pump System for Units U1 and U2*

The company's system includes four pumps with a capacity of 1,600 kW each, with two pumps supplying each unit. The valve opening angle is typically maintained at a low level of 55–56% (on average at minimum and maximum operating loads), which increases resistance in the pipeline. When flow is regulated by throttling the valve, the pump must still operate at a constant (or near-constant) speed with electrical power close to its maximum capacity. The energy is used to generate excessive head, which is then dissipated as heat and hydraulic losses at the valve. This is the main cause of energy waste.

**Proposed Solution**

The consulting team collected data on the electrical power consumption and seawater flow rate of the circulating pump system. The collected data are summarized in the table below:

*Table 4.2. Data Collection Results for the Seawater Circulating Pump System*

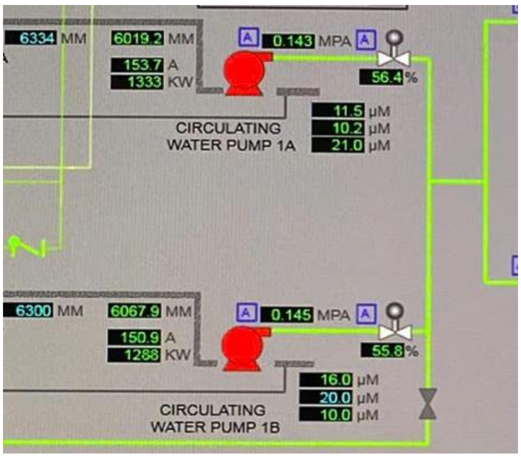
| No. | Equipment Name | Rated Power (kW) | Actual Power (kW) | Valve Opening (%) | Rated Flow (m³/h) | Actual Flow (m³/h) | Load Level (%) | Operating Hours (hours/year) |
|---|---|---|---|---|---|---|---|---|
| **Unit U1** | | | | | | | | |
| 1 | Circulating Pump 1A | 1,600 | 1,333 | 56.4 | 22,000 | 12,408 | 83.31 | 8,760 |
| 2 | Circulating Pump 1B | 1,600 | 1,288 | 55.8 | 22,000 | 12,276 | 80.50 | 8,760 |
| **Unit U2** | | | | | | | | |
| 1 | Circulating Pump 2A | 1,600 | 1,252 | 55.6 | 22,000 | 12,232 | 78.25 | 8,760 |
| 2 | Circulating Pump 2B | 1,600 | 1,320 | 55.5 | 22,000 | 12,210 | 82.50 | 8,760 |

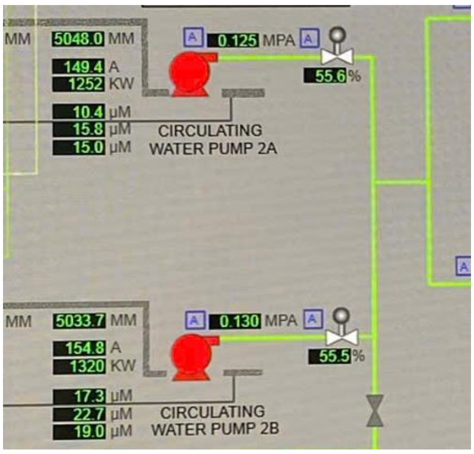
The actual power consumption of **1,252 kW to 1,333 kW** remains very high compared to the rated power of 1,600 kW, even though the actual flow rate of **12,210 m³/h to 12,408 m³/h** only reaches approximately **55.5%–56.4%** of the rated flow of 22,000 m³/h.

Through the energy audit, the plant now has a clearer understanding of the proposed solution and is currently preparing to submit the proposal to "**install variable frequency drives (INVERTERs) for the seawater circulating pumps**" to the **DEPP3 Project Management Unit** for support in implementing the Feasibility Study (FS).

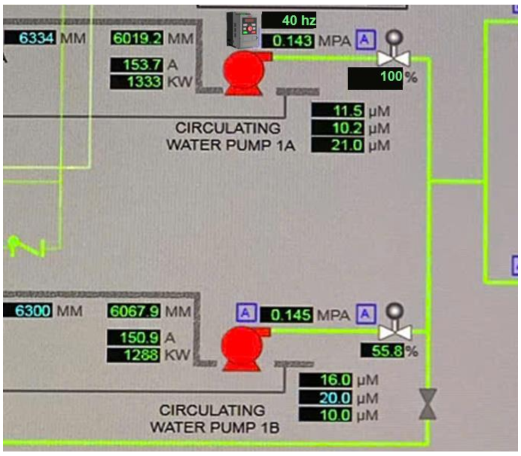
**Illustrative Process Flow Diagram (PFD)**

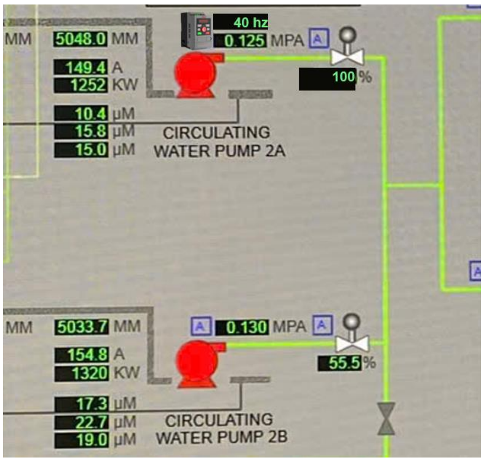
Before Improvement:



After Improvement:




**Project Budget**

- Capital Expenditure (CAPEX): Purchase of INVERTERs and accessories, installation costs
- Operating Expenditure (OPEX): Maintenance, operation, additional electricity consumption for INVERTERs
- Personnel training costs

**Estimated total investment cost:** Approximately **658,800 EUR**

**EXPECTED TIMELINE**

| No. | Tasks | 1st month | | | | 2nd month | | | | 3rd month | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | W 1 | W 2 | W 3 | W 4 | W 1 | W 2 | W 3 | W 4 | W 1 | W 2 | W 3 | W 4 |
| **1** | ***Kick-off meeting, measurement planning, and data collection*** | | | | | | | | | | | | |
| 1.1 | Kick-off meeting, preparation of the detailed survey plan | | | | | | | | | | | | |
| 1.2 | Conducting surveys and data collection | | | | | | | | | | | | |
| *1.2.1* | *Field survey and data collection at the project site (meteorological and hydrological data; topographical and geological data)* | | | | | | | | | | | | |
| *1.2.2* | *Survey, measurement, and collection of operating data of the existing circulating water pump system* | | | | | | | | | | | | |
| *1.2.3* | *Preliminary survey and data collection for circulating pumps:*<br>– *Measuring pump power (kW), water flow rate (m³/h), operating hours (hours/day)*<br>– *Recording electricity consumption (kWh/month)* | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1.2.4* | Collecting additional data and information to support performance evaluation and reporting | | | | | | | | | | | | |
| 1.3 | Discussion with the plant on the direction of the feasible solution (FS) | | | | | | | | | | | | |
| **2** | **Additional data collection to support the solution** | | | | | | | | | | | | |
| 2.1 | Experts and automation engineers assess the feasibility of implementing the solution | | | | | | | | | | | | |
| *2.1.1* | Experts and engineers determine the minimum required cooling water flow rate | | | | | | | | | | | | |
| *2.1.2* | Assessment of the compatibility of the INVERTER with the existing PLC/SCADA system. Evaluation of environmental conditions (dust, temperature) | | | | | | | | | | | | |
| *2.1.3* | – Pilot design on one pump: install the INVERTER, perform trial operation, measure results<br>– Assess impacts on the condenser and other systems | | | | | | | | | | | | |
| 2.2 | Development of technical options for the solution (in coordination with solution and INVERTER suppliers) | | | | | | | | | | | | |
| **3** | ***Preliminary calculation of the effectiveness of implementation options*** | | | | | | | | | | | | |
| 3.1 | Development of the technical solution | | | | | | | | | | | | |
| *3.1.1* | Develop the technical solution for implementation (in coordination with experts) | | | | | | | | | | | | |
| *3.1.2* | Estimation of investment costs (CAPEX – INVERTER, installation, training). Estimation of operating costs (OPEX – maintenance, operation) | | | | | | | | | | | | |
| *3.1.3* | Calculation of electricity savings and payback period | | | | | | | | | | | | |
| *3.1.4* | Identification of risks (underperformance of drying, | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | integration errors, equipment failure)<br>Proposal of mitigation measures (sensors, pilot testing) | | | | | | | | | | | | |
| 3.2 | Cost–benefit comparison of technical options | | | | | | | | | | | | |
| 3.3 | Presentation of preliminary calculation results to the plant, discussion, and agreement on a feasible option to be included in the FS report | | | | | | | | | | | | |
| **4** | ***Preparation of the Feasibility Study (FS) Report*** | | | | | | | | | | | | |
| 4.1 | Preparation of the Feasibility Study Report (based on Article 54 of the Construction Law No. 50/2014/QH13 dated 18/06/2014, Article 8 of Decree No. 15/2021/NĐ-CP dated 03/03/2021, and Law No. 62/2020/QH14) | | | | | | | | | | | | |
| 4.2 | Meeting to clarify the FS report with stakeholders | | | | | | | | | | | | |
| 4.3 | Finalization of the report based on comments from relevant stakeholders | | | | | | | | | | | | |

| **Energy-Saving Potential** | |
|---|---|
| Annual electricity savings: **7,371,817 kWh/year** | Annual cost savings: **364,241 EUR** |
| Annual $CO_2$ emission reduction: **4,987.77 tons** | Simple payback period: **1.81 years** |

**Risk Analysis**

- **Identification of Risk Factors**
- ***Hydraulic – Process Risks***
- Operating off the Best Efficiency Point (BEP) when reducing speed too much → recirculation, vibration, increased pump water temperature.
- Insufficient flow/head under extreme conditions (low water level, fouling in pipes/condenser, hot season) if the minimum speed setpoint is incorrect.
- Check valve instability at low flow → risk of backflow via by-pass.

- ***Mechanical Risks***
- Poor motor cooling at low speed (shaft-mounted cooling fan turning slowly) → overheating of windings/bearings.
- Seal leakage/failure due to altered operating conditions when running for long periods at low speed.
- Increased vibration due to new frequency spectrum; potential resonance with base/pipe structure.
- Accelerated corrosion in salty/marine environments if coating/paint material is not suitable.

- ***Electrical – Power Quality Risks***

- High current harmonics (THDi), especially when multiple large INVERTERs run in parallel.
- Electromagnetic interference (EMI/RFI) affecting PT/FT/HMI signals if grounding/cabling is improper.
- Fast voltage rise (dV/dt) at motor terminals (especially with long cables) → insulation degradation, shaft currents causing bearing pitting.
- Voltage dips/flicker → risk of large-scale INVERTER tripping if no ride-through solution is installed.
- Reactive power compensation equipment may overload due to harmonics (even when displacement power factor is close to 1).

- **Control – Interlocks – Integration Risks**
- Flow fluctuation due to unclear priority logic between INVERTER-driven and DOL-driven pumps.
- Controller parameters not properly tuned → overshoot, oscillation.
- Sensor malfunction causing improper INVERTER operation.
- ***Environmental – Installation – Operational Risks***
- INVERTER cabinet without proper IP rating/cooling in humid marine environment → condensation, corrosion of circuit boards.
- Limited cabinet space, poor heat dissipation; salt dust/moisture accumulation → surface tracking/faults.
- Installation errors: undersized cables, lack of shielded cables, poor grounding.
- Limited operator skills in INVERTER diagnostics → slow incident response.

- **Assessment of Risk Tolerance**
- Financial capacity: Assess whether the company can handle investment risks if expected savings are not achieved.
- Payback period: Evaluate whether the plant accepts the proposed payback duration.
- Access to concessional finance: Because the solution saves energy and reduces environmental impact, low-interest loans or support programs may be considered to reduce financial burdens.

| Risk Group | Likelihood | Impact | Risk Level | Remarks |
|---|---|---|---|---|
| Insufficient flow/head at peak conditions | Medium | High | High | Depends on minimum speed & setpoints |
| Off-BEP operation → vibration/noise/heat | Medium | Medium | Medium | Higher risk for extended low-speed operation |
| Poor motor cooling at low speed | Medium | Medium–High | Medium–High | Especially for shaft-mounted fans |
| Harmonics & voltage distortion | Medium–High | Medium | Medium–High | When several large INVERTERs run in parallel |
| Fast voltage rise → insulation/bearing damage | Medium | Medium | Medium | Long cable run, older motors |
| Control fluctuation among pumps | Medium | Medium | Medium | |
| Voltage dip tripping | Low–Medium | Medium–High | Medium | Stable supply needed |
| Corrosion/moisture in INVERTER cabinet | Medium | Medium | Medium | If no proper enclosure/cooling |
| Installation/grounding errors | Thấp–Trung | Medium | Medium | Strong QC significantly reduces risk |

- **Risk Mitigation Plan**
- ***Hydraulic – Process Mitigation***

- Establish system curve (including fouling margins) and pump curve to define safe minimum speed for year-round flow/head.
- Define pump operating zone (e.g., 70–120% of BEP flow) and avoid long-term operation outside the recommended band.
- Check NPSH margin at low water levels; set level/pressure thresholds to limit speed reduction.
- If a minimum condenser flow is required, install a recirculation or minimum-flow bypass line.

- ***Mechanical – Motor – Material Mitigation***

- Ensure motor suitability for INVERTER operation: enhanced insulation, temperature sensors; if using existing motors → check insulation condition, surge withstand; install forced cooling for low-speed operation.
- Bearing protection: insulated bearing at one end + shaft grounding ring to eliminate shaft currents.
- Alignment verification, base/frame inspection; if vibration occurs at specific frequencies → establish speed avoidance zones.
- Apply anti-corrosion coating for motors, couplings, fasteners in saline environments.

- ***Electrical – Power Quality Mitigation***

- Harmonic reduction: install line/load reactors or active filters; for strict requirements, use active front-end INVERTERs or multi-pulse rectifiers.
- Reduce dV/dt: install dV/dt filters or sine-wave filters depending on cable length; use shielded cables; separate motor power cables from signal cables.
- Proper grounding & EMI management: grounding clamps at both cable ends, EMI filters for nearby control cabinets.
- Supply reliability: ensure UPS for control circuits; enable ride-through functions; provide bypass path for DOL operation if INVERTER fails (if process permits).
- INVERTER cabinet: select suitable IP rating, apply conformal coating, install cabinet AC/cooling, monitor cabinet humidity/temperature.

- ***Control – Interlocks Mitigation***

- Structured main–auxiliary pump logic; clear load-sharing sequence; anti-hunting times for adding/removing pumps.
- Proper PID tuning with anti-windup, signal filtering, and ramp limits.
- Critical interlocks: prevent speed reduction during low water level, high condenser backpressure, rapid temperature rise; ensure safe transition during shutdown.
- Define standard procedure for switching 3↔4 pumps (roles, criteria, authorizations).

- ***Installation – Commissioning – Training Mitigation***

- Use correct cable specifications/cable trays/termination; conduct insulation resistance testing, direction-of-rotation checks, FAT/SAT for INVERTER–motor integration.
- Plan installation windows and bypass provisions to avoid production disruption.
- Operator training on INVERTER alarms/diagnostics; maintenance training for filters and cabinet cooling in humid saline environments.
- Spare parts strategy: cabinet cooling fans, power modules, control boards, shaft grounding rings, temperature sensors.

**Non-Energy Benefits**

- ***Process Stability and Improved Output Quality***
  - More stable condenser outlet water temperature, reduced turbine backpressure fluctuation → more stable unit operation, less risk of sudden load reduction.
  - Smooth transition between operating modes (controlled acceleration/deceleration).

- ***Increased Reliability and Reduced Mechanical Failures***
  - Soft start/soft stop reduces mechanical shock on the impeller, shaft, bearings, and couplings → fewer cracks/looseness and extended mean time between failures.

– Reduced operation outside the optimal efficiency range (less recirculation, less vibration) when an appropriate speed range is set → longer service life of pumps, seals, and bearings.
– Reduced check-valve impact due to smoother flow → less wear on valve discs and seats.

- ***Operational and Maintenance Flexibility***

– Intelligent load distribution between pumps: automatic priority of main pumps and automatic addition/removal of pumps as needed → scenario-based operation, reduced manual intervention.
– Expanded maintenance window: speed control and smooth pump switching allow maintenance while keeping the system operating stably.
– Reduced system recovery time after a fault thanks to pre-configured controller logic.

- ***Environmental Benefits***

– Reduction of greenhouse gas emissions: contributes to Vietnam's Net Zero 2050 target.
– Supports cleaner production: energy optimization aligns with green manufacturing standards, helping the plant achieve ISO 14001 certification or meet international customer requirements.

- ***Power Quality and Auxiliary Equipment Benefits***

– Reduced inrush current → less impact on other equipment on the same busbar, improved internal voltage stability.
– Enhanced protection via soft-trip mechanisms and early fault diagnostics (motor temperature, phase loss, overcurrent, etc.).

*Table 4.3: Selected Project No. 2*

| **Project's information** | | |
|---|---|---|
| **Project: Retrofitting the common pipeline for the seawater circulation pump system for 2 units** | **Project No.2** | **Implemention period: Scheduled 2025 - 2026** |
| **Enterprises:**<br>**Power Generation Company** | **Energy Auditing Organization (EAC): Vietnam Technology Solution Joint Stock Company (VETS)** | **Energy Audit Team Leader: Duong Chi Cong** |

| **Project's description** |
|---|
| **Current status:**<br>At the factory, multiple heating processes occur simultaneously and are closely interconnected to ensure product quality throughout the entire production line. The Energy Mapping tool helps visualize heat sources, providing a clearer overview of energy sources, systems, equipment, and energy-consuming processes within the production line. This enables energy managers to monitor and optimize energy usage, thereby proposing improvements such as equipment upgrades, process optimization, operational enhancements, and the implementation of energy-saving technologies.<br>During the energy audit, the consulting team combined system analysis using the Energy Mapping tool with professional expertise. This tool helps identify the areas of highest energy consumption, allowing the plant to focus improvement efforts effectively. It serves as a vital tool for enterprises to manage and use energy more efficiently, while systematically promoting energy-saving activities. |

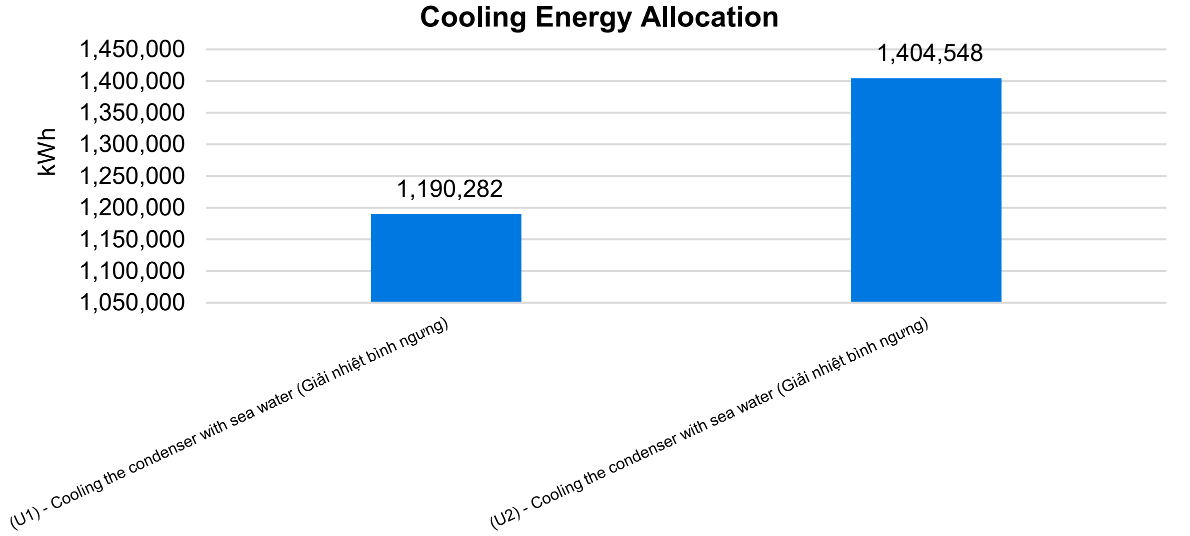



Figure 4.4. Water-based cooling consumption distribution chart

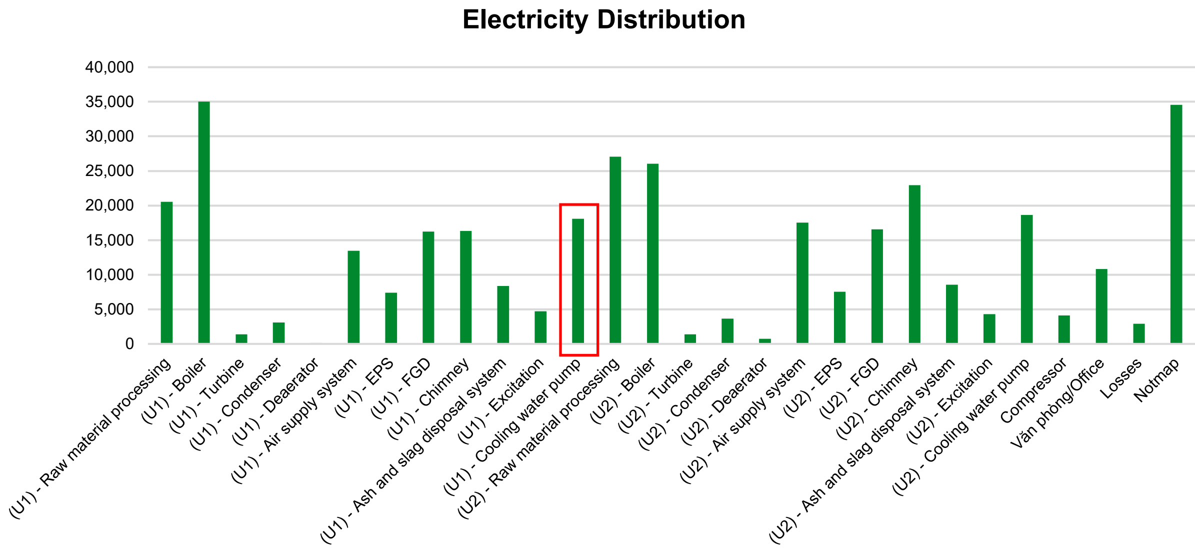



Figure 4.5. Energy consumption distribution chart by production stage

*Table 4.4. Evaluation and comments on lpg vaporization unit measurement results*

| No. | Equipment Name | Rated Power (kW) | Actual Power (kW) | Valve Opening (%) | Rated Flow (m³/h) | Actual Flow (m³/h) | Load Factor (%) | Operating Hours (hours/year) |
|---|---|---|---|---|---|---|---|---|
| **Unit U1** | | | | | | | | |
| 1 | Circulation Pump 1A | 1,600 | 1,333 | 56.4 | 22,000 | 12,408 | 83.31 | 8,760 |
| 2 | Circulation Pump 1b | 1,600 | 1,288 | 55.8 | 22,000 | 12,276 | 80.50 | 8,760 |
| **Unit U2** | | | | | | | | |
| 1 | Circulation Pump 2A | 1,600 | 1,252 | 55.6 | 22,000 | 12,232 | 78.25 | 8,760 |
| 2 | Circulation Pump 2B | 1,600 | 1,320 | 55.5 | 22,000 | 12,210 | 82.50 | 8,760 |

*Table 4.5. Calculation of Seawater Circulation Flow Rate in the Factory*

| No. | Indicator | Unit | U1 | U2 |
|---|---|---|---|---|
| 1 | Rated Flow Rate | m³/h | 22,000 | 22,000 |
| 2 | Average Valve Opening | % | 56.40 | 55.60 |
| 3 | Total Power | kW | 2,621 | 2,581 |
| 4 | Actual Flow Rate of 2 Circulation Pumps | m³/h | 24,816 | 24,464 |
| 5 | Actual Flow Rate of 2 Circulation Pumps | m³/s | 6.89 | 6.80 |
| 6 | Average Inlet Water Temperature | °C | 30.52 | 25.52 |
| 7 | Average Outlet Water Temperature | °C | 36.37 | 32.22 |
| 8 | Seawater Density | kg/m³ | 1.025 | |
| 9 | Specific Heat Capacity of Seawater | kJ/kg·K | 3,99 | |
| 10 | Seawater Mass Flow Rate | kg/s | 7,065.67 | 6,965.44 |
| 11 | Heat Transfer | MW | 165.047 | 186.347 |
| 12 | Seawater Temperature in 4 Winter Months | °C | 25.63 | |
| 13 | Seawater Temperature in 8 Summer Months | °C | 29 | |
| 14 | Cooled Water Temperature | °C | 36 | |
| 15 | Summer Seawater Mass Flow Rate | kg/s | 12,571.80 | |
| 16 | Winter Seawater Mass Flow Rate | kg/s | 8,486.27 | |
| 17 | Summer Seawater Volumetric Flow Rate | m³/h | 44,154.63 | |
| 18 | Winter Seawater Volumetric Flow Rate | m³/h | 29,805.44 | |

**Proposed Project:**

Study the solution of interconnecting the pipelines between the two seawater circulation pump systems. This solution will allow the system to reduce the number of operating pumps during periods of lower cooling demand, while ensuring mutual backup in case a pump fails.

Three potential implementation options are considered:

- Option 1: Install two connecting pipelines between the seawater lines of Unit 1 and Unit 2. One pipeline is for supplying water from the Unit 1 system to Unit 2, and the other is for supplying water from the Unit 2 system to Unit 1.
- Option 2: Install a connecting pipeline between the seawater circulation pump systems of Unit 1 and Unit 2 via the flanges of adjacent manholes on the two pipelines (these manholes are used for worker entry to inspect the pipe interior during maintenance and repair).
- Option 3: Install a common seawater header for the two systems where the two pipelines run parallel.

Implementation Plan for Option 1:

- Install two connecting pipelines as illustrated in the figure below. These two pipelines are installed to form Y-shaped connection points to minimize pressure loss.
- At the connection points between the two pipelines, install flow control valves to regulate and balance the water supply pressure and flow rate.
- When the system reduces capacity by 1 pump, only 3 pumps need to operate: 3 main pumps supply the common flow rate for the entire plant, with 1 pump on standby.

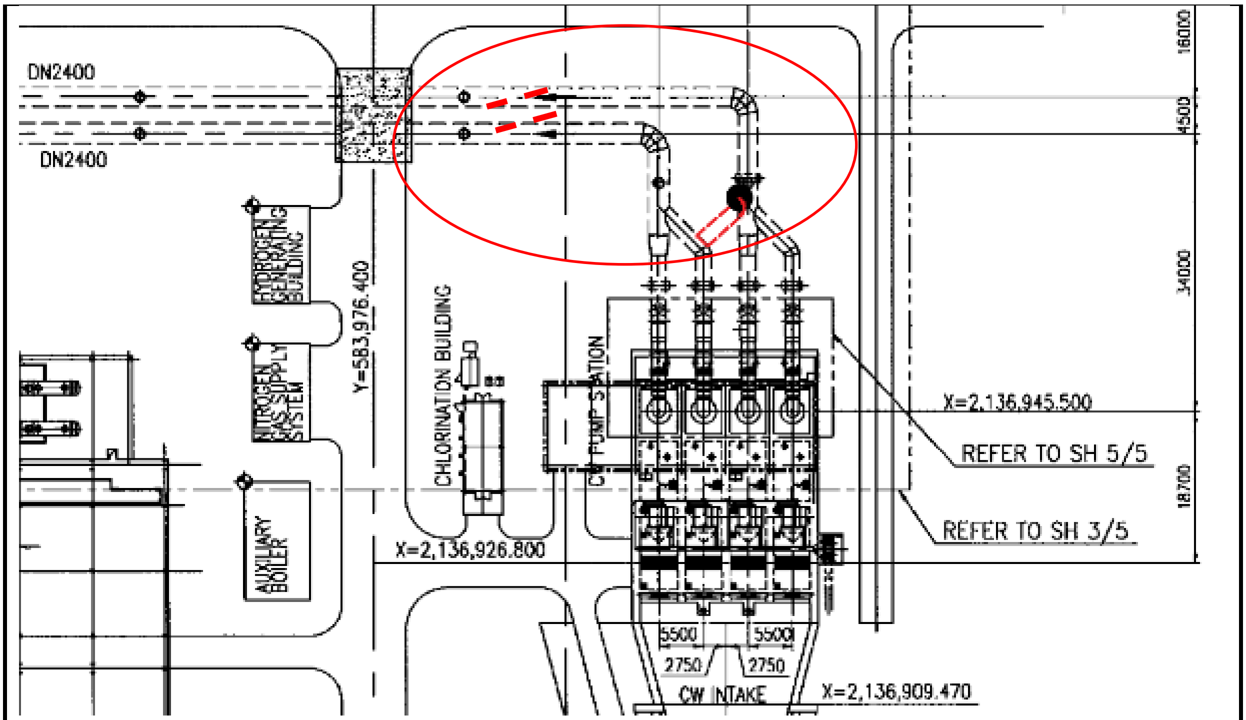



*Figure 4.6. Location of connecting pipelines for the seawater circulation pump system*

This option has the advantage of low pressure loss in the connecting pipelines and relatively easy construction. However, a disadvantage is that construction requires excavation, and the construction schedule could potentially impact the normal operation of the power generation units.

Implementation Plan for Option 2:

The seawater circulation system for each unit has 8 manholes. These access points are arranged along the entire length of the main pipeline. Most manholes on the two pipelines are positioned adjacent to each other, facilitating the installation of connecting pipelines via these manholes.

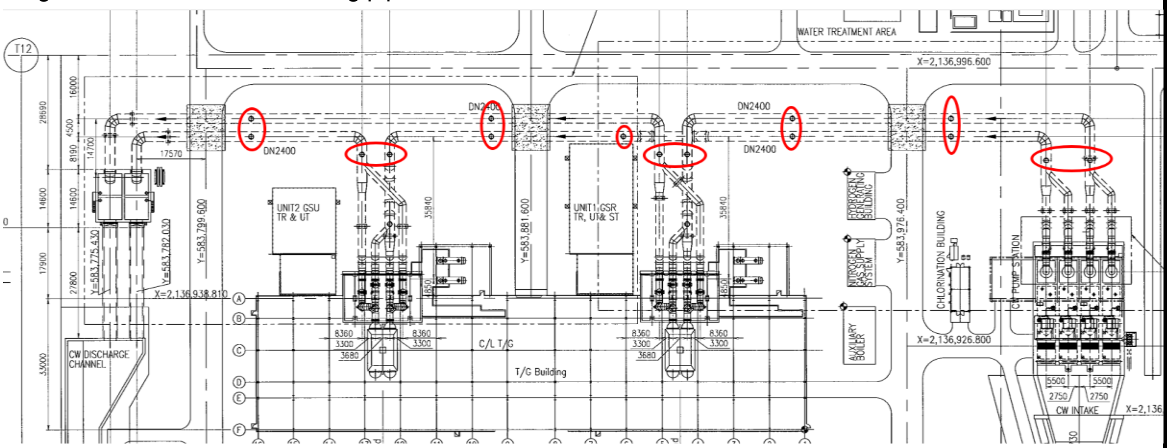



*Figure 4.7. Location of Manholes on the Seawater Pipeline*

*Figure 4.8. Actual Images of the Manholes*

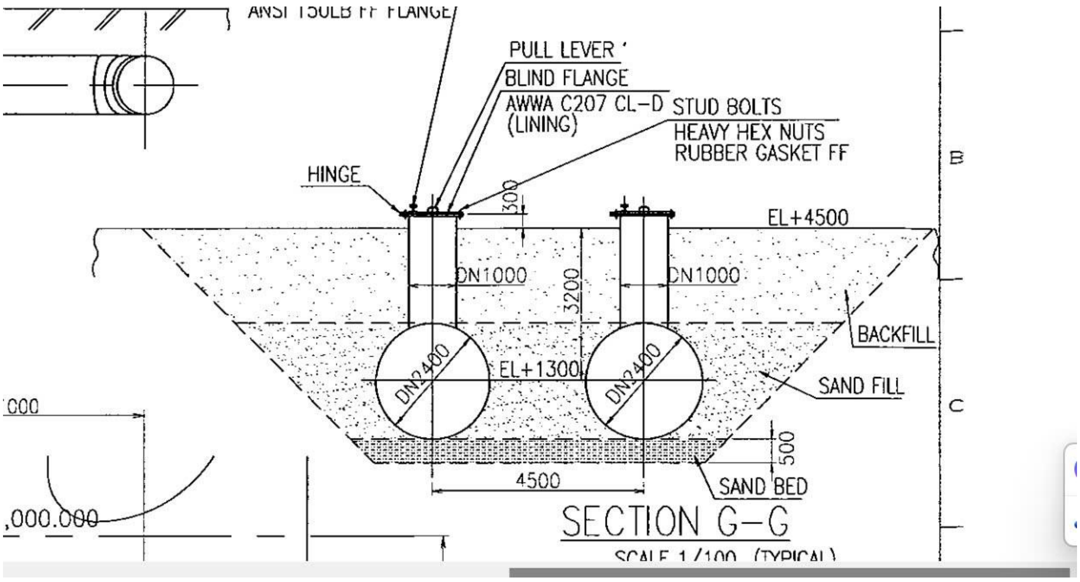



*Figure 4.9. Cross-Sectional Drawing of the Manholes*

However, at least two connecting pipes need to be installed at different manhole locations because the cross-sectional area of a manhole is significantly smaller than that of the main pipe (the manhole diameter is 1,000 mm, while the main pipe diameter is 2,400 mm).

The specific implementation plan is presented as follows:

Install two connecting pipes as illustrated in the figure below.

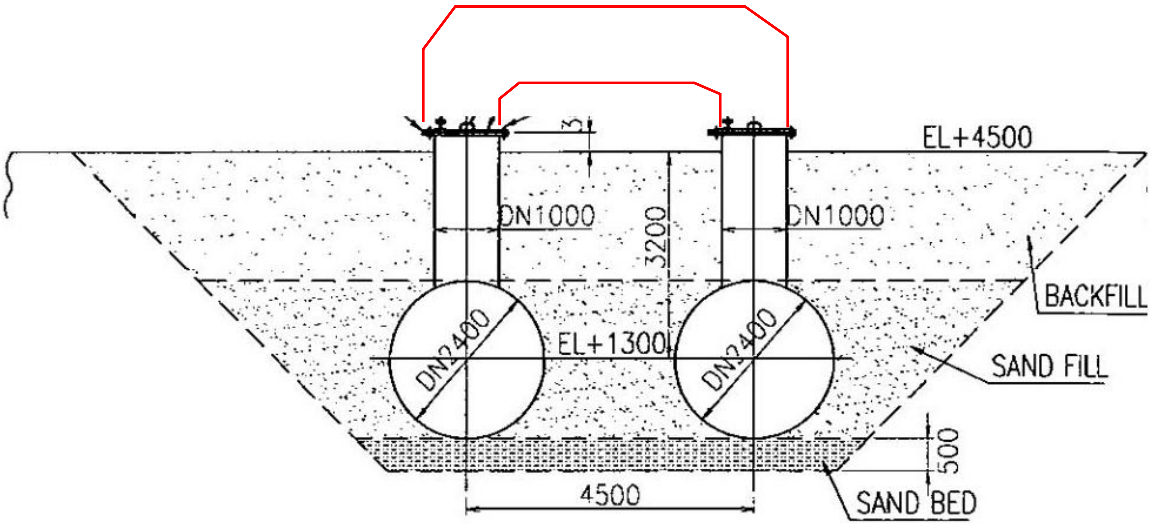



*Figure 4.10. Pipe connection installation plan*

- Install a control valve in the middle of each connecting pipe to allow active opening/closing as needed.
- When the system reduces capacity by one pump, only 3 pumps need to operate: 3 main pumps supply the common flow rate for the entire plant, with 1 pump on standby.
- The proposed locations for installing the connecting pipes are shown in the figure below.

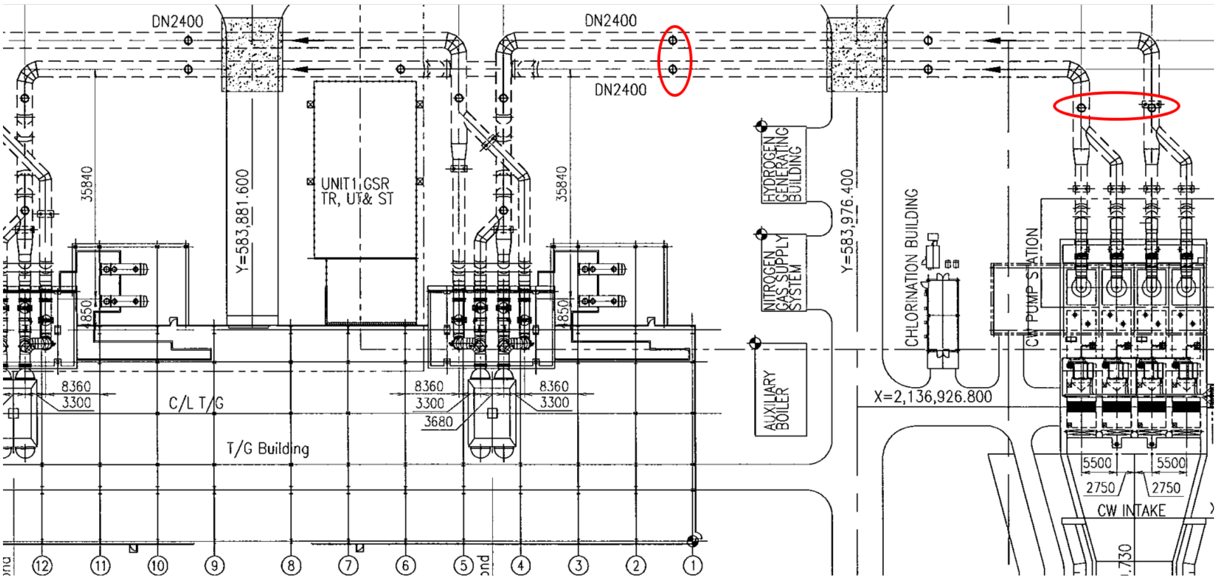



*Figure 4.11. Proposed Location for Pipeline Installation (1)*

This option has the advantage of not requiring excavation during installation, allowing for faster construction and causing minimal disruption to the plant's operations. However, the disadvantage of Option 2 is that pressure losses will occur in the connecting pipeline due to the pipe being installed perpendicular to the main flow direction.

**Implementation plan for Option 3:**

This option requires installing a common manifold for the two seawater circulation pump systems. The location and installation method are illustrated in the figure below.

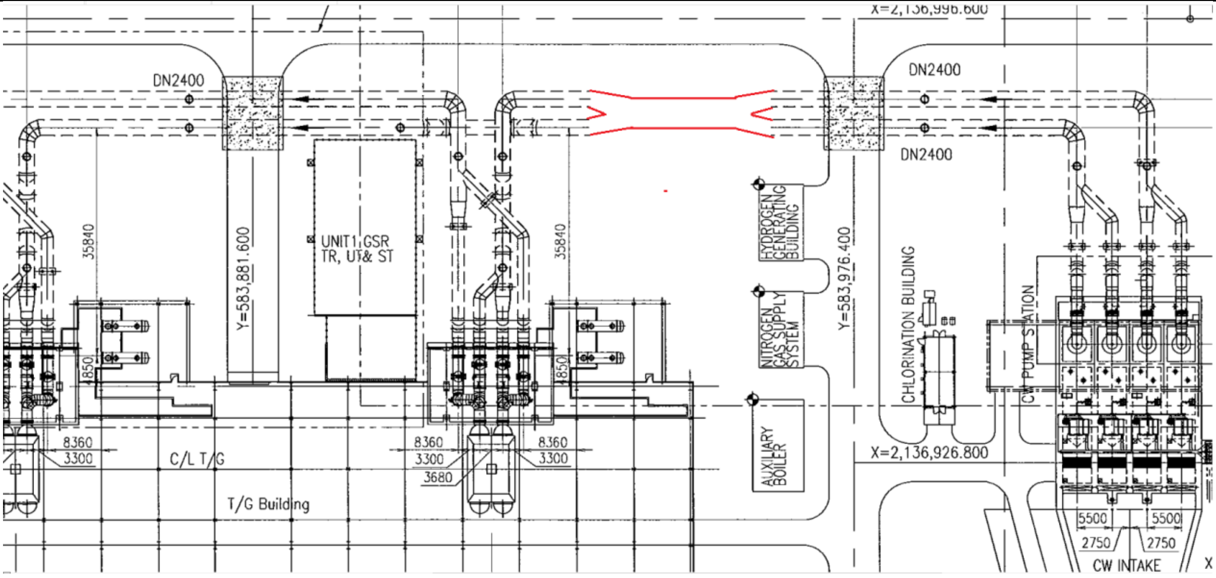



*Figure 4.12. Proposed Pipe Installation Location (2)*

This option has the advantage of achieving the lowest pressure loss within the pipeline system and delivering the highest energy-saving efficiency. However, it also requires the largest investment, has the longest construction timeline among the three options, and could significantly impact the operation of the power generation units during the construction phase.

The table below compares the advantages and disadvantages of the three options:

*Table A.4. Comparison of Advantages and Disadvantages of the Three Seawater Pipeline Retrofit Options*

| Criteria | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| **Advantages** | - Low pressure loss in connecting pipes<br>- Easy construction | - No excavation required for installation<br>- Simple installation<br>- Low cost<br>- Minimal or no impact on unit operation | - Lowest pressure loss in the pipeline system<br>- Highest energy saving efficiency |
| **Disadvantages** | - Requires excavation during construction<br>- Impacts operation of power generation units | - Significant pressure loss in connecting pipes<br>- Lowest energy saving efficiency among the three options | - Highest investment cost<br>- Longest implementation time<br>- More complex than the other two options<br>- Requires large construction space |

Through the evaluation of the implementation plans for the three options, it is evident that each option has its own distinct advantages and disadvantages. However, all three options have the potential to deliver significant energy savings for the plant and offer a high return on investment. The plant needs to carefully consider all factors before deciding on the implementation option to proceed with.

## Project Budget

- **Capital Expenditure (CAPEX):** Design, valves, control equipment, mechanical accessories (couplings, supports, etc.), construction, and installation costs.
- **Operational Expenditure (OPEX):** Maintenance, operation, and electricity consumption costs of the seawater circulation pumps.
- **Training Costs:** Costs for training operational staff.

**Total Estimated Investment Cost: Approximately 65,880 EUR.**

## EXPECTED TIMELINE

| No. | Task | 1st month | 2nd month | 3rd month |
|---|---|---|---|---|

| | | W 1 | W 2 | W 3 | W 4 | W 1 | W 2 | W 3 | W 4 | W 1 | W 2 | W 3 | W 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | ***Kick-off Meeting, Measurement Planning, and Data Collection*** | | | | | | | | | | | | |
| 1.1 | Kick-off meeting, preparing detailed survey plan content | | | | | | | | | | | | |
| 1.2 | Conduct survey and data collection | | | | | | | | | | | | |
| *1.2.1* | *Survey and collect data at the project site (hydrometeorological data; topography - geology, seasonal operation logs)* | | | | | | | | | | | | |
| *1.2.2* | *Survey, measure, and collect operational data of existing seawater circulation pump equipment and assess the feasibility of implementing the solution for each option* | | | | | | | | | | | | |
| *1.2.3* | *Collect other data and information for the effectiveness evaluation and reporting process (Inventory of existing valves & accessories, Sensors & measurement points, corrosion assessment, support structures & foundations)* | | | | | | | | | | | | |
| 1.3 | Discuss with the plant regarding solution directions during the feasibility stage | | | | | | | | | | | | |
| **2** | ***Collect Additional Data for the Solution*** | | | | | | | | | | | | |
| 2.1 | Survey and work with suppliers on the solution for retrofitting the common pipeline of the seawater circulation pump system for 2 units | | | | | | | | | | | | |
| *2.1.1* | *Survey, identify, and work with suppliers providing the solution for retrofitting the common pipeline of the seawater circulation pump system for 2 units* | | | | | | | | | | | | |
| *2.1.2* | *Survey, identify, and work with equipment and component suppliers* | | | | | | | | | | | | |
| *2.1.3* | *Survey, identify, and work with construction contractors* | | | | | | | | | | | | |
| 2.2 | Develop technical options for the solution (in coordination with solution suppliers) | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **3** | ***Preliminary Assessment of Implementation Option Effectiveness*** | | | | | | | | | | | | |
| 3.1 | Develop technical solutions | | | | | | | | | | | | |
| *3.1.1* | *Develop the technical solution for implementation (in coordination with experts)* | | | | | | | | | | | | |
| *3.1.2* | *Calculate basic technical parameters of the pump system* | | | | | | | | | | | | |
| *3.1.3* | *Develop the basic technical solution for the pump system when reducing the number of operating pumps* | | | | | | | | | | | | |
| 3.2 | Compare the effectiveness, benefits, and costs of the technical options | | | | | | | | | | | | |
| 3.3 | Present preliminary calculation results to the Company for discussion and agreement on the most feasible option to include in the feasibility study report | | | | | | | | | | | | |
| **4** | ***Prepare Feasibility Study Report*** | | | | | | | | | | | | |
| 4.1 | Prepare the Feasibility Study Report (Based on Article 54 of the Construction Law No. 50/2014/QH13 dated June 18, 2014, Article 8 of Decree No. 15/2021/ND-CP dated March 03, 2021, and Law No. 62/2020/QH14) | | | | | | | | | | | | |
| 4.2 | Hold meetings to clarify the content of the feasibility report with relevant stakeholders | | | | | | | | | | | | |
| 4.3 | Finalize the report based on feedback from relevant stakeholders | | | | | | | | | | | | |

| Savings Potential | |
|---|---|
| **Financial (Annual):** 184,991 EUR | **Annual Savings:** 184,991 EUR |
| **Simple Payback Period:** 0.36 years | **Simple Payback Period:** 0.36 years (approximately 4.3 months) |

**Risk Analysis**

**a) Risk Identification**

- **Hydraulics & Performance**
  - Increased Δp (pressure drop) in the connecting line causing insufficient CW flow → higher condenser outlet water temperature, increased turbine backpressure.
  - Flow imbalance between the two systems when the interconnecting valve is open (flow reversal, local pressure differentials).
  - Water hammer during rapid valve opening/closing or pump mode changes (3 pumps ↔ 4 pumps).
  - Air ingress at pipeline high points, causing cavitation and reduced pump efficiency.

- **Option 2 (Manhole):** Restricted cross-section → "bottleneck" risk; requires multiple parallel branches.
- **Option 3 (Large Header):** Risk of pressure oscillation resonance if supports are poorly designed.

- **Structure & Construction**
  - Misalignment of pipes/elevations, insufficient space for large valves/actuators.
  - Clash with underground utilities, requiring temporary cuts/rerouting; risk of local flooding during tie-ins.
  - Poor weld/flange joint quality → seawater leakage (accelerated corrosion).
  - **Option 1:** Risk of excavation while the plant is operational.
  - **Option 3:** Large civil works volume → schedule risk.
- **Corrosion & Fouling**
  - Galvanic/electrochemical corrosion at material junctions (steel–FRP–HDPE–duplex).
  - Biofouling, sand/silt causing abrasion; damage to epoxy/FRP lining during construction.
- **Control & Instrumentation**
  - FT/PT (Flow/Pressure Transmitter) errors → incorrect flow balancing control.
  - Inadequate interlocks: interconnection opened under unpermitted conditions (low level, standby pump not ready...).
  - Incorrect valve fail-mode selection (fail-open causes cross-flow; fail-close causes sudden blockage).
- **Operation & Maintenance**
  - Mud/debris entering the connection line → clogging, increased Δp.
  - Difficult access for valve/sensor maintenance (especially manhole locations).
  - Inadequate SOPs → incorrect procedures when switching between 3↔4 pump modes.
- **Safety – HSE**
  - Confined space in manholes; risk of asphyxiation, toxic gases, flooding.
  - Inadequate LOTO (Lockout-Tagout) during tie-ins; risk of high-pressure water flooding.
  - Lifting/rigging of large valves.
- **Environmental & Regulatory**
  - Discharge regime changes potentially affecting temperature/turbidity at outfall; may require legal document updates.
  - Noise/construction impact on surrounding areas.

**b) Risk Appetite Assessment**

- **Financial Capacity:** Assess whether the enterprise has sufficient financial resources to withstand risks if expected benefits are not fully realized.
- **Payback Period:** Assess whether the enterprise finds the investment's payback period acceptable.
- **Seeking Preferential Financing:** As the solution saves energy and reduces environmental impact, explore access to low-interest loans or support programs to lessen the financial burden.

| Risk Category | Likelihood | Impact | Risk Level | Notes by Option |
|---|---|---|---|---|
| Increased Δp / Insufficient Flow | Med–High | High | High | Highest for Option 2; Lowest for Option 3 |
| Flow Imbalance | Med | Med–High | Med–High | Depends on measurement/control quality |
| Water Hammer | Low–Med | High | Med | Increases with fast valve operation |
| Installation/Tie-in Errors | Med | Med | Med | Higher for Option 3 due to larger scope |
| Risk Category | Likelihood | Impact | Risk Level | Notes by Option |
| Increased Δp / Insufficient Flow | Med–High | High | High | Highest for Option 2; Lowest for Option 3 |

| | | | | |
|---|---|---|---|---|
| Flow Imbalance | Med | Med–High | Med–High | Depends on measurement/control quality |
| Water Hammer | Low–Med | High | Med | Increases with fast valve operation |
| Installation/Tie-in Errors | Med | Med | Med | Higher for Option 3 due to larger scope |

**c) Risk Mitigation Plan**

- **Engineering & Design**
    - Detailed hydraulic analysis (AFT Fathom/CFD) for all options; check Δp, velocity, NPSH; optimize diameter & number of parallel branches (Option 2 needs ≥2–3 branches to reduce Δp).
    - Place control valves mid-line, select equal-percentage characteristic, include positioner & limit switch; default to fail-close to prevent unwanted flow.
    - Limit valve stroking speed (≥20–60 s) + use pressure balancing bypass to eliminate water hammer.
    - Materials & Corrosion Protection:
        - Economic Option: HDPE/FRP for connecting lines, FRP-lined flanges.
        - Durable Option: Duplex 2205/2507 for critical areas.
        - Thick epoxy coating + sacrificial anodes if using carbon steel.
        - Gaskets: EPDM/Viton suitable for seawater; insulating bolt sleeves to prevent galvanic corrosion.
    - Install strainers on connection branches; use long-radius elbows (R/D ≥ 3) to reduce local losses.
    - Design supports/foundations for vibration/thermal expansion; include expansion joints near large valves.
    - **Option 3:** Use modular design (pre-fabricated spools), maximize pre-fab to shorten tie-in duration.
- **Control & Instrumentation**
    - Flow balancing control loop: Use 2×FT (each side) + 2×PT (upstream/downstream) → control valve based on Δp & flow setpoint between systems.
    - Interlocks/Permissives: Only allow interconnection opening when ≥3 pumps running/stable pressure/sufficient level; auto-close on high Δp, low level, FT/PT failure.
    - Redundancy: UPS for control panel; manual gear override for valves.
    - Alarms & Limits: For Δp, Q, valve position, seawater level, pump vibration.
- **Construction & Operation**
    - Detailed Method Statement & JSA: Temporary bypass plan, outage windows; FAT/SAT, hydrotest to design pressure; NDT (UT/RT/MT) on welds.
    - Full LOTO; flood prevention measures at tie-in points; standby local dewatering pumps.
    - **Confined Space (Option 2):** Permit, gas monitoring, standby rescue; standard ladders/hoists.
    - Route cables/pipes to avoid clashes; proper rigging procedures for large valves.
    - SOP Training: Procedures for switching 4→3 pumps and vice versa; pre-connection checklists.

**d) Monitoring & Evaluation**

- **Technical:**
    - Δp across connection; Flow (Q) per system; Valve position; Operating hours (3 pumps + 1 standby).
    - Condenser outlet water temperature, turbine backpressure; COP/heat exchange efficiency.
    - Pump vibration & current; water hammer events (peak pressure).
- **Reliability & Maintenance:**
    - Valve/sensor failure rate; interconnection valve availability.
    - Corrosion/Biofouling: Coupon/ER probe, periodic coating inspection.
    - Financial Performance: kWh saved, net annual savings (VND/year); comparison with baseline.
- **Alert & Action Thresholds:**

- Δp exceeds design by X% → move valve to safe position, check for blockage.
- Flow deviation between systems >Y% for Z minutes → activate balancing loop/reduce opening.
- Backpressure increase >threshold → prioritize restoring 4 pumps/closing interconnection.

- **Review Cycle:**
  - Post-commissioning (30–90 days): Performance evaluation & PID/Setpoint fine-tuning.
  - Quarterly: MOC meeting, review event/alarm logs, update SOPs.
  - Annually: Local borescope/ultrasonic inspection, repainting/relining; FT/PT calibration; review energy savings benefits.

**Non-Energy Benefits**

+ **Reliability & Availability**
  - True N-1 redundancy → if one pipeline, pump, or valve fails, the other line can still supply cooling water, reducing unplanned downtime.
  - Maintain load during local incidents (debris blockage, low water level) by sharing flow between the two systems.
  - Stabilizes condenser operating conditions across day/night and seasons, facilitating easier power dispatch.
  - **Key Performance Indicators (KPIs):** Unit Availability Rate; Forced Outage Rate; Downtime hours due to cooling water system issues.
+ **Operational & Maintenance Flexibility**
  - **Maintenance:** Ability to isolate one branch, pump, or pipe section for maintenance while the unit remains operational using the other line.
  - Active load sharing between systems: prioritize flow to the unit under heavy load (e.g., during peak hot season) without starting an additional pump.
  - Reduces emergency operations around water intakes/trash racks.
  - **KPIs:** Maintenance hours performed while the unit is online; Number of emergency mode switches; Time to restore operation after a fault.
+ **Equipment Lifespan & Operational Quality**
  - Reduces frequent pump starts/stops and hydraulic pressure fluctuations for pumps, valves, bearings, and pipelines.
  - Minimizes vibration caused by flow imbalances.
  - Reduces thermal shock in the condenser due to stable flow → protects heat exchanger tubes, flanges, and gaskets.
  - **KPIs:** Mean Time Between Failures (MTBF) for pumps/valves; Number of major overhauls per year; Number of vibration alarm threshold exceedances.
+ **Environmental Benefits**
  - **Reduction of Greenhouse Gas Emissions:** Contributes to Vietnam's Net Zero target by 2050.
  - **Supports Cleaner Production:** Energy optimization aligns with green production standards, assisting the plant in achieving ISO 14001 certification or meeting requirements from international customers.
+ **Regulatory Compliance & Enhanced Corporate Image**
  - **Regulatory Compliance:** Helps the plant fulfill its energy-saving obligations under the Law on Economical and Efficient Use of Energy (2010), especially as a significant energy-consuming facility.
  - **Enhanced Corporate Image:** Adopting modern, environmentally friendly technology boosts credibility with partners, customers, and regulatory bodies.

# 5 Appendix

*Table 5.1. Economic Performance Calculation for the Solution of Installing a INVERTER to Control Repair Air Compressor A*

| No | Indicator | Unit | Value |
|---|---|---|---|
| **I** | **Energy saving potential** | | |
| 1 | Rated capacity of air compressor motor | kW | 90 |
| 2 | Idle time ratio | % | 32 |
| 3 | Power consumption of air compressor when running without load | kW | 20.41 |
| 4 | Operating time during the day | hour | 24 |
| 5 | Number of days of operation | Day | 365 |
| 6 | Power consumption during unloading period | kWh/year | 57,213 |
| 7 | Ability to save energy during unloading operation when installing an inverter | | 65% |
| 8 | Annual energy savings | kWh/year | 37,189 |
| 9 | Average electricity price | VND | 1,500 |
| 10 | Amount of money saved per year | VND/year | 55,782,979 |
| 11 | Total investment and installation costs | VND | 200,000,000 |
| 12 | Simple payback period | Year | 3.59 |
| 13 | Internal Rate of Return IRR | % | 12.2% |
| 14 | Net present value NPV (in 5 years, discounted at 12%/year) | VND | 1,085,156 |
| **II** | **Environment** | | |
| 1 | TOE Conversion | TOE/year | 5.74 |
| 2 | $CO_2$ emissions | tons of CO2 / year | 25.16 |

*Table 5.2. Calculation of energy savings of insulation solutions for heat loss locations*

| No | Parameter | Formula | Unit | Value |
|---|---|---|---|---|
| | **Current parameters** | | | |
| 1 | Surface temperature | $t_w$ | °C | 200 |
| 2 | Ambient air temperature | tf | °C | 40 |
| 3 | Average temperature | $t_{tb}$ | °C | 120.0 |
| 4 | Average Prandtl criterion | $Pr_{tb}$ | | 0.686 |
| 5 | Prandtl standard pipe surface temperature | Prtw | | 0.680 |
| 6 | Prandtl standard ambient temperature | Prf | | 0.700 |
| 7 | Acceleration of gravity | g | $m^2/s$ | 9.81 |

| No | Parameter | Formula | Unit | Value |
|---|---|---|---|---|
| 8 | Coefficient of volume expansion | $\beta = 1/(273+t_{tb})$ | | 0.00254 |
| 9 | Heat exchange surface area for 50m of pipe | F | $m^2$ | 50 |
| 10 | Equivalent size | d | m | 0.05 |
| 11 | Thermal conductivity | $\lambda$ | W/mK | 0.0276 |
| 12 | Kinematic viscosity | $\upsilon$ | $m^2/s$ | 0.0000167 |
| 13 | Grashof Standard | $Gr = (g.\beta.d^3.(t_w - t_f))/\upsilon^2$ | | 1,792,230 |
| 14 | Nusselt standard | $Nu = 0.15.(Gr.Pr)^{0.33}.(Prf/Prw)^{0.25}$ | | 15.45 |
| 15 | Heat transfer coefficient | $\alpha = Nu.\lambda/d$ | $W/m^2.K$ | 8.53 |
| 16 | Heat released into the environment | $Qtr = \alpha.(t_w - t_f).F$ | W | 68,214.16 |
| | **After implementing the solution** | | | |
| 17 | Pipe surface temperature | $t_w$ | $^oC$ | 45 |
| 18 | Ambient air temperature | tf | $^oC$ | 40 |
| 19 | Average temperature | $t_{tb}$ | $^oC$ | 42.5 |
| 20 | Average Prandtl criterion | $Pr_{tb}$ | | 0.687 |
| 21 | Prandtl standard pipe surface temperature | Prtw | | 0.698 |
| 22 | Prandtl standard ambient temperature | Prf | | 0.699 |
| 23 | Acceleration of gravity | g | $m^2/s$ | 9.81 |
| 24 | Coefficient of volume expansion | $\beta = 1/(273+t_{tb})$ | | 0.0032 |
| 25 | Heat exchange surface area for 50m of pipe | F | $m^2$ | 50 |
| 26 | Equivalent size | d | m | 1.00 |
| 27 | Thermal conductivity | $\lambda$ | W/mK | 0.0296 |
| 28 | Kinematic viscosity | $\upsilon$ | $m^2/s$ | 0.000017 |
| 29 | Grashof Standard | $Gr = (g.\beta.d^3.(t_w - t_f))/\upsilon^2$ | | 540,012,649 |
| 30 | Nusselt standard | $Nu = 0.15.(Gr.Pr)^{0.33}.(Prf/Prw)^{0.25}$ | | 100.94 |
| 31 | Heat transfer coefficient | $\alpha = Nu.\lambda/d$ | $W/m^2.K$ | 2.99 |
| 32 | Heat released into the environment | $Qtr = \alpha.(t_w - t_f).F$ | W | 746,961 |
| 33 | Solution implementation performance | | % | 85 |
| 34 | Actual heat output | Qtt | W | 878.78 |

*Table 5.3. Calculation of economic efficiency of insulation solutions for heat loss locations*

| No | Parameter | Formula | Value |
|---|---|---|---|
| | **Operating parameters** | | |
| 1 | Average operating hours per day | Hour | 24 |
| 2 | Average number of operating days per year | Day | 365 |
| | **Energy Savings Calculation** | | |
| 3 | Heat saved | kW | 67,335 |
| 4 | Conversion factor of coal | kJ/kg | 22,121 |
| 5 | Fuel economy | kg/s | 0.00304396 |
| 6 | Fuel savings in 1 year | tons/year | 95.99 |
| 7 | Fuel price per ton | VND/ton | 1,986,699 |
| 8 | Fuel cost savings in 1 year | VND/year | 190,711,653 |
| 9 | Investment costs | VND | 100,000,000 |
| 10 | Payback period | Year | 0.52 |
| | **Environment** | | |
| 11 | TOE Conversion | TOE/year | 57.60 |
| 12 | $CO_2$ emissions | tons of CO2 / year | 237.11 |

*Table 5.4. Calculation of economic efficiency of thermal valve insulation solution*

| No | Indicator | Unit | Value |
|---|---|---|---|
| **Saving calculations** | | | |
| 1 | Temperature difference between valve and ambient temperature | degrees Celsius | 140 |
| 2 | Heat loss | kcal/(m $^2$ h) | 2,326 |
| 3 | | kJ/(m $^2$ s) | 2.70 |
| 4 | Number of valves | Valve | 50 |
| 5 | Heat exchange area of valve | m $^2$ | 10.32 |
| 6 | Total heat loss of valve | kJ/s | 27,871 |
| 7 | Average operating hours per day | hour | 24 |
| 8 | Average number of operating days per year | day | 365 |
| 9 | Solution performance | % | 90% |
| 10 | Amount of heat saved in 1 year | kJ | 791,052,023 |
| 11 | Calorific value of coal | kJ/kg | 22,121 |
| 12 | Fuel savings in 1 year | ton | 35.76 |
| 13 | Price of fuel | VND/ton | 1,986,699 |

| No | Indicator | Unit | Value |
|---|---|---|---|
| 14 | Cost savings | VND/year | 71,044,811 |
| 15 | Investment costs | VND | 200,000,000 |
| 16 | Payback period | year | 2.82 |
| 17 | Internal Rate of Return IRR | % | 22.80% |
| 18 | Net present value NPV (in 5 years, discounted at 12%/year) | VND | 56,100,644 |
| **Environment** | | | |
| 19 | TOE Conversion | TOE/year | 21.46 |
| 20 | $CO_2$ emissions | tons of CO2 / year | 88.33 |

*Table 5.5. Economic calculation of the solution of installing frequency converter to control seawater circulation pump of 2 units*

| No | Indicator | Unit | Circulation pump 1A | Circulation pump 2B |
|---|---|---|---|---|
| **1** | **Base data** | | | |
| 1.1 | Actual pump capacity | kW | 1,333 | 1,320 |
| 1.5 | Motor power frequency without inverter installed | Hz | 50 | 50 |
| 1.6 | Valve opening angle | % | 56.4 | 55.5 |
| 1.7 | Hours of operation per day | Hour | 24 | 24 |
| 1.8 | Number of operating days per year | Day | 365 | 365 |
| 1.9 | Total electricity consumption in the year | kWh/year | 11,677,080 | 11,563,200 |
| **2** | **Energy saving potential** | | | |
| 2.1 | Average frequency of power supply to motor when inverter is installed | Hz | 40 | 40 |
| 2.2 | Valve opening angle after inverter installation | % | 100 | 100 |
| 2.3 | Power used when installing inverter | kW | 682.50 | 675.84 |
| 2.4 | Power saving | kW | 650.50 | 644.16 |
| 2.5 | Power saving time ratio | % | 65% | 65% |

| No | Indicator | Unit | Circulation pump 1A | Circulation pump 2B |
|---|---|---|---|---|
| 2.6 | Energy saved when using inverter | kWh/year | 3,703,970 | 3,667,847 |
| 2.7 | Average electricity cost | VND/kWh | 1,500 | 1,500 |
| 2.8 | Total annual savings | VND/year | 5,555,954,664 | 5,501,770,560 |
| 2.9 | Total investment and installation costs | VND | 10,000,000,000 | 10,000,000,000 |
| 2.10 | Payback period | Year | 1.80 | 1.82 |
| **3** | **Environment** | | | |
| 3.1 | TOE Conversion | TOE/year | 571.52 | 565.95 |
| 3.2 | $CO_2$ emissions | tons of CO2 / year | 2506.11 | 2481.67 |

*Table 5.6. Economic calculation of the solution of installing frequency converter to control seawater booster pump*

| No. | Indicator | Unit | 1A booster pump | 2A booster pump |
|---|---|---|---|---|
| **1** | **Base data** | | | |
| 1.1 | Actual pump capacity | kW | 78 | 150 |
| 1.5 | Motor power frequency without inverter installed | Hz | 50 | 50 |
| 1.6 | Valve opening angle | % | 51.2 | 50 |
| 1.7 | Hours of operation per day | Hour | 24 | 24 |
| 1.8 | Number of operating days per year | Day | 365 | 365 |
| 1.9 | Total electricity consumption in the year | kWh/year | 683,280 | 1,314,000 |
| **2** | **Energy saving potential** | | | |
| 2.1 | Average frequency of power supply to motor when inverter is installed | Hz | 35 | 35 |
| 2.2 | Valve opening angle after inverter installation | % | 100 | 100 |
| 2.3 | Power used when installing inverter | kW | 26.75 | 51.45 |
| 2.4 | Power saving | kW | 51.25 | 98.55 |
| 2.5 | Power saving time ratio | % | 65% | 65% |
| 2.6 | Energy saved when using inverter | kWh/year | 291,795 | 561,144 |
| 2.7 | Average electricity cost | VND/kWh | 1,500 | 1,500 |
| 2.8 | Total annual savings | VND/year | 437,692,086 | 841,715,550 |

| No. | Indicator | Unit | 1A booster pump | 2A booster pump |
|---|---|---|---|---|
| 2.9 | Total investment and installation costs | VND | 1,000,000,000 | 1,000,000,000 |
| 2.10 | Payback period | Year | 2.28 | 1.19 |
| **3** | **Environment** | | | |
| 3.1 | TOE Conversion | TOE/year | 45.02 | 86.58 |
| 3.2 | $CO_2$ emissions | tons of CO2 / year | 197.43 | 379.67 |

*Table 5.7. Economic Evaluation of Installing Variable Frequency Drives (INVERTERs) for the Seawater Circulation Pumps of Two Generating Units*

| No. | Indicators | Unit | Circulation Pump 1A | Circulation Pump 2B |
|---|---|---|---|---|
| **1** | **Baseline Data** | | | |
| 1.1 | Actual pump power | kW | 1,333 | 1,320 |
| 1.5 | Motor supply frequency before INVERTER installation | Hz | 50 | 50 |
| 1.6 | Valve opening | % | 56.4 | 55.5 |
| 1.7 | Operating hours per day | Hour | 24 | 24 |
| 1.8 | Operating days per year | Day | 365 | 365 |
| 1.9 | Total annual electricity consumption | kWh/year | 11,677,080 | 11,563,200 |
| **2** | Energy Saving Potential | | | |
| 2.1 | Average operating frequency with INVERTER | Hz | 40 | 40 |
| 2.2 | Valve opening after INVERTER installation | % | 100 | 100 |
| 2.3 | Power consumption with INVERTER | kW | 682.50 | 675.84 |
| 2.4 | Power savings | kW | 650.50 | 644.16 |
| 2.5 | Percentage of time savings apply | % | 65% | 65% |

| No. | Indicators | Unit | Circulation Pump 1A | Circulation Pump 2B |
|---|---|---|---|---|
| 2.6 | Annual energy savings with INVERTER | kWh/year | 3,703,970 | 3,667,847 |
| 2.7 | Average electricity price | VND/kWh | 1,500 | 1,500 |
| 2.8 | Total annual monetary savings | VND/year | 5,555,954,664 | 5,501,770,560 |
| 2.9 | Total investment and installation cost | VND | 10,000,000,000 | 10,000,000,000 |
| 2.10 | Payback period | Year | 1.80 | 1.82 |
| **3** | **Environment** | | | |
| 3.1 | TOE conversion | TOE/year | 571.52 | 565.95 |
| 3.2 | $CO_2$ emissions reduction | tons $CO_2$ /year | 2506.11 | 2481.67 |

*Table 5.8. Economic analysis of the retrofit solution for the common pipeline connection of the seawater circulation pump system of the two units*

| No | Indicator | Unit | Value |
|---|---|---|---|
| **I** | **Base data** | | |
| 1 | Average power consumption of one circulation pump | kW | 1,300 |
| 2 | Operating time during 4 winter months | hours/year | 2,880 |
| 3 | Electricity saved | kWh/year | 3,744,000 |
| 4 | Average electricity price | VND | 1,500 |
| 5 | Annual cost savings | VND/year | 5,616,000,000 |
| 6 | Total investment and installation cost | VND | 2,000,000,000 |
| 7 | Simple payback period | Years | 0.36 |
| 8 | Internal Rate of Return (IRR) | % | 280.4% |
| 9 | Net Present Value (NPV) (over 5 years, 12% annual discount rate) | VND | 18,244,423,152 |
| **II** | **Environmental benefits** | | |
| 10 | Equivalent TOE saved | TOE/year | 577.70 |
| 11 | $CO_2$ emission reduction | Tons $CO_2$/year | 2,533.19 |

*Table 5.9. Economic analysis of the Utilize waste heat from flash steam and blowdown to preheat makeup water*

| No | Parameter | Unit | Value |
|---|---|---|---|
| **Operating Information** | | | |
| 1 | Average Operating Hours per Day | hour | 24 |
| 2 | Average Operating Days per Year | day | 320 |
| 3 | Celeration Value of Coal | kJ/kg | 22,121 |
| 4 | Boiler Efficiency | % | 85 |
| 5 | Specific Heat of Water | kJ/(kg.K) | 4,186 |
| **Current status information before solution** | | | |
| 6 | Boiler discharge water | ton/year | 21,672 |
| 7 | Boiler discharge water | kg/s | 0.78 |
| 8 | Total makeup water flow (2 units) | ton/year | 253,860 |
| 9 | Makeup water flow to the heater (15%) | ton/year | 38,079 |
| 10 | Makeup water flow to the heater | kg/s | 1.38 |
| 11 | Boiler discharge temperature | °C | 90 |
| 12 | Makeup water temperature before solution | °C | 30 |
| **Information after solution** | | | |
| 13 | Boiler discharge water temperature after heat exchanger | °C | 40 |
| 14 | Total heat transfer of boiler discharge water | kW | 164.06 |
| 15 | Heat exchanger efficiency ε | | 0.8 |
| 16 | Total heat transfer of boiler makeup water | kW | 131.25 |
| 17 | Boiler makeup water temperature after heating | °C | 52.76 |
| **Economic calculation** | | | |
| 18 | Heat saved | kW | 131.25 |
| 19 | Convert kW to kJ | kJ/kWh | 3,600 |
| 20 | Heat saved | MJ | 3,628,709 |
| 21 | Coal saved in 1 year | ton/year | 193 |
| 22 | Average coal price in 2024 | VND/ton | 1,986,699 |
| 23 | Coal cost saved | VND/year | 383,407,392 |
| 24 | Investment cost | VND | 1,000,000,000 |
| 25 | Payback period | year | 2.61 |
| **Environment** | | | |
| 26 | TOE Conversion | TOE/year | 115.79 |
| 27 | $CO_2$ Emission Reduction | tonnes CO2/year | 476.68 |

*Table 5.10. Economic analysis of the Utilize waste heat from auxiliary steam to preheat makeup water*

| No | Parameter | Unit | Value |
|---|---|---|---|
| **Operating Information** | | | |
| 1 | Average Operating Hours per Day | hour | 24 |
| 2 | Average Operating Days per Year | day | 320 |
| 3 | Celeration Value of Coal | kJ/kg | 22,121 |
| 4 | Boiler Efficiency | % | 85 |
| 5 | Specific Heat of Water | kJ/(kg.K) | 4.186 |
| **Current status information before solution** | | | |
| 6 | Auxiliary Steam Condensate Amount | ton/year | 127,734 |
| 7 | Auxiliary Steam Condensate Amount | kg/s | 4.62 |
| 8 | Total Makeup Water Flow (2 Units) | ton/year | 253,860 |
| 9 | Makeup Water Flow to the Heater (85%) | ton/year | 215,781 |
| 10 | Makeup Water Flow to the Heater | kg/s | 7.80 |
| 11 | Auxiliary Steam Condensate Temperature | $^{o}C$ | 90 |
| 12 | Make-up Water Temperature Before Solution | $^{o}C$ | 30 |
| **Information after solution** | | | |
| 13 | Auxiliary steam condensate temperature after heat exchanger | $^{o}C$ | 40 |
| 14 | Total heat transfer of auxiliary steam condensate | kW | 966.97 |
| 15 | Heat exchanger efficiency ε | | 0.8 |
| 16 | Total heat transfer of boiler makeup water | kW | 773.57 |
| 17 | Boiler makeup water temperature after preheating | $^{o}C$ | 53.68 |
| **Economic calculation** | | | |
| 18 | Heat saved | kW | 773.57 |
| 19 | Convert kW to kJ | kJ/kWh | 3,600 |
| 20 | Heat saved | MJ | 21,387,741 |
| 21 | Coal saved in 1 year | ton/year | 1,137 |
| 22 | Average coal price in 2024 | VND/ton | 1,986,699 |
| 23 | Coal cost saved | VND/year | 2,259,817,166 |
| 24 | Investment cost | VND | 4,000,000,000 |
| 25 | Payback period | year | 1.77 |
| **Environment** | | | |
| 26 | TOE Conversion | TOE/year | 682.48 |

| No | Parameter | Unit | Value |
|---|---|---|---|
| 27 | $CO_2$ Emission Reduction | tonnes CO2/year | 2,809.56 |

*Table 5.11. Economic calculation of the solution to replace the low-efficiency IE1 lime sludge storage tank agitator motor with a high-efficiency IE4 motor*

| No | Parameter | Unit | Replace the IE1 motor with an IE4 motor | | Replace the IE2 motor with an IE4 motor | | Replace the IE3 motor with an IE4 motor | |
|---|---|---|---|---|---|---|---|---|
| | | | **Fly Ash Silo Fan – IE1** | **New IE4 motor** | **Lime Sludge Pump – IE2** | **New IE4 motor** | **Limestone Mill – IE2** | **New IE4 motor** |
| **I** | **Baseline Data** | | | | | | | |
| 1.1 | Rated power | kW | 8 | | 15 | | 105 | |
| 1.2 | Number of motors to replace | unit | **4** | | **2** | | **2** | |
| 1.3 | Required load power | kW | 30 | 30 | 30 | 30 | 210 | 210 |
| 1.5 | Rated power factor | – | 0.79 | 0.93 | 0.84 | 0.93 | 0.89 | 0.93 |
| 1.6 | Rated efficiency | % | 0.79 | 0.93 | 0.84 | 0.93 | 0.89 | 0.93 |
| 1.7 | Average operating hours per day | hour | 24 | 24 | 24 | 24 | 24 | 24 |
| 1.8 | Operating days per year | days | 320 | 320 | 320 | 320 | 320 | 320 |
| 1.9 | Simultaneous operation rate | % | 70% | 70% | 70% | 70% | 70% | 70% |
| 1.10 | Operating hours per year | hours | 7,680 | 7,680 | 7,680 | 7,680 | 7,680 | 7,680 |
| 1.11 | Expected apparent power consumption | kVA | 26.58 | 22.58 | 25.00 | 22.58 | 165.17 | 158.06 |
| 1.12 | Iron loss in motor | kW | 0.25 | 0.68 | 0.50 | 0.68 | 3.50 | 4.74 |
| 1.13 | Copper loss in motor | kW | 3.91 | 1.11 | 2.80 | 1.11 | 12.72 | 7.75 |
| 1.14 | Total loss | kW | 4.16 | 1.78 | 3.30 | 1.78 | 16.22 | 12.49 |

| No | Parameter | Unit | Replace the IE1 motor with an IE4 motor | | Replace the IE2 motor with an IE4 motor | | Replace the IE3 motor with an IE4 motor | |
|---|---|---|---|---|---|---|---|---|
| | | | Fly Ash Silo Fan – IE1 | New IE4 motor | Lime Sludge Pump – IE2 | New IE4 motor | Limestone Mill – IE2 | New IE4 motor |
| **II** | **Energy Saving Potential** | | | | | | | |
| 2.1 | Power savings | kW | | 28.48 | | 1.52 | | 3.73 |
| 2.2 | Electricity savings | kWh | | 218,762 | | 11,644 | | 28,653 |
| 2.3 | Average electricity price | VND/kWh | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 | 1,500 |
| 2.4 | Annual cost savings | VND/year | | 328,143,601 | | 17,465,806 | | 42,979,746 |
| 2.5 | Total investment cost | VND | | 1,280,000,000 | | 174,000,000 | | 600,000,000 |
| 2.6 | Payback period | year | | 3.90 | | 9.96 | | 13.96 |
| **III** | **Environment** | | | | | | | |
| 3.1 | TOE conversion | TOE/year | | 33.76 | | 1.80 | | 4.42 |
| 3.2 | $CO_2$ emission reduction | $tCO_2$/year | | 148.01 | | 7.88 | | 19.39 |

*Table 5.12. Economic Evaluation of Installing Variable Frequency Drives (INVERTERs) for Auxiliary Fans in the Boiler Area*

| No. | Indicators | Formula | Unit | ID Fan | FD Fan | PA Fan |
|---|---|---|---|---|---|---|
| **1** | **Baseline Data** | | | | | |
| 1.1 | Actual fan power | A | kW | 1,361 | 323 | 1,061 |
| 1.2 | Motor frequency before INVERTER installation | B | Hz | 50 | 50 | 50 |
| 1.3 | Damper opening angle | C | % | 37.1 | 53.5 | 54.2 |
| 1.4 | Operating hours/day | D | Hour | 24 | 24 | 24 |
| 1.5 | Operating days/year | E | Day | 365 | 365 | 365 |
| 1.6 | Total annual electricity consumption | F= A*D*E | kWh/year | 11,922,360 | 2,829,480 | 9,294,360 |
| **2** | **Energy Saving Potential** | | | | | |
| 2.1 | Average operating frequency with INVERTER | G | Hz | 35 | 35 | 35 |
| 2.2 | Damper opening angle after INVERTER installation | H | % | 100 | 100 | 100 |
| 2.3 | Power consumption with INVERTER | I=A*(G^3/B^3) | kW | 466.82 | 110.79 | 363.92 |
| 2.4 | Power saved | J= A-I | kW | 894.18 | 212.21 | 697.08 |
| 2.5 | Percentage of time savings apply | K | | 80% | 80% | 80% |
| 2.6 | Energy savings with INVERTER | L=D*E*J*K | kWh/year | 6,266,392 | 1,487,175 | 4,885,116 |
| 2.7 | Average electricity cost | M | VND/kWh | 1,500 | 1,500 | 1,500 |
| 2.8 | Total annual monetary savings | N=L*M | VND/year | 9,399,588,624 | 2,230,762,032 | 7,327,673,424 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2.9 | Total investment and installation cost | O | VND | 20,000,000,000 | 10,000,000,000 | 10,000,000,000 |
| 2.10 | Payback period | P=O/N | Year | 2.13 | 4.48 | 1.36 |
| **3** | **Environmental Impact** | | | | | |
| 3.1 | TOE conversion | Q=L*0,000543 | TOE/year | 966.90 | 229.47 | 753.77 |
| 3.2 | $CO_2$ emissions reduction | R=L*0,0006766 | tons $CO_2$ /year | 4,524.96 | 1,073.89 | 3,527.54 |

*Table 5.13. Economic calculation of the solution to replace the existing ball mill with a vertical mill*

| No. | Parameter | Unit | Ball Mill | Loesche LM 30.3 D VRM |
|---|---|---|---|---|
| **I. Baseline Data** | | | | |
| 1 | Number of mills | Unit | 4 | 4 |
| 2 | Rated power | kW | 1,498 | 1,000 |
| 3 | Simultaneous operation rate | % | 70 | 70 |
| 4 | Operating hours | h/year | 8,760 | 8,760 |
| 5 | Electricity consumption | kWh/year | 36,742,944 | 24,528,000 |
| **II. Energy Saving Potential** | | | | |
| 6 | Electricity savings | kWh/year | – | 12,214,944 |
| 7 | Average electricity price | VND/kWh | 1,500 | 1,500 |
| 8 | Annual monetary savings | VND/year | – | 18,322,416,000 |
| 9 | Total investment cost | VND | – | 125,000,000,000 |
| 10 | Payback period | Year | – | 6.82 |
| **III. Environment** | | | | |
| 11 | TOE conversion | TOE/year | – | 1,884.77 |
| 12 | $CO_2$ emission reduction | $tCO_2$/year | – | 8,264.63 |