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Danish Energy Agency

# Anonymous Audit Report

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# Introduction to the context

On 13 March 2019, Decision No. 280/QĐ-TTg approving the National Programme on Efficient and Sustainable Energy Use (VNEEP) for the 2019–2030 period was issued by the Prime Minister of Vietnam.

VNEEP coordinates comprehensive activities in the field of energy efficiency and conservation, reflecting the commitment of government authorities, associations, enterprises, organisations, and individuals to energy efficiency in particular, and to climate resilience and environmental protection in general.

The Vietnam–Denmark Energy Partnership Programme Phase 3 (DEPP3) for 2020–2025 implements a range of activities that contribute significantly and effectively to the transformation of Vietnam's energy sector towards green growth and carbon emission reduction. This is achieved through the development of a sustainable energy system, flexible electricity operation, and effective implementation of policies and measures promoting efficient and prudent energy use.

One particularly important activity is the promotion of energy efficiency through Energy Audits across various industrial sectors in Vietnam.

This document is an anonymous summary of a detailed energy audit report conducted as part of the DEPP3 programme. The audit was carried out at a garment manufacturing facility by ENERVI Vietnam Environmental Energy Joint Stock Company, in collaboration with an international expert from Viegand Maagøe

# Summary

This is a garment manufacturing facility (excluding leather and fur products) with over 20 years of experience in factory development. The facility comprises multiple production workshops, with the two main product lines being shirts and knitwear.

The detailed energy audit process assessed all energy-consuming and energy-generating equipment within the company, identifying patterns of energy consumption, benchmarks, and characteristics of both the equipment and processes. Based on these insights, the audit team developed energy management measures and proposed energy efficiency (EE) solutions for future implementation, ensuring both technical and financial feasibility.

The audit primarily focused on key operational areas, including:

- Electricity: used across most production line equipment, such as sewing machines, cutting machines, fabric spreading machines, electric boilers, heat-label presses, and auxiliary systems like thermal oil boilers, oil-fired boilers, chillers, air compressors, AHUs, and lighting.
- Steam: from oil-fired boilers is used directly in washing processes, while steam from electric boilers is applied in ironing and pressing operations.
- Chilled water: from the chiller is pumped to copper coils for heat exchange with fresh air, which is then supplied to production units via AHUs.
- Thermal oil: heated in the thermal oil boiler and delivered to the Dipping area to treat knit fabric surfaces once the required temperature is reached.

Through these assessments and discussions with technical staff and operators, the team gathered valuable input to map the factory’s energy flows and identify practical solutions. The proposed EE measures, presented in the table below, are categorized into three main groups:

***Table 1. Summary of proposed EE measures***

| No | List of proposed EE measures |
|---|---|
| **I. Management solution** | |
| 1 | Implement an Energy Management System (EnMS) according to ISO 50001:2018, combined with the existing Energy Map and HIGG FEM standards. |
| **II. Technical solution** | |
| 2 | Installing Variable Frequency Drives (VFDs) for Washing Machine Motors |
| 3 | Optimizing Chiller Operation |
| 4 | Installing Airflow and Temperature Controllers for AHUs |
| 5 | Installing Exhaust Heat Recovery Water Heaters for Boilers |
| 6 | Adjusting Boiler Blowdown Settings |

| No | List of proposed EE measures |
| --- | --- |
| **III. Recommended Solutions** | |
| 7 | Gradually Replace Belt-Driven Ventilation Fans with Direct-Drive Fans |
| 8 | Repair Compressed Air Leaks in the Compressed Air Distribution System |
| 9 | Install Temperature Sensors for Cooling Towers |
| 10 | Improve Power Quality |
| 11 | Install Flue Gas Oxygen Sensors and Use Existing VFDs to Control Boiler and Oil Furnace Fans Based on Oxygen Levels |
| 12 | Install a New 2,000 kW Thermal Oil Furnace Combined with a 1-ton Steam/Hour Boiler, Fully Using High-Efficiency Biomass Combustion to Replace Low-Efficiency Oil-Fired Thermal Oil Furnace and Boilers. |
| 13 | Upgrade Boiler Water Heaters to Recover Heat from Thermal Oil Furnace Flue Gas |

The combined implementation of these measures is expected to achieve energy savings of approximately 591,669 kWh and provide environmental benefits to the Company, with an estimated emission reduction of around 345 $tCO_2$.

# 1. About the enterprise

The factory was established in 2004, by 2014, the enterprise's output had gradually stabilized, reaching 12 million products, an increase of 25% compared to 2013. After more than 20 years of establishment and development, the factory has become not only one of the leading garment enterprises in the province but also a pioneer in promoting emulation movements and in caring for and training its workforce. Currently, the enterprise has 9 production units, nearly 100 production lines, and 76 sewing lines.

The enterprise mainly produces two primary products: woven shirts and knitted shirts, manufactured at PU4 (Woven Shirts) and PU8 (Knitted Shirts) of the enterprise. Woven shirts are made from shirt fabric, while knitted shirts are made from knit fabric.

Additionally, the enterprise includes production units PU1, PU2, PU3, PU5, PU6, PU9, Dipping, Lab, Office, Packaging, Warehouse, Main Office, and Canteen. The supporting systems include Chillers, Air Compressors, Wastewater Treatment, and Lighting systems.

## 1.1. Description the company

- Sector: Garment manufacturing and trading
- Main products: Shirts and knitted shirts
    - Shirts and Knitted shirts12,697,270 pcs/year
- Total energy consumption in 2024
    - Electricity:
        - Grid: 8,207,644 kWh, equivalent to 1,266 TOE, 8,208 MWh
        - Rooftop solar: 1,980 kWp.
    - Diesel Oil: 3,525,040 kWh, equivalent to 303 TOE, 3,525 MWh

- Annual carbon emissions: 6,352 $tCO_{2eq}$

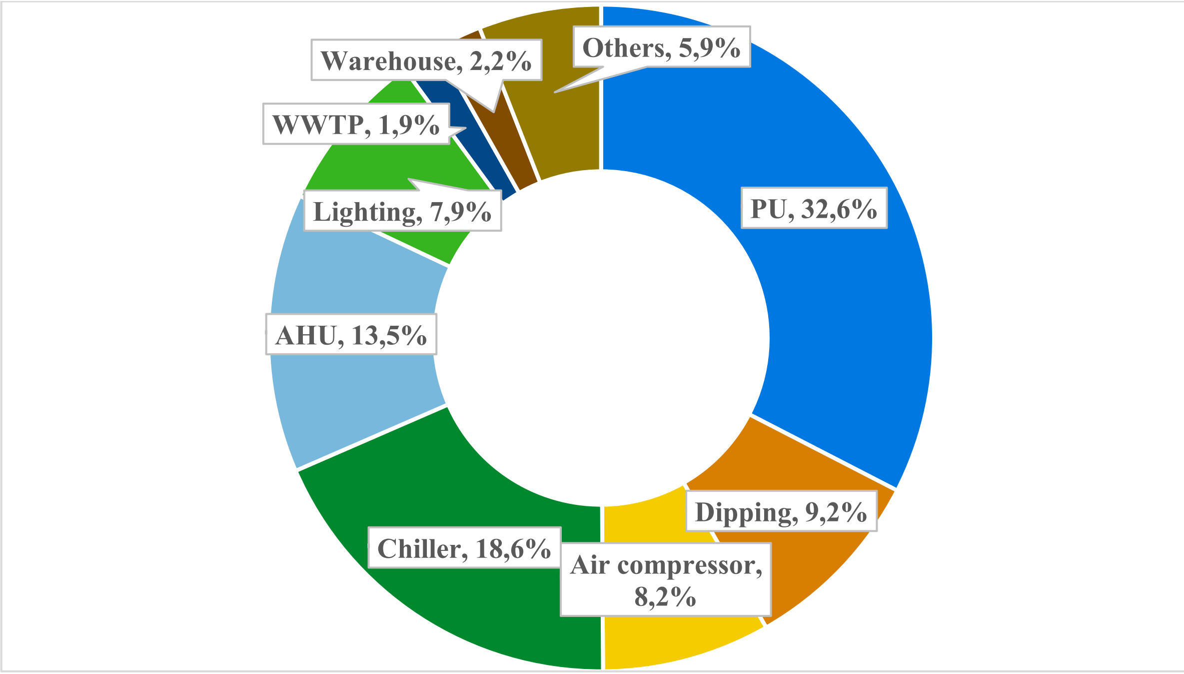


*Figure 1. Electricity Consumption Distribution in the Enterprise*

The chart indicates that electricity consumption in the PU system (including production line machinery and electric boilers) accounts for the highest share at 32% of the total electricity consumption of the Enterprise. This is followed by the Chiller system at 18.6% and the AHU system at 13.5%. The compressed air system and the treatment area account for 8.2% and 9.2%, respectively. Lighting also represents a significant share at 7.9%. Other areas, such as water treatment or boiler rooms, account for less than 2.2%. Thus, the chart provides the most comprehensive overview of energy usage and helps identify the key areas of energy consumption, enabling the implementation of energy control measures in these areas to the greatest extent possible.

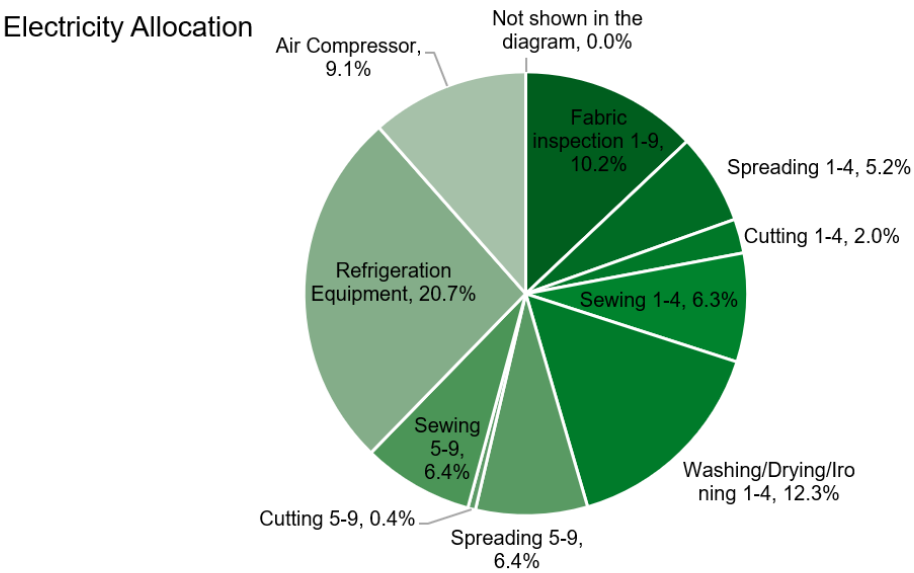


*Figure 2. Electricity Consumption Distribution in the Production Line*

Although this chart was constructed based on representative measurement data for each type of production equipment and then scaled according to the number of devices of the same type, some deviations are expected. However, it can still be observed that the share of the cooling and compressed air areas does not differ significantly from data measured directly by meters at the enterprise. Therefore, the enterprise can still use this chart to monitor and manage process equipment systems to minimize electricity losses in key electricity-consuming stages.

The enterprise has three main heat consumers: washing machines, dryers, and fabric processing machines. Below is the heat consumption distribution chart for the washing and drying system.

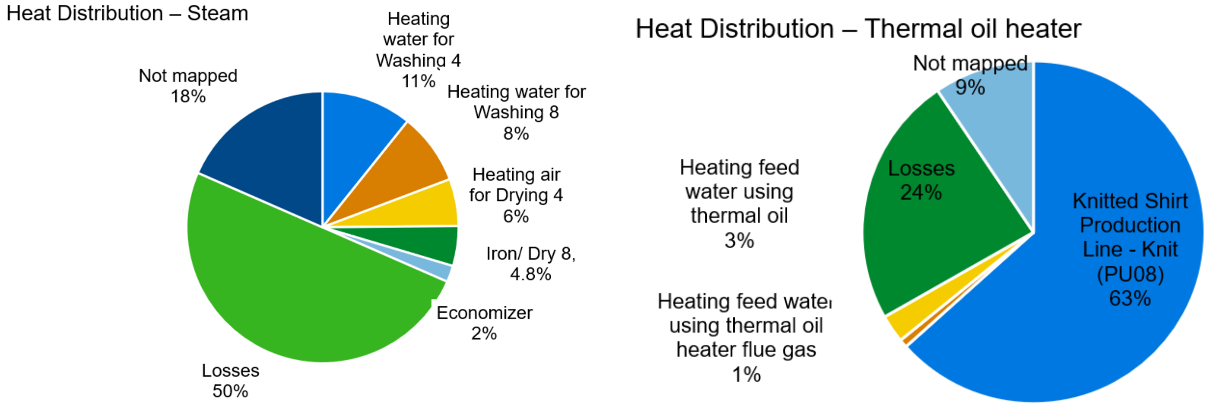


*Figure 3. Heat Consumption Distribution Chart of Systems in 2024*

The total heat consumption for the washing, drying, and fabric processing stages across the enterprise in 2024, converted to electricity equivalent, was 1,863,520 kWh. Among this, the heat demand for fabric processing accounted for the largest share, approximately 70% of heat consumption, while the washing and drying systems together accounted for around 24%.

Based on the survey, the expert team noted that the heat demand for the washing and drying systems was relatively low, as the machines operate only when required. The drying system employed a two-stage air–water and air–steam heat exchanger and recovered condensate for reuse in the boiler. The washing system used direct steam to heat the washing water, and the heat from discharged hot washing water is recovered to exchange with the boiler feed water. This demonstrates that both heat-consuming systems maximize and efficiently utilize heat.

### 1.2. Description process

Below is the process flow diagram, including mass balance, for the production of woven shirts and knitwear corresponding to Production Units PU4 and PU8

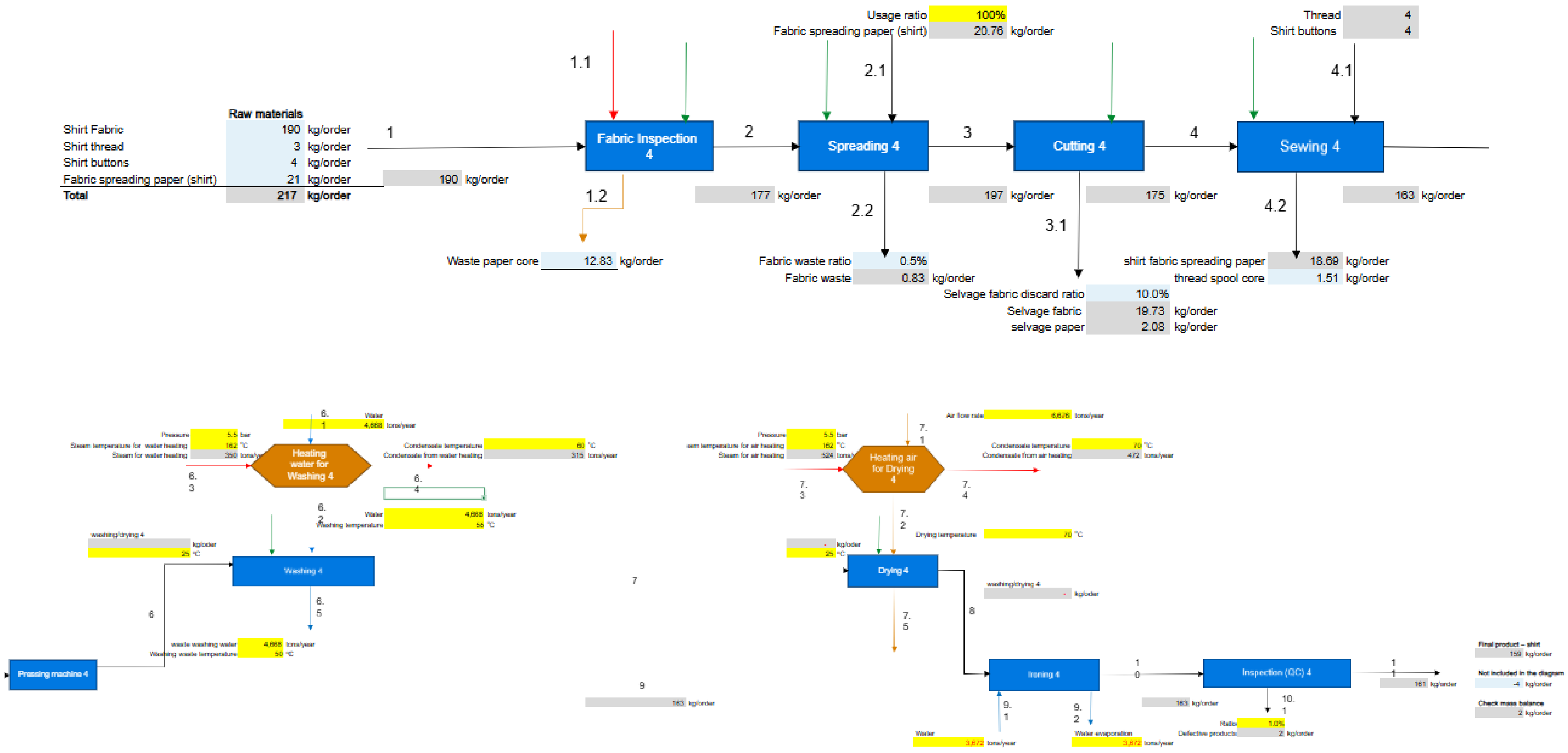


*Figure 4. Shirt Production Process*

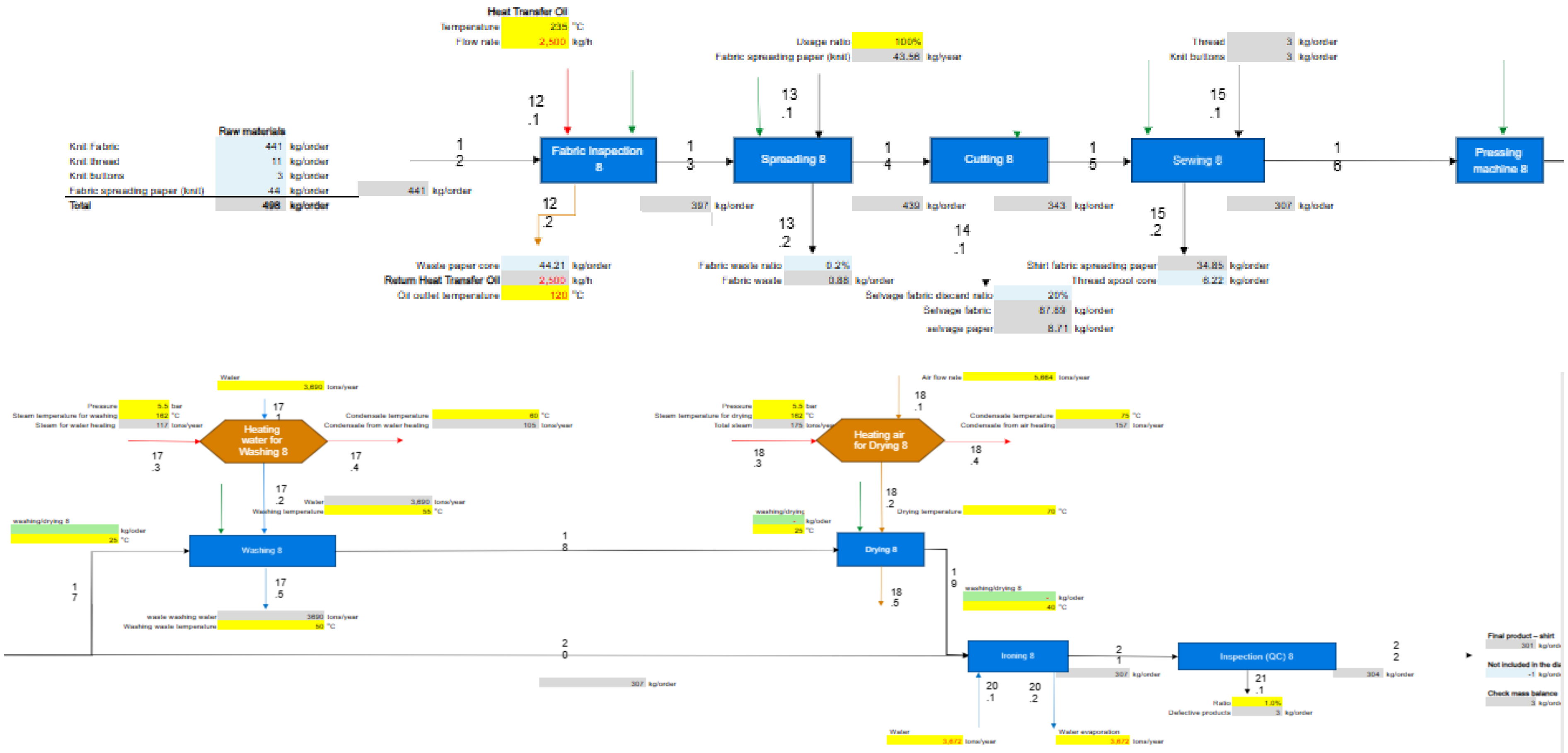


*Figure 5. Knitted Shirt Production Process*

After the fabric is received in the raw material warehouse, depending on customer requirements, it will either go through the Dipping process or be sent directly to the cutting house. For knit fabric, surface treatment is usually required before cutting, whereas shirt fabric is typically sent straight to the cutting house to be cut into components according to the specified shapes and sizes. The fabric pieces are then sewn into finished products on production lines using specialized sewing machines for shirts and knitwear. After sewing, the products are inspected before ironing. Some sample products or orders with specific requirements are washed, dried, and ironed before being sent to QC for quality inspection. QC staff on the sewing line are responsible for checking product quality to ensure there are no defects before the products are quickly packed and moved to the finished goods warehouse for shipment

## 1.3. Description of Utility Systems

The main auxiliary systems of the enterprise include the Oil-Fired Boiler Unit, the Compressed Air Unit, and the Chiller System.

### *1.3.1. Boiler Workshop*

Below is the information on the oil-fired boiler system:

***Table 2. The Oil-Fired Boiler System***

| Specifications | Thermal Oil heater AB&CO | Thermal Oil heater Vietnam Boiler | Steam Boiler |
|---|---|---|---|
| Quantity | 1 | 1 | 1 |
| Design capacity | 1,400 kW | 1,754 kW | 2 t/h |
| Operating parameters | Thermal oil:<br>- Pressure: 4.9 – 6.9 bar<br>- Temperature: 230 – 240°C | | Saturated steam:<br>- Pressure: 6 bar<br>- Temperature: 165 °C<br>Feedwater:<br>Temperature: 70 °C |
| Heat supply for end-use processes | Fabric treatment processes | | Washing and drying processes |

Below is the diagram of the boiler used DO oil.

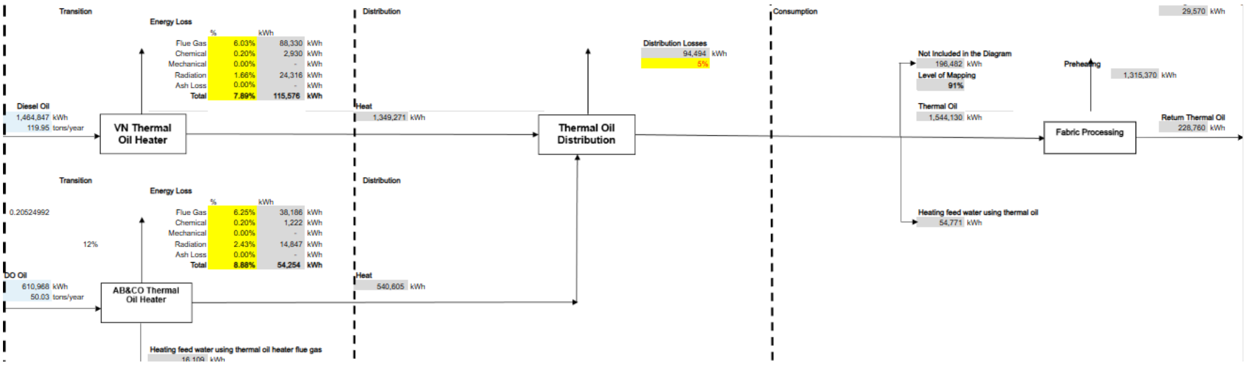


***Figure 6. Thermal Oil Heater System Diagram***

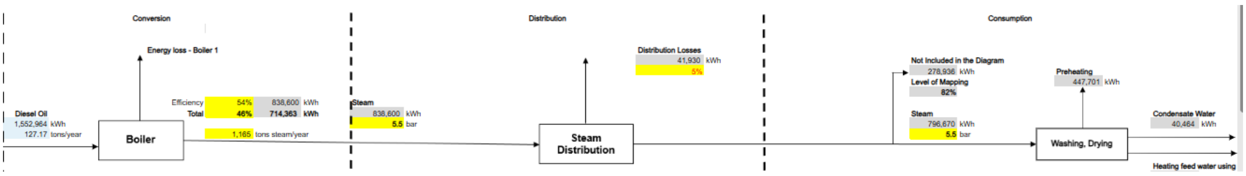


***Figure 7. Boiler System Diagram***

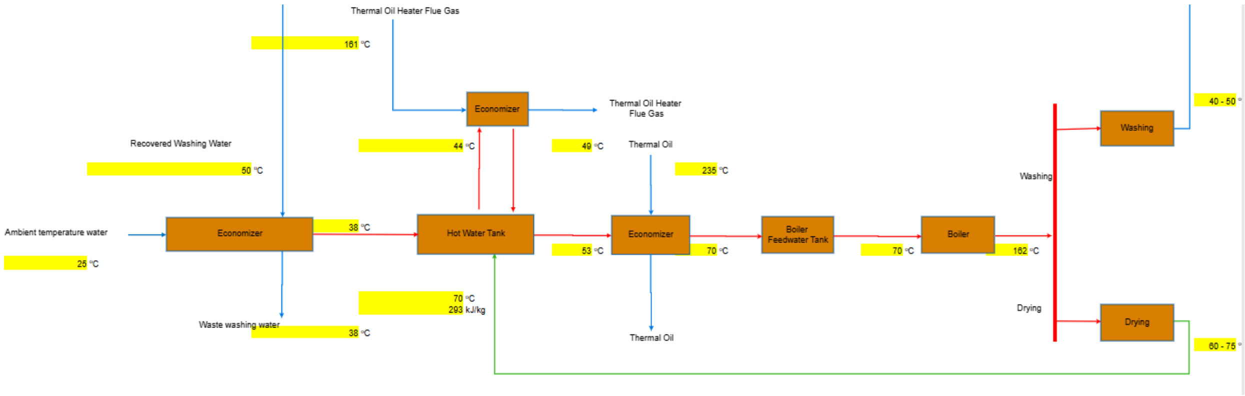


*Figure 8. Steam and Waste Heat Recovery System Diagram*

This thermal oil heater system is equipped with an economiser that utilises flue-gas heat, as well as an economiser that recovers residual heat from the thermal oil. These components help increase the feedwater temperature for the steam boiler, thereby improving the overall thermal efficiency of the system. Following the onsite inspection of the boiler house and the analysis of the flue-gas composition, the indirect efficiency of the three boilers is presented below..

*Table 3. Calculation results based on the indirect efficiency method*

| No | Parameter | Symbol | Unit | Thermal Oil heater Vietnam Boiler | Thermal Oil heater AB&CO | Steam Boiler |
|---|---|---|---|---|---|---|
| 1 | Heat loss through flue gas | $q_2$ | % | 6.03 | 6.25 | 8.65 |
| 2 | Heat loss due to incomplete chemical combustion | $q_3$ | % | 0.2 | 0.2 | 0.2 |
| 3 | Heat loss due to incomplete mechanical combustion | $q_4$ | % | 0 | 0 | 0 |
| 4 | Heat loss to the surrounding environment | $q_5$ | % | 1.66 | 2.43 | 1.08 |
| 5 | Heat loss carried by ash | $q_6$ | % | 0 | 0 | 0 |
| 6 | Heat loss from boiler blowdown | $q_7$ | % | 0 | 0 | 2.88 |
| **7** | **Indirect efficiency** | **$\eta$** | **%** | **92.12** | **91.13** | **87.19** |

*Table 4. Caculation result Steam Boiler based on the direct efficiency method*

| Parameter | Unit | Value |
|---|---|---|
| $B_{\Sigma}$ | Tons of fuel/year | 127.17 |
| $D_{\Sigma}$ | Tons of steam/year | 1,165 |
| $Q_t^{lv}$ | kJ/kg | 43,963 |

| Parameter | Unit | Value |
|---|---|---|
| $h_h$ | kJ/kg | 2,762 |
| $h_{nc}$ | kJ/kg | 168 |
| **$\eta_t$** | **%** | **54.09** |

***General Observations on the Heat Supply System:***

The heat supply system at the enterprise is equipped with multiple supporting devices to enhance boiler operation efficiency and save energy. However, there are still several operational and management issues that need to be addressed:

- The enterprise maintains an operational log, but it currently only tracks water and fuel consumption. Installing additional flue gas oxygen sensors would help operate the boiler system at higher efficiency.
- The blowdown rate is relatively high. Boilers often operate under partial load, which slows down scale formation; if blowdown occurs at full-load frequency, it results in significant energy losses.
- The flue gas oxygen concentration averages 5.73%, which is not yet optimal. It can potentially be reduced to around 3–4% by controlling the combustion process more precisely.
- Flue gas temperatures from the two boilers are high, around 206°C, causing significant heat losses and indicating strong potential for flue gas heat recovery.

#### *1.3.2. Compressed Air workshop*

The compressed air system consists of five compressors, of which compressor no. 4 is out of service and compressor no. 2 is not operating. Compressors no. 4 and 5 are water-cooled via a water-cooling system. The compressed air system operates 24 hours per day. Below is the list of compressors:

***Table 5. The technical information of Compressor***

| No | Manufacturer | Quantity | Capacity (kW) | Pressure (bar) | Operating hours (giờ/ngày) | VFD | Status |
|---|---|---|---|---|---|---|---|
| 1 | Ingersoll Rand | 01 | 75 | 5.1 | 24 | No | Good |
| 2 | Ingersoll Rand | 01 | 75 | 5.1 | - | No | Not use |
| 3 | Ingersoll Rand | 01 | 75 | 5.1 | 24 | Yes | Good |
| 4 | Ingersoll Rand | 01 | 75 | 5.1 | - | Yes | Broken |
| 5 | Ingersoll Rand | 01 | 75 | 5.1 | 24 | Yes | Good |

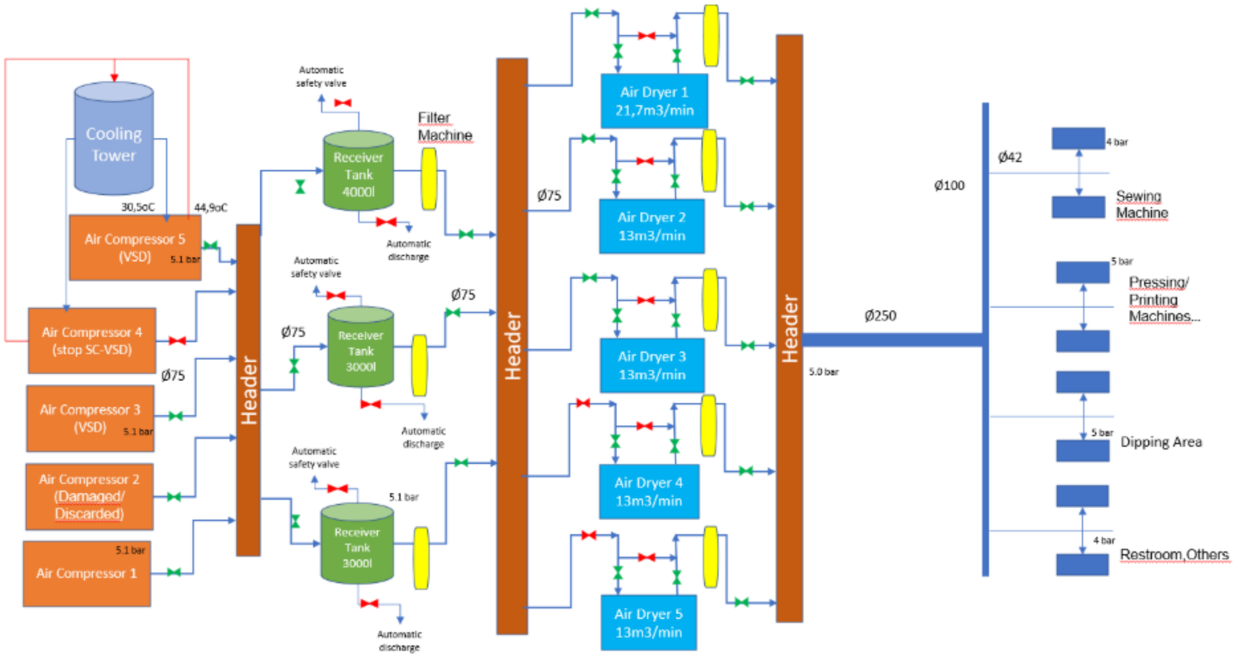


*Figure 9. Compressed air system diagram*

Air is drawn into the compressors and pressurized to 5.1 bar, then the compressed air is combined into a common manifold and directed to the compressed air receiver through the manifold, passing through filters to the air dryer units. Here, the air is dried and continues through filters to the manifold, and finally to the end-use points.

Currently operating 3 MNKs No. 1.4 and 5 for the day shift and No. 1 and 3 for the night shift. Monday is the first day of the week. The plant will turn on all 3 air compressors to operate to meet the initial load demand from 6:30 to 7:00. At 7:30, the plant will start working and then the machines will be operated again according to the load mode. The air compressor system will be turned off and completely stopped every Sunday.

Below is the energy balance diagram for the compressed air system, based on measured data and the enterprise's electricity meters.

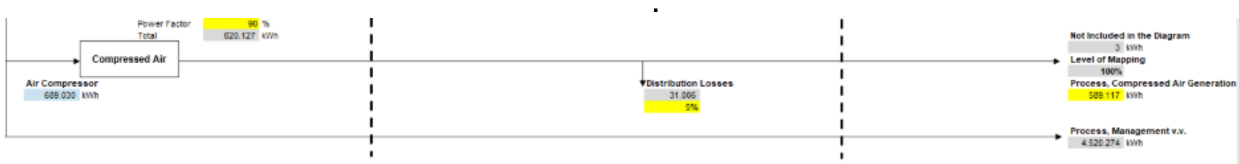


*Figure 10. Energy balance diagram of the compressed air system*

Overall, the company's air compressor system operates quite stably. However, there are still some operational and distribution issues as follows:

- Air leaks still occur in some end-use areas, such as PU4, resulting in significant air losses → repair all leak points throughout the compressed air distribution system.
- The harmonic distortion of two VFD-equipped compressors is very high, over 31%, which is detrimental to long-term operation → install harmonic filters for compressors No. 3 and 5.
- The harmonic distortion of two air dryers is also very high, ranging from 21% to 78%, which is not favorable for long-term operation → install harmonic filters for these two air dryers.

- The phase deviation of the two air dryers is quite high, over 150% → rebalance the phase to prevent overheating and potential damage or explosion of the equipment.

### *1.3.3. Chiller and AHU System*

The cooling system consists of 05 chillers with two different capacities (180 kW and 162 kW) and 18 AHUs with capacities ranging from 22 kW to 37 kW. Among them, Chiller No. 2 is equipped with a variable frequency drive (VFD). The chillers are cooled using cooling towers. In addition, there are a few small air conditioning units installed in certain isolated areas, though not in significant numbers.

The cooling system operates according to the following plan: When the ambient temperature exceeds 30°C, 03 chillers, 03 chilled water pumps, 02 hot water pumps and 03 cooling towers are switched on. When the ambient temperature is below 30°C, only 1 – 2 chillers operate, with the operation of other auxiliary equipment adjusted flexibly. In the cold season, the cooling system (Chillers) is almost inactive, and the workshops mainly receive fresh air directly. Below is the list and some images of the cooling system.

Table 6. *List of cooling system equipment*

| **No.** | **Equipment** | **Number** *(units)* | **Capacity** *(kW/unit)* | **Refrigerant** | **Operating Time** *(hours/day)* | **Purpose** |
|---|---|---|---|---|---|---|
| 1 | Trane Chiller | 2 | 180 | R134a | 12 | Chilled water cooling |
| 2 | Trane Chiller | 3 | 162 | R134a | 12 | Chilled water cooling |
| 3 | AHU | 2 | 37 | - | 24 | Cold air exchange |
| 4 | AHU | 2 | 37 | - | 24 | |
| 5 | AHU | 10 | 22 | - | 24 | |
| 6 | AHU | 4 | 30 | - | 24 | |

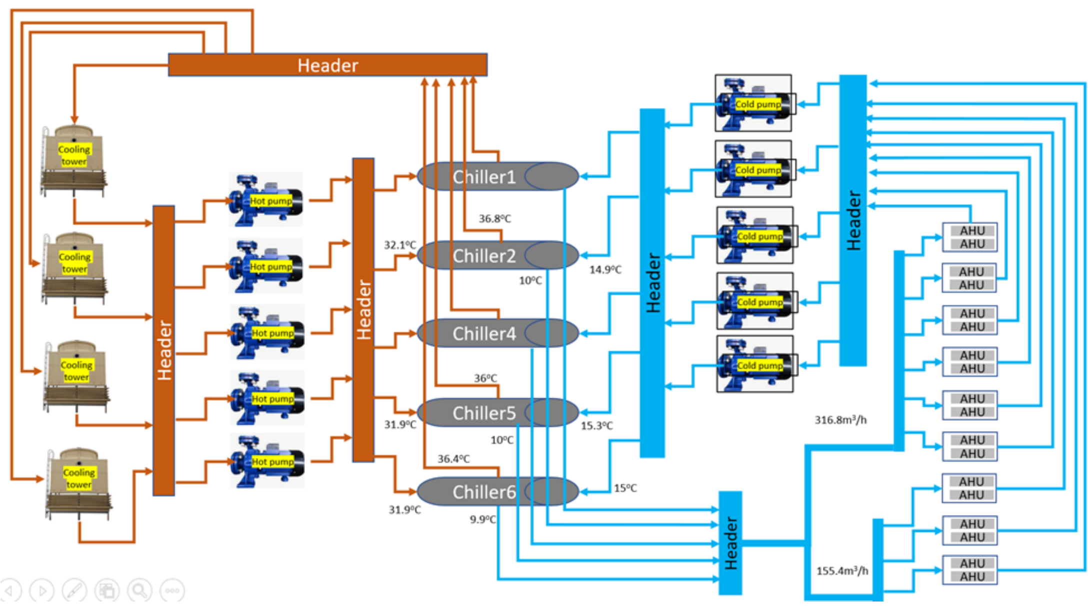


*Figure 11. Diagram of the factory's cooling supply system*

The factory's chiller system operates in two water-loop modes: a closed loop and an open loop:

- **Closed loop:** Water circulates through the pipes and the chiller for cooling. The chilled-water pump delivers it to the AHU coils to cool the workshop. After heat exchange, the water is returned to the chiller by the chilled-water pump to continue the cycle.
- **Open loop:** Water is pumped through the chiller's condenser to reduce temperature during operation. The heated water is then sent to the cooling tower for cooling before returning to the chiller to continue the cycle.

Each workshop is equipped with two AHUs operating continuously to maintain the indoor temperature between 27°C and 28°C. Below are the results of electricity consumption distribution during the cooling process across different areas.

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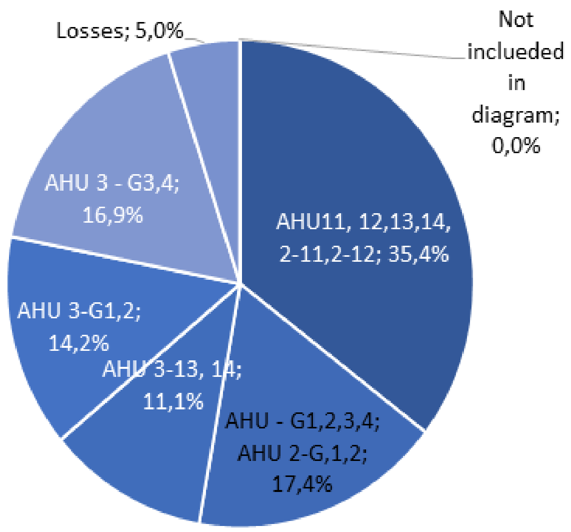



*Figure 12. Distribution of Electricity Consumption for the Cooling System*

The chart shows that areas AHU 11, 12, 13, 14, 2-22, and 2-12 consume the most electricity, accounting for 35.4%. Next are areas AHU G1,2,3,4 and AHU 2-G1,2, which account for 17.45%. The areas with the lowest consumption are AHU 3-13 and 14, representing 11.1%.

In general, a chiller with a COP greater than 4 is considered highly efficient. However, the Plant's operation can still be optimized to further improve chiller performance, as follows:

- Currently, the Plant operates four compressors alternately, including both inverter and non-inverter units. Typically, non-inverter compressors are used for base load, while inverter compressors are used for load trimming, which helps reduce the idle power consumption of the chillers;
- The AHU system is not yet equipped with inverters or smart control systems that can automatically adjust airflow, temperature and humidity based on sensors and algorithms, thus optimizing efficiency and saving energy. It is therefore necessary to reassess the load requirements and configure the AHU control system accordingly

# 2. Methodology Used to Identify EE Projects

## 2.1. How EE Projects Were Identified and Developed

The energy audit was conducted in accordance with Circular 25/2020/TT-BCT, “Regulations on Planning and Reporting the Implementation of Energy Efficiency and Conservation Plans; Conducting Energy Audits,” and aligned with EA guidance on auditing, energy mapping, project development, and project templates, including the Onion Diagram approach. For each layer of the Onion Diagram, it is essential to assess whether additional energy-saving measures and practices can be applied. Reducing energy consumption at the core layer has a cascading effect on secondary energy use, thereby maximizing overall efficiency.

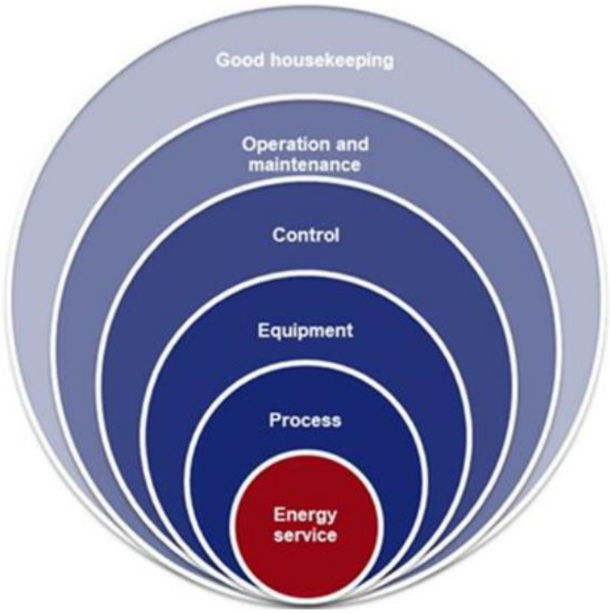



*Figure 13. Onion Diagram Approach for Identifying Energy Efficiency (EE) Opportunities*

**Energy Service**: “Energy service” refers to the specific requirement that a process must fulfill.

**Process:** “Process” refers to the type of method chosen to deliver the energy service. Alternative processes can often be considered to improve energy efficiency.

**Equipment:** “Equipment” relates to the energy efficiency of the tools and machinery used to carry out the process. Some equipment may inherently be less efficient, while others are designed to optimize energy use. One way to assess equipment efficiency is through the Total Cost of Ownership (TCO) approach, considering not only upfront costs but also operational energy consumption and maintenance costs.

**Control:** Control systems used to manage the process play a critical role in achieving energy-efficient operation. Processes often operate under varying conditions with fluctuating outputs, so control systems must adapt to maintain efficiency.

**Operation and Maintenance:** Operation and maintenance procedures are crucial for sustaining energy efficiency both in daily operations and over the long term. Focusing on regular maintenance and correct operation often leads to EE projects with little or no investment.

**Good Corporate Culture:** The culture and approach to energy management within a company have a limited impact on overall energy consumption**.**

Data collection at the enterprise was carried out using the following main methods:

- On-site surveys at the enterprise, including interviews with management staff and operational workers in each production unit and equipment area;
- Collection of records from the enterprise such as electricity consumption, biomass usage in recent years, and other documents related to equipment characteristics, production lines, and operating instructions;
- Use of specialized measurement devices (Table 5) to measure and analyze key equipment, areas, and energy-consuming lines within the enterprise. The data from this period were used for analysis and calculation;
- Collection of measurement indices from field meters installed by the enterprise, though some instruments were not periodically calibrated, leading to deviations in certain measurements;
- Some data were calculated using energy and mass balances based on other primary data collected through the methods outlined above.

***Table 7. List of Measurement Devices***

| No | Measurement Device | Model | Quantity | Made in |
|---|---|---|---|---|
| 1 | Kyoritsu Kyoritsu Power Analysis Equipment | 6315 | 01 | Japan |
| 2 | Clamp Meter | Extech EX720 | 01 | Germany |
| 3 | Environmental Measurement Equipment (temperature, air velocity, illumination, humidity) | Lutron LM8000A | 01 | Taiwan |
| 4 | Infrared Thermometer | Voltcraft IR 900-30S | 01 | Germany |
| 5 | Flue Gas Analysis Equipment | KIGAZ 310 | 01 | France |
| 6 | Infrared Temperature Measurement Equipment | TESTO 845 | 01 | Germany |
| 7 | Boiler Water Analysis Equipment | EC600 | 01 | Japan |

The Energy Map has been used to develop projects through the following methods:

- **Calculation and comparison of KPIs:** The method for calculating electricity consumption based on flow uses the rated power, operating time, and load factor of equipment in a production stage. The KPI-based electricity consumption calculation uses the standard energy consumption (kWh per ton of raw material) and the flow of material into a stage to evaluate the electricity use of that stage.

The flow-based method is simple, easy to understand, and easy to implement, but it does not accurately reflect other factors affecting electricity consumption such as equipment efficiency or operating conditions. The KPI-based method provides a more comprehensive view of energy efficiency, helping to identify issues and improvement opportunities; however, it is more complex, requiring more data and in-depth analysis.

The differences between the two calculation methods for heat and electricity consumption are mainly due to energy management practices at the enterprise. Currently, the enterprise only establishes energy consumption standards for finished products (tons of steam per ton of finished product and kWh per ton of finished product). Since Workshop I is the oldest production line, electricity consumption standards for Workshop I have not been established, and some production stages in other workshops also lack standards. Other factors that may lead to differences between these two methods include:

- **Material characteristics:** Different products may require different production processes, leading to different energy consumption levels even for the same product volume;
- **Equipment efficiency:** Equipment efficiency may vary over time, so the energy consumption per unit of finished product also changes;
- **Operating conditions:** Factors such as temperature, humidity, pressure, and other variables can affect equipment efficiency and thus energy consumption;
- **External factors:** Input material quality and equipment failures can also influence energy consumption.

The difference between the flow-based and KPI-based methods represents the potential energy savings that the enterprise can achieve.

- **Combining KPI calculations and temperature analysis:** By comparing steam consumption per ton of product according to KPI and flow-based methods, the expert team also found that the steam consumption of Workshop I was the highest at 3.4 tons, while other workshops ranged from 2.1–2.5 tons. The higher steam consumption in Workshop I is due to the use of outdated drying technology, where water removal before drying is low, resulting in paper moisture content of up to 80%, compared to 68% in Workshops II and III. The steam pressure in Workshop I's drying batch reaches only 1.4 bar, leading to low drying temperature, low evaporation efficiency, and inefficient heat recovery from evaporated steam. Steam pressures in Workshop II and III are 6 bar and 6.8–7 bar, respectively, allowing better drying capacity and improved reuse of hot air from the drying process.
- **Energy loss analysis:** By applying the Energy Map to calculate energy consumption, the audit team constructed charts showing electricity and heat use across workshops and areas within the enterprise. Thermal energy losses are the highest, far exceeding the thermal energy used in the workshops. This is a primary concern as thermal energy losses represent the largest portion of energy sources and need optimization to save costs. Thermal energy use in the three paper workshops accounts for a significant share of energy allocation. The drying system in Workshop I could be further improved through process optimization or equipment upgrades. Workshop V's drying system has lower thermal energy consumption compared to each Yankee drying system, but it is still substantial. Although unknown thermal energy is not large, understanding its source ensures more comprehensive data.

Energy consumption allocation charts have also been developed for workshops and the production processes within them, allowing the identification of processes where efficiency can be improved or wasted energy can be recovered to reduce operational and production costs.

Based on the Energy Map analysis and an in-depth review of utility systems, numerous observations with potential energy-saving opportunities were identified. A screening list of 29 observations related to energy use was compiled for further verification and discussion to uncover additional potential opportunities. The 11 most promising observations on this list were classified as **Level B projects**, with their potential energy savings and investment assessed based on available estimates.

The Level B project list was further evaluated, and 7 projects were selected for additional development. These selected projects are referred to as **Level A projects** and must be sufficiently developed to determine whether a pre-feasibility study should be undertaken.

### 2.2. Energy Efficiency (EE) Project Evaluation

During the energy audit, after assessing the current status at the enterprise, the expert team studied, proposed, and developed energy-saving solutions by identifying the following factors:

- **Annual energy savings**: in the form of electricity and heat, and evaluating the percentage of savings (%) compared to the current situation at the enterprise;
- **Cost savings after project implementation**: this cost is calculated based on reduced consumption of input energy (such as biomass, coal, electricity, water), increased product output, or savings from reduced operational labor;
- **Investment cost**: may include costs for workforce training, establishing management systems, purchasing new or replacement equipment, repairs, changes in energy type, production downtime for project implementation, environmental costs, etc.;
- **Payback period**: short-term, medium-term, or long-term;
- **CO2 emission reduction**: potential for direct and indirect CO2 reductions, and some projects may reduce CO2 emissions by using clean energy.

### 2.3. Prioritization of EE Projects

When selecting energy efficiency (EE) measures for enterprises, the following criteria were discussed, prioritized from highest to lowest:

- **Energy savings efficiency**
  - Reduction in electricity/fuel consumption (%);
  - Potential to improve overall energy efficiency.
- **Investment cost and payback period**
  - Total initial investment cost;
  - Payback period (short-term, medium-term, long-term);
  - Long-term financial benefits (operating and maintenance cost savings, electricity/fuel bills).
- **Impact on production/business operations**
  - Will it disrupt production?
  - Will it affect product/service quality?
- **Technical feasibility**

    - Is the technology compatible with existing systems?
    - Ease of integration into the enterprise's production/service processes;
    - Complexity of operation and maintenance.
- **Environmental impact and regulatory compliance**
    - Reduction of $CO_2$ emissions impacting the environment;
    - Compliance with energy standards (ISO 50001:2018, Law on Efficient and Sustainable Use of Energy);
    - Access to financial incentives from the government or clean energy support organizations.
- **Scalability and flexibility**
    - Potential for future expansion;
    - Ease of adjustment according to enterprise development needs

# 3. Identified Energy Efficiency (EE) Projects

## 3.1. Enterprise Feedback

Below is the energy saving potential identified in certain areas and key equipment of the enterprise, along with the enterprise's feedback on these solutions.

*Table 8. Summary of Findings from the Audit and Factory Feedback*

| No | Solution Description | Location | Equipment | Energy Saving | Energy Saving Potential (kWh) | Investment Cost (EUR) | Solution | Feedback of enterprise |
|---|---|---|---|---|---|---|---|---|
| **I. Entire Plant** | | | | | | | | |
| 1.1 | Improving KPI Development The plant manages energy consumption by setting KPIs for machines and workshops. However. for certain production lines, there is a significant gap between the calculated energy consumption and the KPI targets. Identifying the root causes of these large discrepancies will help improve the effectiveness of energy management for machines and production lines. | Entire Plant | All Equipment | Electricity | 57,454 | 6,506 | Implement an Energy Management System (EnMS) in accordance with ISO 50001:2018, integrated with the Energy Mapping Tool and the existing HIGG FEM standard | Should be implemented |
| **II. Electricity Section – Main Equipment** | | | | | | | | |
| 2.1 | VFDs ensure stable operation, flexible contr ol and energy savings. . | Washing Area | Washing Machine Drive Motor | Electricity | 53,939 | 4,000 | Install a frequency inverter for the washing machine | Should be implemented |

| No | Solution Description | Location | Equipment | Energy Saving | Energy Saving Potential (kWh) | Investment Cost (EUR) | Solution | Feedback of enterprise |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | drum motor | |
| 2.2 | Older sewing machines reduce machine efficiency, increase mechanical resistance, cause electrical energy losses, and lower product productivity. | Production Units | Sewing machines | Electricity | - | - | Gradually phase out ageing sewing machines | Should be considered |
| **III. Electrical Section – Auxiliary Equipment** | | | | | | | | |
| 3.1 | Check power quality of motors/pumps/fans; perform routine cleaning and inspect the operating condition of equipment components. | Auxiliary systems | Motors, pumps, fans | Electricity | - | - | Regular maintenance of motors, pumps, and fans | Should be implemented |
| 3.2 | Direct-drive fans improve energy efficiency and working environment. | Production Units | Ventilation System | Electricity | - | - | Gradually replace belt-driven ventilation fans with direct-driven fans | Recommended for consideration |
| 3.3 | Install temperature sensor for cooling tower fans. | Cooling Tower Workshop (2nd floor) | Cooling Tower Fan | Electricity | - | - | Install a temperature sensor for the cooling tower | Recommended for consideration |
| 3.4 | Identify degraded 18W fluorescent lamps with low | QC inspection | 18W fluorescent lamps | Electricity | 17,554 | 3,962 | Gradual replacemen | Should be implemented |

| No | Solution Description | Location | Equipment | Energy Saving | Energy Saving Potential (kWh) | Investment Cost (EUR) | Solution | Feedback of enterprise |
|---|---|---|---|---|---|---|---|---|
| | efficiency and gradually replace them with 18W LED lamps that offer higher efficiency and higher lux levels, reducing the total quantity from 800 units to 530 units. | tables, QA room, OBA | | | | | t of 18W fluorescent lamps with higher-efficiency LED lamps | |
| 3.5 | Install harmonic filters;<br>Add power factor correction capacitors;<br>Balance electrical phases | Entire Pla nt | Multiple Equipment incl, Auxiliaries | Electricity | - | - | Improve power quality | Should be implemented |
| 3.6 | Assign non-VFD units for base load and VFD unit for peak load to reduce unnecessary energy use. Reassess load demand to minimize cooling requirements. | hiller Workshop (2nd floor) | Chiller | Electricity | 131,102 | - | Optimize ch iller operation | Should be implemented |
| 3.7 | Includes AHU control unit; temperature sensors for load-based control of cooling valve; VFD for fans to reduce power under low load. | Production Units | AHU Fans and System | Electricity | 221,606 | 47,167 | Install an air flow and temperatur e control unit for the AHU | Should be implemented |
| | Assign tasks. mark leakage points, repair/replace joints. remove punctures/tears | Production Units | Air Compressed Distribution System | Electricity | - | - | Repair compresse d air leaks | Should be implemented |

| No | Solution Description | Location | Equipment | Energy Saving | Energy Saving Potential (kWh) | Investment Cost (EUR) | Solution | Feedback of enterprise |
|---|---|---|---|---|---|---|---|---|
| | ; keep a leak log; monitor using leak detection equipment, sound/touch inspection. or soapy water. | | | | | | in the compressed air distribution system | |
| **IV. Thermal Section – Main devices** | | | | | | | | |
| 4.1 | The factory currently uses steam at 6 bar for the washing/drying process after the finishing sewing stage. However, the actual washing water temperature only needs to be around 40–50°C. The heat demand for the washing process is relatively low, which falls well within the efficient operating range of a solar hot water system, meaning high-pressure steam is not necessary to meet the process requirements. | Washing area | Industrial washing machines | Thermal energy | - | - | Install a solar hot water system to supply hot water for the washing process | Worth considering |
| **V. Heat – Auxiliary Equipment** | | | | | | | | |
| 5.1 | The flue gas temperature of the boiler system is very high (over 206 °C) and can be used to preheat the boiler feedwater. Install a flue gas heat recovery | Boiler area | Boiler | Thermal energy | 37,000 | 3,920.16 | Install flue gas heat recovery economizer | Should be implemented |

| No | Solution Description | Location | Equipment | Energy Saving | Energy Saving Potential (kWh) | Investment Cost (EUR) | Solution | Feedback of enterprise |
|---|---|---|---|---|---|---|---|---|
| | economizer to reduce the boiler fuel consumption. | | | | | | | |
| 5.2 | The factory needs to control the conductivity of boiler blowdown water at around 5,500 µS/cm by performing regular conductivity checks; invest in a boiler water conductivity meter and adjust the blowdown frequency accordingly | Boiler area | Boiler | Nhiệt năng | 50,393 | 163.34 | Adjust blowdown operation | Should be implemented |
| 5.3 | Investigate reducing paper breaks. Causes may relate to condensation, material mix, and chemicals used.. | Thermal system area | Boiler, thermal oil heater | Thermal energy | - | - | Install a new 2,000 kW thermal oil heater combined with 1 t/h steam generation, using high-efficiency biomass combustion to fully replace the old thermal oil heater | Should be implemented |

| No | Solution Description | Location | Equipment | Energy Saving | Energy Saving Potential (kWh) | Investment Cost (EUR) | Solution | Feedback of enterprise |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | and low-efficiency oil-fired boilers | |
| 5.4 | Inspect and maintain the deaerator; establish a regular maintenance plan. | Thermal system area | Thermal oil heater | Thermal energy | 6,776 | 0 | Renovate the deaerator to recover heat from thermal oil flue gas | Should be Applied |
| 5.5 | Using a frequency inverter to control the diesel-fired boiler fan based on flue gas oxygen concentration both saves electricity for the fan and reduces fuel consumption for the boiler. | Boiler area | Boiler and thermal oil heater | Thermal energy | - | - | Install an oxygen sensor in the flue gas and use the existing frequency inverter to control the boiler and thermal oil heater fans according to the oxygen signal | Should be implemented |

### 3.2. Identified EE Projects (Level B)

The table below summarizes the findings identified during the audit and measurements (Level B).

***Table 9. Summary of Projects (Level B Energy Map)***

| No | Solution Description | Energy Saving Potential *(kWh/year)* | Cost Saving *(EUR/year)* | Investment Cost (based on experience) *(EUR)* | Payback Period (year) |
|---|---|---|---|---|---|
| 1 | Implement an Energy Management System (EnMS) according to ISO 50001:2018 combined with the Energy Map and existing HIGG FEM standard | 68,349 | 3,548 | 6,506 | 1.8 |
| 2 | Optimize Chiller operation | 131,102 | 8,279 | - | - |
| 3 | Install air flow and temperature controllers for AHUs | 221,606 | 13,994 | 47,167 | 3.4 |
| 4 | Gradually replace belt-driven ventilation fans with direct-driven fans | - | - | - | - |
| 5 | Repair leaks in the compressed air distribution system | - | - | - | - |
| 6 | Install temperature sensors for cooling towers | - | - | - | - |
| 7 | Improve power quality | - | - | - | - |
| 8 | Install a deaerator to recover heat from boiler flue gas | 37,000 | 1,992 | 3,920 | 2.0 |
| 9 | Adjust boiler blowdown settings | 50,393 | 2,924 | 163 | 0.06 |

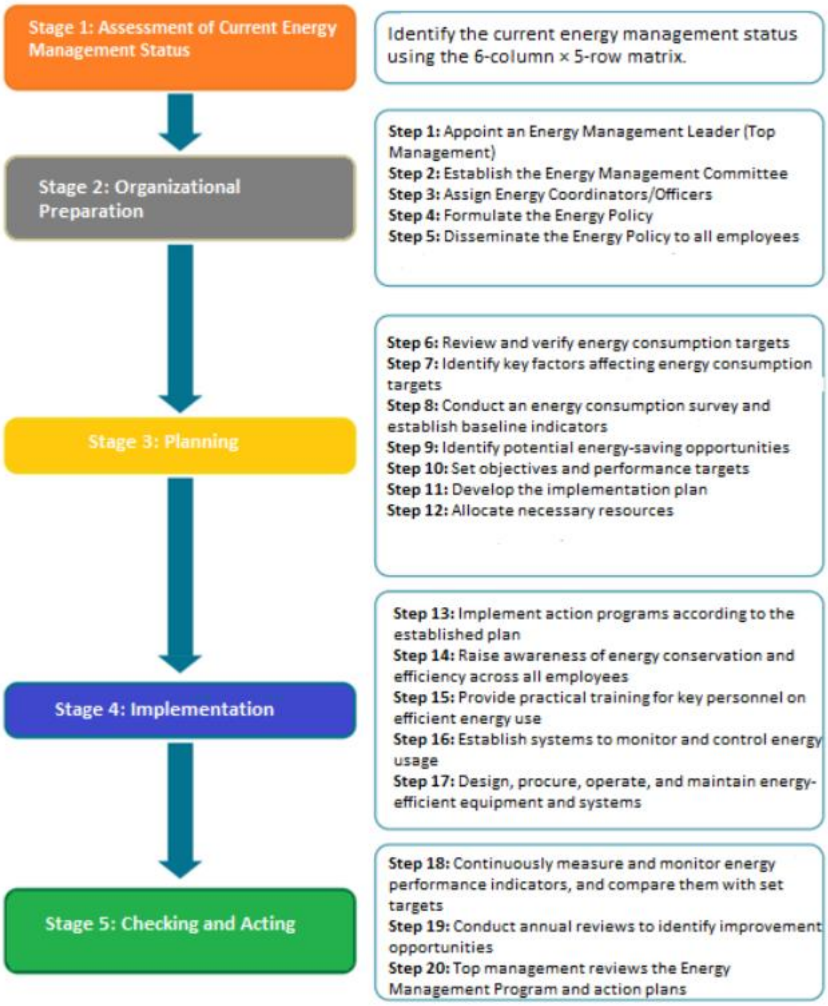
| No | Solution Description | Energy Saving Potential *(kWh/year)* | Cost Saving *(EUR/year)* | Investment Cost (based on experience) *(EUR)* | Payback Period (year) |
|---|---|---|---|---|---|
| 10 | Install a new 2,000 kW thermal oil heater combined with a 1 t/h steam generator, using high-efficiency biomass to replace existing thermal oil heaters and low-efficiency oil-fired boilers | - | - | - | - |
| 11 | Renovate the boiler deaerator to recover heat from thermal oil flue gas | 6,776 | 359 | 0 | 0 |
| 12 | Install an oxygen sensor in the flue gas and use the existing frequency inverter to control the boiler and thermal oil heater fans based on the oxygen signal | - | - | - | - |
| 13 | Install a frequency inverter for industrial washing machine motors | 53,939 | 3,500 | 4,000 | 1.2 |

# 4. EE Projects Selected for Further Support

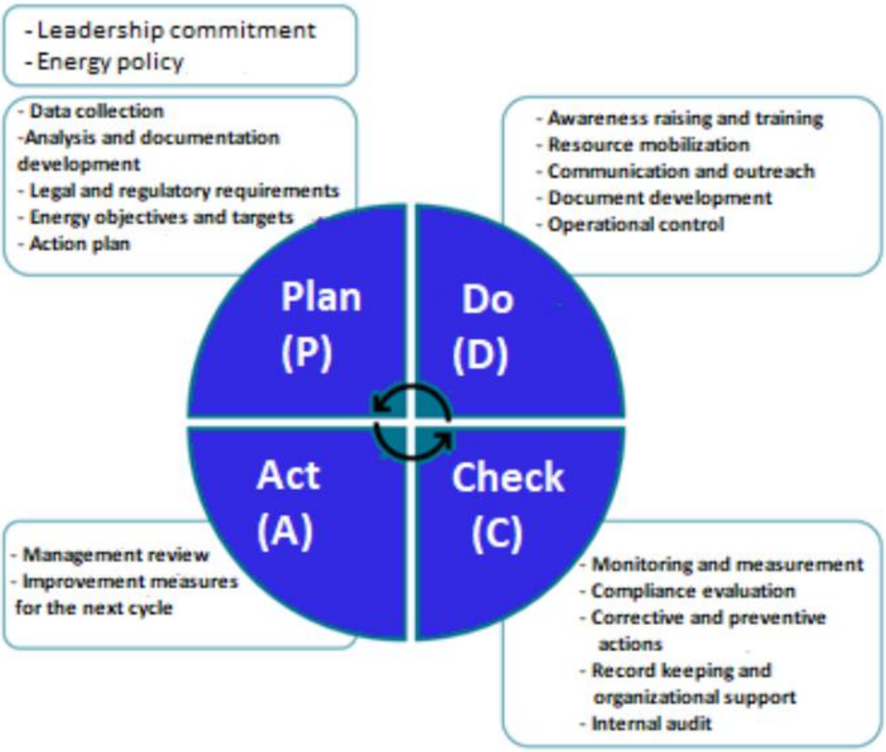
This section includes the projects selected for further development (Level A). The tables below summarize the findings identified during inspection and measurement (Level A).

***Bảng 10. Project: “Implementing an Energy Management System (EnMS) according to ISO 50001:2018 combined with the existing Energy Map and HIGG FEM standards”***

<table>
<tr><th colspan="3">Project information</th></tr>
<tr><td>Project: Implementing an Energy Management System (EnMS) according to ISO 50001:2018 combined with the existing Energy Map and HIGG FEM standards</td><td>Project No 1</td><td>Date:</td></tr>
<tr><td>Enterprise:</td><td>Auditing Unit: ENERVI Environmental Energy Joint Stock Company, Vietnam</td><td>Lead Auditor: Nguyen Xuan Quang</td></tr>
<tr><th colspan="3">Project Description</th></tr>
<tr><td colspan="3">Current Status:<br><br>The plant has implemented basic energy management measures, including a long-term energy savings roadmap and a data monitoring system aligned with HIGG FEM standards. An Energy Management Team has been established, and budgets have been allocated for energy-saving projects. However, a formal energy policy has not yet been issued, and the current strategy prioritizes emission offsets through the purchase of Renewable Energy Certificates (RECs) rather than improving intrinsic efficiency.<br><br>Key challenges include organizational capacity and data management: the Energy Management Team operates on a part-time basis with no dedicated staff; production/operation data is often delayed and incomplete, hindering analysis, proposal development, and solution implementation. Additionally, the company lacks comprehensive energy-economic analysis (e.g., cost/ROI assessment), leading to missed opportunities for long-term benefits that do not provide immediate returns.<br><br>The plant has a strong technical foundation and investment commitment. However, without strengthening dedicated personnel, addressing data provision limitations, and integrating cost analysis into decision-making, the current roadmap will struggle to translate into real and sustainable energy savings. The Energy Map provides a foundational dataset to address these issues, offering detailed insights into energy flows, process diagrams, and supporting systems based on 2024 data.</td></tr>
<tr><td colspan="3">Proposed Project<br><br>The energy audit team proposes the solution: “Implement an Energy Management System (EnMS) according to ISO 50001:2018, combined with the existing Energy Map and HIGG FEM standards” through the following steps:</td></tr>
</table>




## Project Illustration (PFD)




Energy Management System Model by Cycle PDCA

## Project Budget

| | | | | | |
|---|---|---|---|---|---|
| **Total** | **6.500 EUR** | | | | |
| **TIMELINE** | | | | | |
| **Year** | **2025** | **2026** | **2027** | **2028** | **Sau 2028** |
| **Project timeline** | | | | | |
| **Saving** | | | | | |
| **Energy (Annual): 82,076 kWh** | | | **Financials (Annual): 5,200 EUR** | | |
| **CO2 (Annual): 54 tCO2** | | | **Simple Payback (year): 1.3** | | |

**Risk Analysis**

**Risks:**

- Requires initial investment and dedicated implementation resources.
- Potential resistance from staff due to lack of awareness of long-term benefits.
- Payback period may be extended if the system is not maintained effectively.

**Risk Mitigation Recommendations:**

- Provide training and raise awareness among employees..
- Ensure periodic audits of the system to maintain its effectiveness.

**Non-energy benefit**

| **Increase the Competitiveness of the Enterprise** | **Reduce Greenhouse Gas Emissions** | **Compliance with Regulations** |
|---|---|---|
|  |  |  |

*Table 11. Project "Installation of Airflow and Temperature Control Units for AHU"*

| | | |
|---|---|---|
| **Project information** | | |
| **Project: "Installation of Airflow and Temperature Control Units for AHU"** | **Project No 2** | **Date:** |
| **Enterprise:** | **Auditing Unit: ENERVI Vietnam Energy and Environment JSC** | **Lead Auditor: Nguyen Xuan Quang** |

**Project Description**

**Current Status:**

The AHU systems are installed in the workshops, with two AHUs per workshop to maintain a temperature of 27°C–28°C. However, the operation still has some issues as follows:

- The fans are manually controlled based on workshop temperature since temperature sensors have not been installed and the valves are not yet controlled by variable frequency drives (VFDs).
- The AHU systems are not equipped with an intelligent control system that can automatically adjust airflow, temperature, and humidity based on sensors and algorithms.
- The load demand does not account for cool air circulating in wide and long corridors, which are designed to connect workshops on the first floor without

closing doors. This increases cooling demand. Although the factory has wind barrier doors, their operation is not effective.

This operational method consumes more energy than necessary, leading to unnecessary energy losses.

**Proposed Project:**

The energy audit team proposes the solution: *"Installation of Airflow and Temperature Control Units for AHU"* through the implementation of the following systems:

- AHU operation control units;
- Temperature sensors based on load demand to adjust cooling airflow by controlling the cooling supply valves;
- Variable frequency drives (VFDs) for fans to reduce power when load demand decreases.

**Project Budget**

| | |
|---|---|
| **Total** | **47,167 EUR** |

**TIMELINE**

| **Year** | **2025** | **2026** | **2027** | **2028** | **Sau 2028** |
|---|---|---|---|---|---|
| **Project timeline** | | | ■ | ■ | ■ |

**Saving**

| | |
|---|---|
| **Energy(annual): 221,606 kWh** | **Finance (Annual): 13,994 EUR** |
| **CO2 (annual): 146 tCO2** | **Simple Payback (year): 3.4** |

**Risk analysis**

**Risk:**

- Requires high investment costs.
- Long payback period for this type of lighting solution.
- Requires personnel to manage and maintain the intelligent control system.

**Risk Mitigation Recommendations:**

- Develop a gradual replacement roadmap.
- Seek funding support for implementation.
- Train skilled personnel to keep up with new technology.

**Non-energy benefits**

| **Increase the company's competitiveness** | **Reduce greenhouse gas emissions** |
|---|---|
|  |  |

*Table 12. Installation of a Feedwater Economiser to Recover Boiler Flue-Gas Waste Heat*

<table>
<tr><th colspan="3">Project Information</th></tr>
<tr><td>Project: Installation of a Feedwater Economiser to Recover Boiler Flue-Gas Waste Heat</td><td>Project No. 3</td><td>Date:</td></tr>
<tr><td>Enterprise:</td><td>Audit Unit:<br>ENERVI Vietnam Energy & Environment Joint Stock Company</td><td>Lead Auditor:<br>Nguyen Xuan Quang</td></tr>
<tr><th colspan="3">Project description</th></tr>
<tr><td colspan="3">

**Current Status:**

At present, the feedwater temperature supplied to the boiler is approximately 70°C. The plant has already installed several heat-recovery systems to preheat the feedwater, including: a waste-water heat recovery unit from the washing process, a feedwater heater utilising thermal oil furnace flue gas, and a feedwater heater using thermal oil. Measurement data indicate that the flue-gas temperature of the boiler system remains very high (over 206°C). Consequently, the heat loss through boiler flue-gas exhaust is significant. The high flue-gas temperature provides an opportunity for additional heat recovery to preheat the boiler feedwater, thereby reducing the boiler's specific fuel consumption. The following presents the recorded flue-gas temperature results

:


Measured Boiler Flue-Gas Temperature Results

</td></tr>
<tr><td colspan="3">

**Proposal Project:**

**The energy audit team recommends the solution: "Installation of a Feedwater Economizer to Recover Boiler Flue-Gas Waste Heat."**

To implement this solution, the plant should carry out the following actions:

- Contact equipment suppliers;
- Conduct on-site surveys to obtain comprehensive installation quotations;
- Review the quotations and select a supplier;
- Proceed with contract signing and installation execution.

</td></tr>
<tr><th colspan="3">Project budget</th></tr>
</table>

| | |
|---|---|
| **Total** | **3.920,16 EUR** |

| **TIMELINE** | | | | | |
|---|---|---|---|---|---|
| **Year** | **2025** | **2026** | **2027** | **2028** | **Sau 2028** |
| **Project Timeline** | | | | | |

| **Saving** | |
|---|---|
| **Energy (annual): 37,000 kWh** | **Finance (annual): 1,992.75 EUR** |
| **$CO_2$ (annual): 10 $tCO_2$** | **Simple payback (year): 2** |

| **Risk analysis** |
|---|
| **Risk:**<br>• Flue-gas temperature that is too low may cause condensation, leading to corrosion of the piping system.<br>• Improper design of the feedwater economizer can increase airflow resistance, reduce boiler efficiency, and affect the operation of the induced draft and forced draft fans.<br>**Proposed Risk Mitigation Measures:**<br>• Calculations to maintain the flue-gas temperature after the economiser above the dew point.<br>• Calculations to ensure a sufficiently large gas flow cross-sectional area in the economiser design.<br>• Use appropriately sized piping and arrange it properly to minimize pressure losses. |

**Non-Energy Benefits**

| **Increase the company's competitiveness** | **Reduce greenhouse gas emissions** |
|---|---|
|  |  |

*Table 13. Project: "Adjustment of Boiler Blowdown Regime"*

| **Information Project** | | |
|---|---|---|
| **Project: "Adjustment of Boiler Blowdown Regime"** | **Project No. 4** | **Date:** |
| **Enterprise:** | **Audit Unit:**<br>**ENERVI Vietnam Energy & Environment Joint Stock Company** | **Lead Auditor:**<br>**Nguyen Xuan Quang** |

| **Project Description** |
|---|
| **Current Status:**<br>During the audit, the energy audit team observed the following:<br>• The conductivity of the feedwater is 109,5 μS/cm, meeting the standard for boiler feedwater; |

- The conductivity of the bottom blowdown water is very low at 380 µS/cm, below the recommended operational range of 5.000 – 6.000 µS/cm.


Analysis of Feedwater and Boiler Blowdown Water

The conductivity of boiler water reflects the concentration of dissolved solids (TDS – Total Dissolved Solids). During boiler operation, as steam is generated, dissolved substances accumulate in the boiler water, increasing its contamination level. Blowdown removes this concentrated "dirty" water, allowing fresh, clean water to replace it and maintain boiler water quality. The frequency of blowdown should correspond to the quality of the feedwater and the amount of steam produced.

Currently, the boiler undergoes periodic bottom blowdown, with one blowdown per production shift. This regime is designed for full-load boiler operation and feedwater quality meeting the manufacturer's standards. However, it is not entirely suitable because the boiler often operates at partial load. At lower steam production rates, it takes much longer for the concentration of impurities in the water to reach the threshold requiring blowdown. Therefore, the current blowdown practice may result in unnecessary water and energy losses.

**Proposed Project:**

The expert team recommends the solution: **"Adjustment of Boiler Blowdown Regime."** The plant should control the conductivity of blowdown water at approximately 5.500 µS/cm through regular conductivity monitoring. This involves investing in boiler water conductivity measurement equipment to check and adjust the blowdown frequency appropriately.

**Project Budget**

| | |
|---|---|
| **Total** | **165.02 EUR** |

**TIMELINE**

| **Year** | **2025** | **2026** | **2027** | **2028** | **Sau 2028** |
|---|---|---|---|---|---|
| **Project Timeline** | | | | | |

**Saving**

| | |
|---|---|
| **Energy (annual): 48,544 kWh** | **Finance (annual): 2,937.35 EUR** |
| **CO2 (annual): 13 tCO2** | **Simple payback (year): 0.06** |

**Risk analysis**

**Risks:**

- Insufficient bottom blowdown (below the required rate) may cause scaling, reduce heat transfer efficiency, and increase fuel consumption.
- Excessive bottom blowdown (above the necessary rate) leads to higher costs for water, water treatment, softening chemicals, and loss of hot water, resulting in increased fuel consumption.

**Proposed Risk Mitigation Measures:**

- Conduct regular TDS measurements (daily or per shift) and maintain comprehensive records.
- Keep a blowdown logbook documenting the time, flow rate, and TDS before and after blowdown.
- Perform periodic calibration of TDS measurement equipment.
- Implement an automatic control system, if available, using TDS sensors and automatic blowdown valves.

**Non-Energy Benefits**

| Increase in Business Competitiveness | Reduction of Greenhouse Gas Emissions | Improved Operational Handling |
|---|---|---|
|  |  | ***Reduction in Daily Boiler Blowdown Frequency*** **.** |

***Table 14. Project: "Installation of a New 2.000 kW Thermal Oil Furnace Combined with a 1 t/h Steam Boiler, Fully Fired by High-Efficiency Biomass to Replace Existing Thermal Oil and Low-Efficiency Oil-Fired Boilers"***

| **Project Information** | | |
|---|---|---|
| **Project: "Installation of a New 2.000 kW Thermal Oil Furnace Combined with a 1 t/h Steam Boiler, Fully Fired by High-Efficiency Biomass to Replace Existing Thermal Oil and Low-Efficiency Oil-Fired Boilers"** | **Project no 5** | **Date:** |
| **Enterprise:** | **Audit Unit:**<br>**ENERVI Vietnam Energy & Environment Joint Stock Company** | **Lead Auditor:**<br>**Nguyen Xuan Quang** |
| **Project Description** | | |

**Currently Status:**

The plant's heat supply system consists of two thermal oil boilers with capacities of 1.400 kW and 1.754 kW, and one steam boiler with a capacity of 2 t/h. All three boilers operate 24 hours per day under an on/off control mode. The two thermal oil boilers operate alternately according to load demand, which depends on the production schedule. The fuel for both the thermal oil boilers and the steam boiler is diesel.

The combustion of diesel and other fossil fuels such as coal and natural gas generates a significant amount of greenhouse gases, causing numerous negative environmental impacts. Specifically, burning fossil fuels produces large quantities of $CO_2$ and other pollutants such as $NO_2$, $SO_2$, and particulate matter. Additionally, the extraction, processing, and distribution of diesel fuel have substantial adverse effects on natural ecosystems and the surrounding environment.

Although biomass combustion also produces greenhouse gases, the $CO_2$ emitted during combustion is roughly equivalent to the $CO_2$ absorbed during plant growth. Therefore, biomass can be considered a carbon-neutral fuel source.

Diesel Fuel Consumption for the Plant's Heat Supply System

| **Year** | **Diesel Oil** *(l)* | **$CO_2$ Emission** *(ton)* |
|---|---|---|
| 2022 | 628,120 | 1,715 |
| 2023 | 353,081 | 964 |
| 2024 | 329,182 | 899 |

Currently, the plant's oil-fired and steam boilers operate in a dispersed manner, which is an inefficient operation method because:

- The boilers operate in an on/off mode depending on production heat demand, consuming significant energy for start-up and maintenance, while also reducing the structural lifespan of the boilers;
- The average efficiency of the boilers is low;
- Implementing energy-saving measures individually for each boiler requires higher investment costs and yields limited improvement in the overall system efficiency;
- The three boilers are installed separately, occupying a large amount of floor space in the workshop.

**Proposal project:**

After calculating the heat demand for the fabric processing stage supplied by the thermal oil and the heat demand for the washing and drying stages supplied by steam, the expert team proposes the solution: "Installation of a new 2,000 kW thermal oil furnace combined with a 1 t/h steam boiler, fully fired by high-efficiency biomass, to replace the existing thermal oil and low-efficiency oil-fired boilers**."**

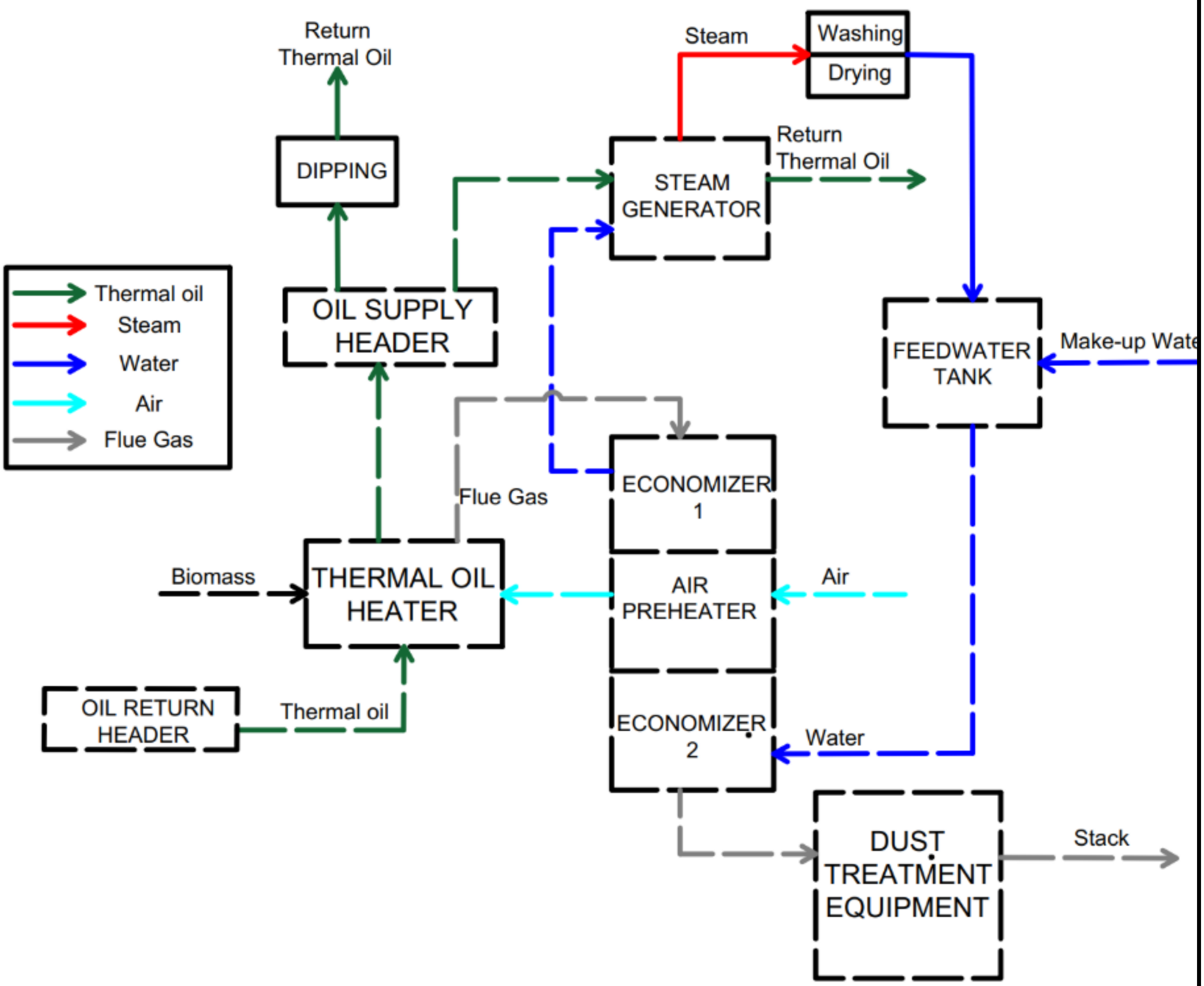
Investing in a large-capacity biomass-fired thermal oil furnace and operating it in a centralized manner will provide the following advantages:

- The new 2.000 kW thermal oil furnace will use bark and wood chips (biomass residues) as fuel, replacing the current diesel fuel. Bark and wood chips are inexpensive and readily available.

- Centralized operation of the high-capacity boiler facilitates easier control and improves boiler operation efficiency.
- It reduces emissions of greenhouse gases such as $CO_2$, $SO_2$, etc., by eliminating fossil fuel use.
- Investing in a high-capacity boiler provides reserve capacity to meet potential future production expansion.
- Reduces the spatial footprint of the heat supply system.

New Biomass Fuel to be Used Upon Implementation of the Solution

**Project Illustration (PFD)**




*Thermal system diagram of the Plant after implementing the solution*

**Project budget**

| | |
|---|---|
| **Total** | **EUR** |

<table>
<tr><th colspan="6">TIMELINE</th></tr>
<tr><td>Year</td><td>2025</td><td>2026</td><td>2027</td><td>2028</td><td>Sau 2028</td></tr>
<tr><td>Project timeline</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th colspan="6">Saving</th></tr>
<tr><td colspan="3">Energy (Annual): kWh</td><td colspan="3">Finance (annual): EUR</td></tr>
<tr><td colspan="3">Co2 (annual): tCO2</td><td colspan="3">Simple payback (year):</td></tr>
<tr><th colspan="6">Risk analysis</th></tr>
<tr><td colspan="6"></td></tr>
<tr><th colspan="6">Non-Energy Benefits</th></tr>
<tr><td colspan="3">Increase in Business Competitiveness</td><td colspan="3">Reduction of Greenhouse Gas Emissions</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
</table>