The Danish Energy Agency

Anonymous Audit Report

Enervi Vietnam Energy and Environment JSC, 14/04/2025

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 anonymised summary of a specific energy audit report conducted as a part of the DEPP3 program. The audit has been conducted on a paper production plant, by Enervi Vietnam Energy and Environment JSC, in collaboration with an international expert from Viegand Maagøe.

Summary

This is a paper manufacturing factory with two main types of paper including fine printed paper and Tissue paper. These products are manufactured using two different technological lines. The fine printed paper production line in workshop V, with a design capacity of 15,000 tons per year, has been operational since 2006, employing alkaline papermaking technology. The Workshop I,II, III produce tissue paper including **14 production lines**, with a design capacity of 45,950 tons per year, and the latest line installed in 2023. Fine printed Paper product of is produced from commercial bleached pulp, unused edges, and recycled edges, whereas Tissue paper is made from virgin pulp mixed with recycled trimmings from its own production process.

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

The audit primarily focused on key operational areas, including production lines, compressed air systems, boilers, and lighting systems. In addition to on-site surveys, discussions with technical staff and operators provided valuable input for identifying practical solutions. The proposed EE measures fall into three main categories indicating the following table:

Table 1. Summaries of proposed EE solutions

No	List of proposed EE solution
I. Management solution	
1	Enhancing Energy Management Efficiency and Establishing an ISO 50001-Compliant Energy Management System
2	Fuel Management Solutions for the Steam Supply System
II. Technical solutions	
3	Reducing Intake Air Temperature for Compressor Room 1
4	Reducing Intake Air Temperature for Compressor Room 3
5	Installing a Rooftop Solar Power System on Factory Buildings
6	Upgrading the Economizer or Air Preheater to Optimize Waste Heat Recovery from Boiler 15T2.1
7	Adjusting Flue Gas Oxygen Levels for Boiler 12T2.1
8	Installing a New High-Efficiency 25-Ton Biomass-Fired Boiler to Replace Low-Efficiency Coal and Biomass Boilers
9	Replacing Seven Small Boilers with a Single 35-Ton Boiler Integrated with a Power Generation Turbine
III. Recommended solution	
10	Installing Power Factor Correction Equipment at Transformer Stations 5, 6, 10, and 13 with Low Power Factors
11	Installing Harmonic Filters for Transformer Station 4, the Workshop V Production Line, Paper Machine 9 at workshop I (Branches 2, 3, and 4), Paper Machine 11 (Branch 2), the 110kW Hydraulic Pulper at workshop II

No	List of proposed EE solution
	and workshop I, Air Compressor 7 (Compressor Room 2), Air Compressor 1 (Compressor Room 3), and Air Compressor 1 (Compressor Room 4)
12	Rebalancing Phases for Transformer Station 7 and the 90kW Fluffing machine at workshop III
13	Utilizing Waste Heat from Boiler Blowdown (Boilers 15T2.1 and 20T2.1) for Preheating Feedwater
14	Replacing Pressure-Reducing Valves with Pressure reducing valves with desuperheater to Improve Heat Exchange Efficiency and Increase Feedwater Temperature

The combined implementation of these measures is expected to yield significant energy savings of 21,778 MWh for electricity energy and 289.885 GJ for heat energy, cost-saving of about 50 billion vnd, and environmental benefits for the company with emission reduction of about 63.853 tCO_2.

1 About the enterprise

The enterprise operating a paper production factory with 2 types of paper including fine printing paper in Workshop V and Tissue paper in other Workshops. There are 15 paper production lines for that 1 production line producing fine printing paper and other 14 production lines produce Tissue paper. Thoser production lines devided into workshops based on the locations for that:

- Workshop V located 1 fine printing paper line
- Workshop I, II, III located tissuel paper lines
- Workshop VI located the machinery for finished production process

The paper production lines using the Chinese technology, Japanese technology and Austria Technology.

There are some other areas including:

- Boiler Workshop including boiler workshop 1 serving for workshop V and workshop I; boiler workshop 2 serving for workshop II and III based on the location of the workshops.
- Auxiliary area
- Office building

The company shows a great desire for management and energy-saving solutions.

1.1 Description of the company

- Sector: Paper
- Main raw materials: Pulp, unused paper edges
  - Pulp: 70,066 (ton/year)
  - Unused paper edges: 2.073 (ton/year)
- Main products: fine printing Paper
  - Fine printing paper: 19,710 (ton/year)

- Tissue paper: 59,353 (ton/year)

- Total energy consumption in 2023
  - Electricity: with 100% electricity from the national grid of 56.314.600 (kWh), equivalent to 8,941 (TOE), 56,314(MWh)
  - Coal: 73,239,589 (kWh), equivalent to 7,544 (TOE), 73,239 (MWh)
  - Biomass: 259,258,166 (kWh), equivalent to 18,884 (TOE), 259,258 (MWh)
  - DO oil: 949,404 (kWh), equivalent to 96 (TOE), 949 (MWh)
- Annual carbon footprint: tCO_2 (Unknown)

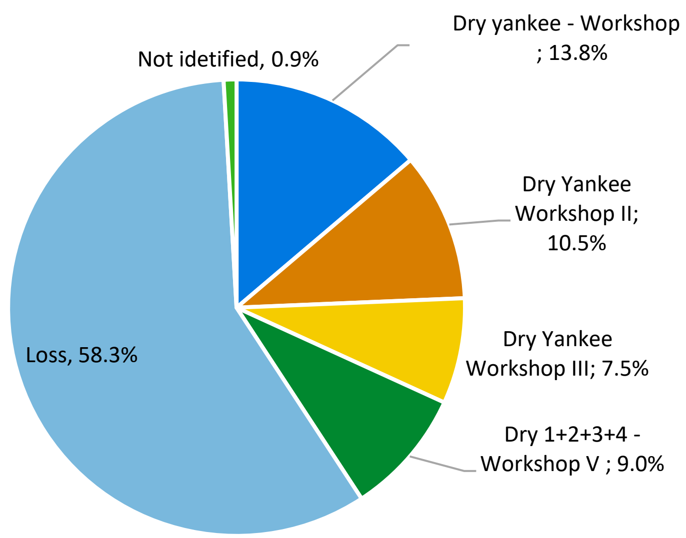


Figure 1. ***Heat distribution***

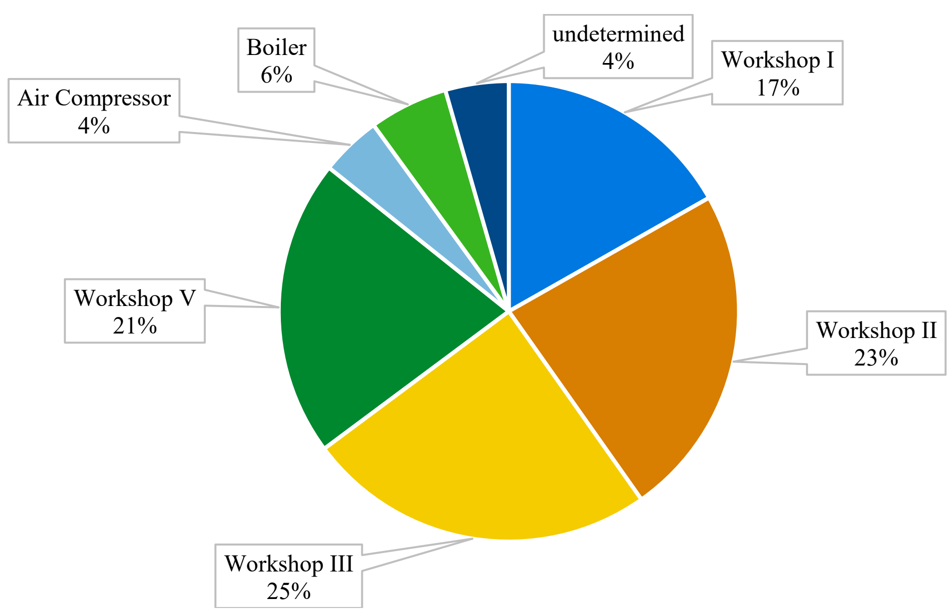


Figure 2. ***Electricity distribution for the whole plant***

Figure 1 shows the main heat energy consumers in the plant. Heat losses account for the largest proportion in the heat energy distribution chart. This shows that there is a significant waste of thermal energy in the drying system in the 4 workshops. This can be an opportunity to implement steam system optimization to minimize steam losses. The heat energy supplied to the Yankee drying system in the workshops accounts for a significant proportion (more than 1/3 of the heat energy used). The drying system in the Workshop V has a lower but still remarkable thermal energy consumption. A small portion of the thermal energy is not determined due to lack of data or inaccurate measurements. The thermal energy of the plant is provided by 2 boiler workshops with the main input fuels being coal and biomass.

Figure 2 shows the distribution of key electricity consumers in the plant. Workshop III is the largest power consuming production line, accounting for 25% of the total electricity consumption of the factory. This shows that this line is large-scale or uses a lot of large-capacity equipment. The workshop II also consumes a significant amount of electricity, second only to Workshop III . Workshop V consumes about 21% of the total electricity. Workshop I is the paper production line that consumes smallest among 4 workshops, accounting for about 17%. The rest is the electricity consumed for auxiliary systems such as boilers and air compressors. A small percentage of electricity consumption has not been clearly defined, either because it has not been classified or by other auxiliary equipment.

The majority of the mill's electricity is used directly for the paper production lines. The fact that part of the electricity consumption has not been determined shows that there are still points for improvement in energy management in the plant.

1.2 Description of the process

The company produces two main types of products including Fine printing paper and Tissue paper. These two types of paper are produced from 2 different technology lines as follows:

Table 2. List of the production technology of the plant

Item	fine printing paper	tissue paper
Design capacity (ton/year)	15,000	45,950
Operation years	2005	2005
Raw materials	Commercial pulp and unprinted white paper margins	Virgin pulp, and circulating marginal paper from the disc filter system
Type of technology	Alkaline paper spinning technology	Total of 14 lines using old Chinese technology; Japanese technology and Austrian Technology
Main stage	- Pulp preparation, - Paper Machine, and - Product finishing (including a roll cutting system and a system for cutting sheets, slitting and packaging finished products) **Details in Figure 3**	- Pulp preparation, - Paper Machine **Details in Figure 4, 5, and 6**

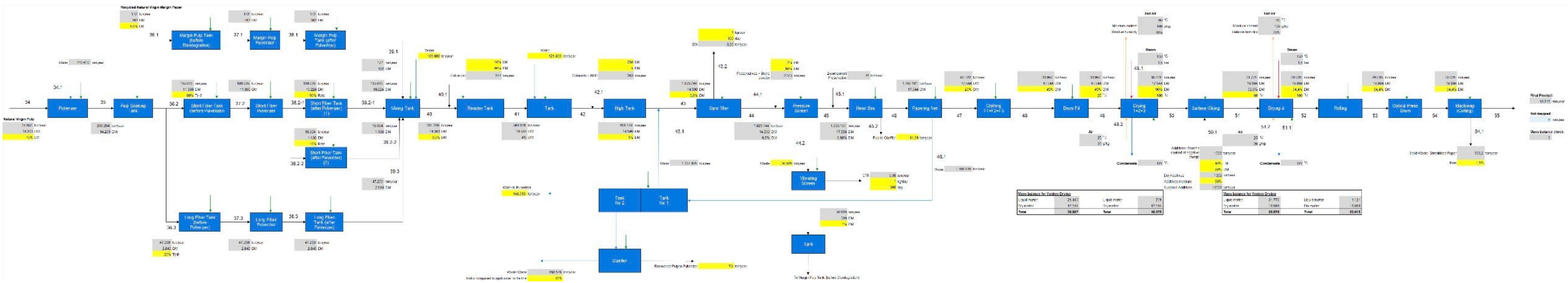


Figure 3. Paper Production Line Diagram in workshop V

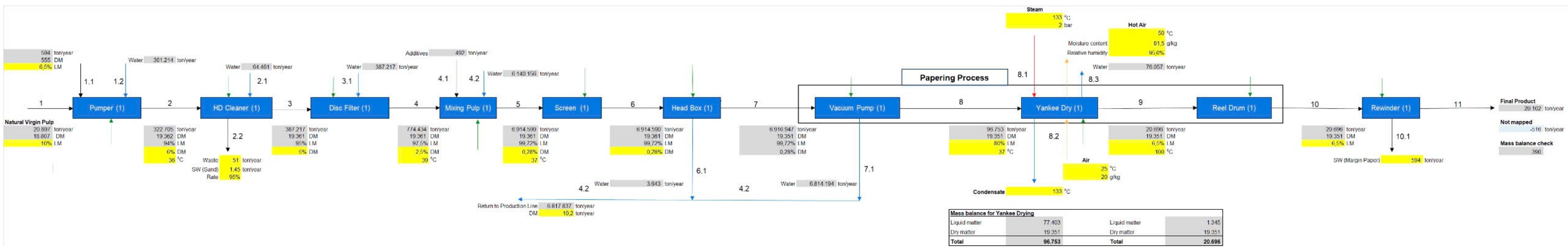


Figure 4. *Paper production line of Workshop I*

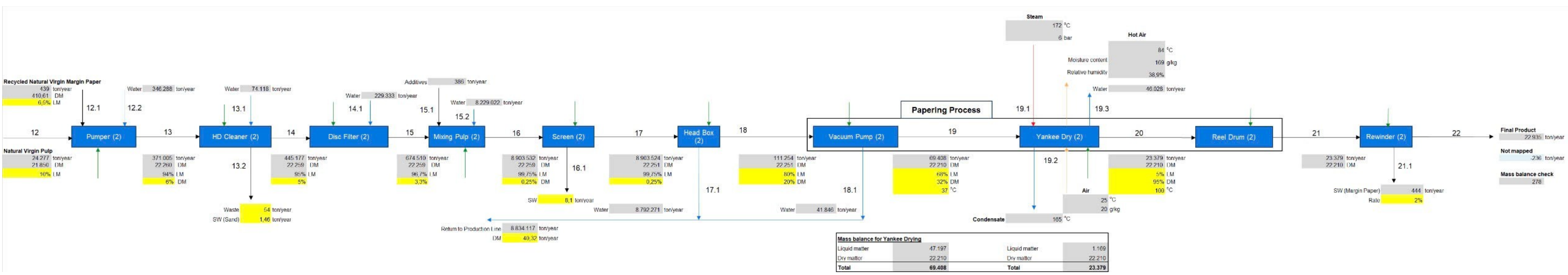


Figure 5. *Paper production line of Workshop II*

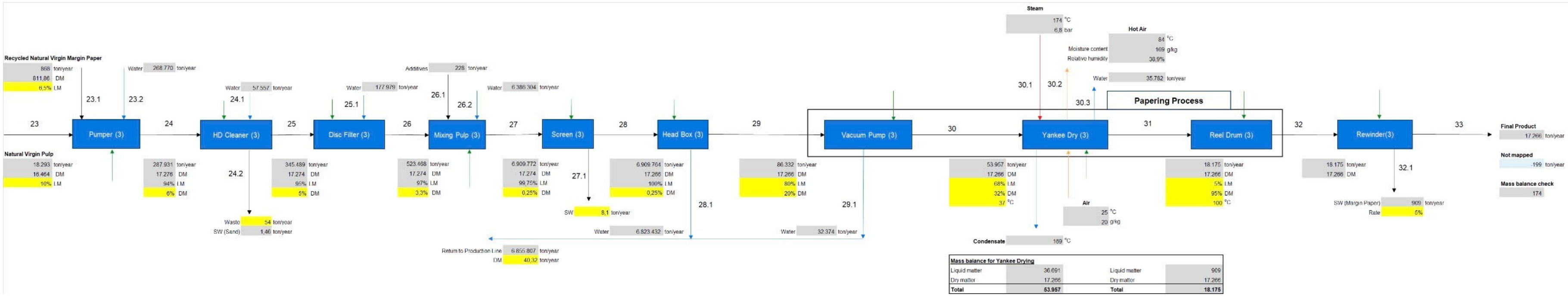


Figure 6. ***Paper production line of Workshop III***

From the field survey by Danish experts and the results of the Energy audit team after measuring and evaluating on the energy mapping, some of the following observations are made.

- The specific electricity consumption for paper production in Workshop I, II and III workshops is 0.766 kWh/kg; 0.737 kWh/kg; 0.81 kWh/kg of finished paper; The heat consumption rate from steam for paper production is 2,131 kWh/kg, respectively; 1,442 kWh/kg; 1,316 kWh/kg. The energy consumption norm applied to paper products in the period from 2021 to the end of 2025 in Circular No. 24/2017/TT-BCT for the Tissue paper category is 13169 MJ/ton of paper, equivalent to 3,658 kWh/kg of paper. Thus, the energy consumption of the tissue production line in workshops is lower than the norm.
- The paper production lines in Workshop I are old lines with low capacity and high energy consumption. These lines do not have a heat recovery system from the hot air obtained after drying. Normally, this hot air can be used to dry the air before feeding it into the drying process. However, because this paper shredding system operates at a slow speed and low steam pressure, it is used, the temperature of hot air after drying is only 50°C, so it is not feasible to take advantage of this heat to preheat the air before using for drying process. The system is small, so the layout of the inlet air preheating will be very complicated and there is no layout space.
- The paper lines in the Workshop II and Workshop III all use high-pressure steam and both have a system that takes advantage of heat to preheat the incoming air for the drying process.
- The hood of yankee dryers of lines of workshop I are removed and installed additional fans to blow air into the drying path for removing evaporated water. This design may lead to heat loss due to cold air from the outside entering the drying area. However, under the specific conditions of the drying line in Workshop I, the drying temperature is low and the moisture content of the input paper is quite high (up to 80%) according to the survey, the phenomenon of dew condensation has taken place, affecting the production process, the solution of dew condensation also increases heat consumption for the drying process. As a result of the renovation of the plant, it reduces the steam consumption for the drying process and solves the dew stagnation well. Calculations from the energy map shows that the steam consumption to evaporate water in the production lines of Workshop I is 0.9 tons of steam per ton of water. This consumption rate is lower than that of Workshop II which is 1.2 tons of steam/ton of water; Workshop III is 1.1 tons of steam per ton of water. This is because the air in the environment has partially supported the evaporation of moisture.
- The Workshop I machines are old technology machines purchased from China, which have a big disadvantage that the vacuum system and mechanical water removal before entering the drying are very poor. The moisture content of the paper before drying is 80% while for Workshop II and III it is only 68%. This results in a very high steam consumption for paper production in Workshop I due to the much greater demand for evaporation than in Workshop II and III. Finding a way to mechanically reduce the moisture content of the paper before it is dried is an important factor to improve the energy efficiency of the yankee drying machine. The steam pressure into the drying system of Workshop I is only 1.3 to 2 bar depending on the machine while the steam pressure into the drying batches of Workshop II is 6 bar and that of Workshop III is 6.8 – 7 bar. Higher pressure produces a higher steam temperature which enhances the drying speed, and the

post-drying air temperature is also much higher, increasing the ability to take advantage of this heat to pre heat the air entering the cross line. These factors make the paper producing lines of Workshop II and III more efficient, of which Workshop III is the most effective due to the application of many of the latest technologies.

- Regarding increasing the speed of the dryers to increase capacity, the factory always pays attention to find ways to renovate to increase the speed with the result that machine 1 and machine 12 of Workshop I have been successfully renovated to increase the drying speed; The line 10 of workshop II has implemented an increase in vacuum to increase speed. Increasing the speed of paper spinning is a collection of many related factors of many stages in the line. An overall assessment is required.
- The Workshop I machines belong to the old Chinese technology, and the ability to calibrate to improve capacity, performance, and product quality is quite difficult. The factory will gradually increase the number of products produced by more advanced lines such as Workshop III to gradually replace the machines of Workshop I.

1.3 Description of the utility systems

The following is list of main utility systems used in the plant:

Table 3. List of main utility systems

Item	Boiler		Air compressor	
Number	7		9	
Designed capacity	1X18 tph 2x12 tph 3x15 tph 1x20 tph		3x55 kW 6x37 kW	
Consumed fuel	- Coal for the 20 tph boiler - Coal/biomass for others (rate of 90/10(biomass/coal) in the first 8 months of the year (from January to August), the ratio of 10/90 in the remaining months)		Electricity	
Main end-users require operation parameters	Feed water temperature	95°C	Workshop V	$P_{operation}$: 5.6bar $P_{end-user}$: 4.5bar
	Saturated vapor pressure	8 -12 bar	Workshop I	$P_{operation}$: 5.6bar $P_{end-user}$: 4.5bar
	Yankee dryer 1,2,3,4 in Workshop V	- P: 1.3 bar - T_{input}: 133°C - T_{output}: 60°C	Workshop II	$P_{operation}$: 6bar $P_{end-user}$: 4.5 – 5.5bar
	Yankee dryer in workshop I	- P: 1.4bar - 2bar	Workshop III	$P_{operation}$: 5.6bar $P_{end-user}$: 4.5 – 5.5bar
	Yankee dryer in workshop II	- P: 6 bar - T_{input}: 172°C - T_{output}: 84°C		
	Yankee dryer in workshop III	- P: 6.8 bar - T_{input}: 174°C - T_{output}: 84°C		
Note	- 8tph boiler: for redundancy - 12tph boiler and 2x15tph boiler: for backup operation **- For details in Figure 7, 8**		- One 37kW device is pausing. - Two 55kW devices run the session **- For details in Figure 9, 10**	

The following is some simple illustration of the utility systems:

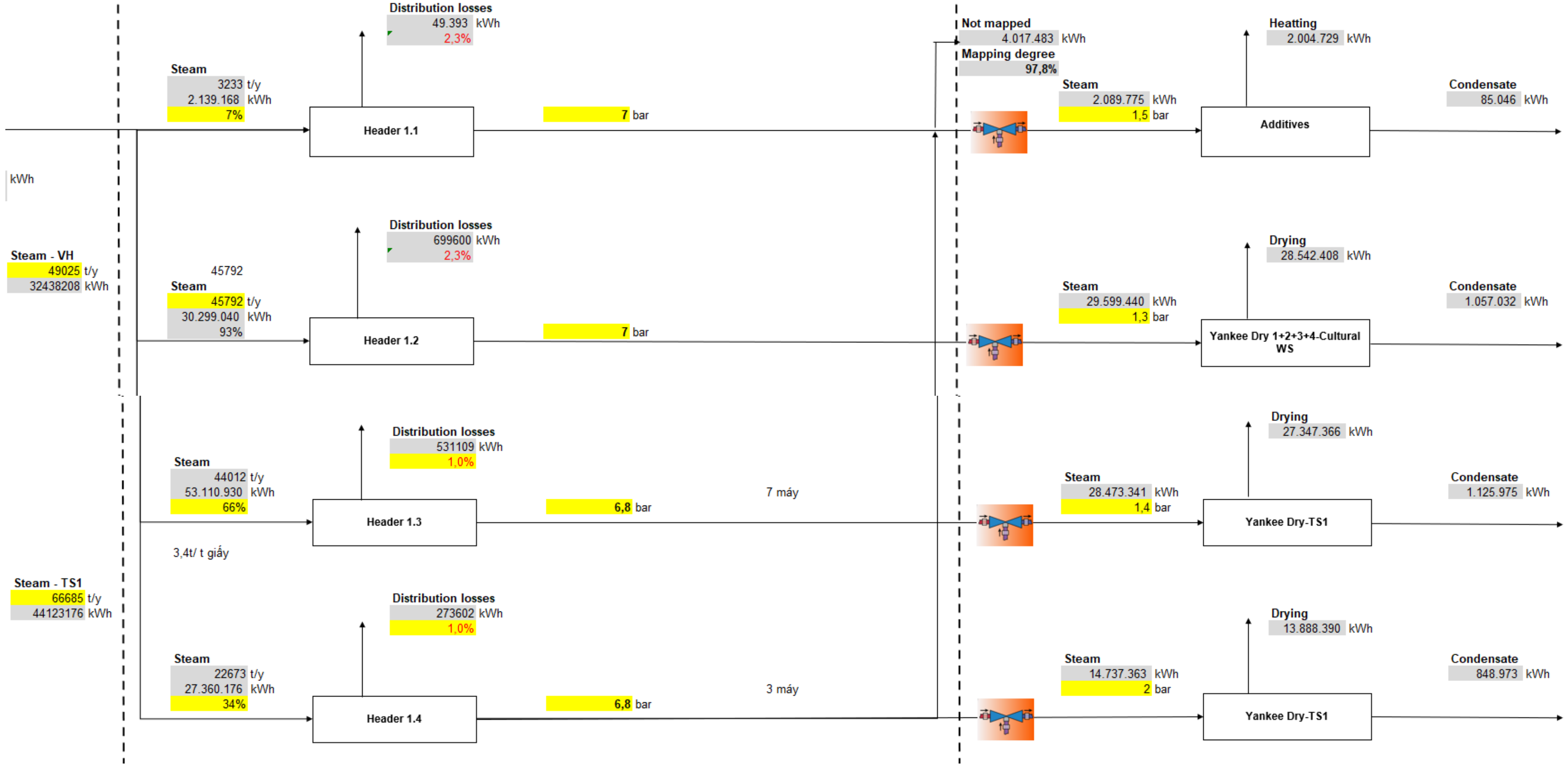


Figure 7. Steam supply from the boiler system for Workshop V and workshops I

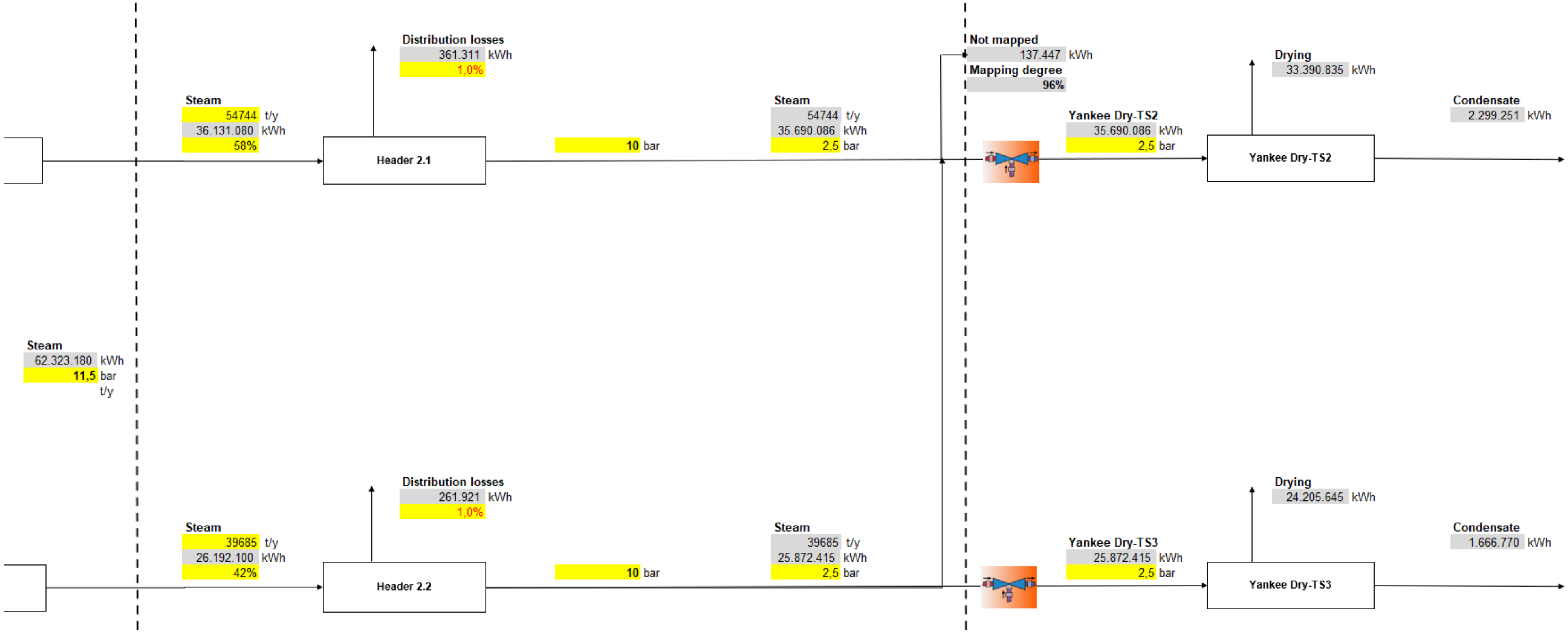


Figure 8. Steam supply from the boiler system for Workshop II and workshops III

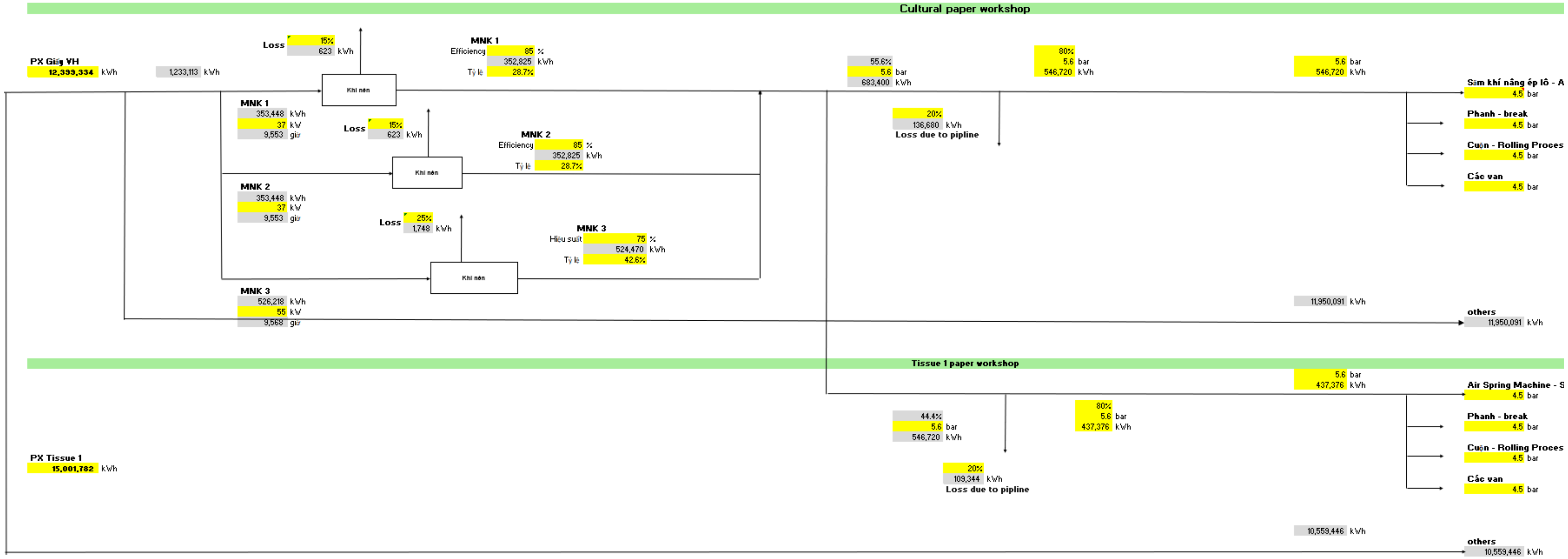


Figure 9. Air compressed supply system for Workshop V and workshops I

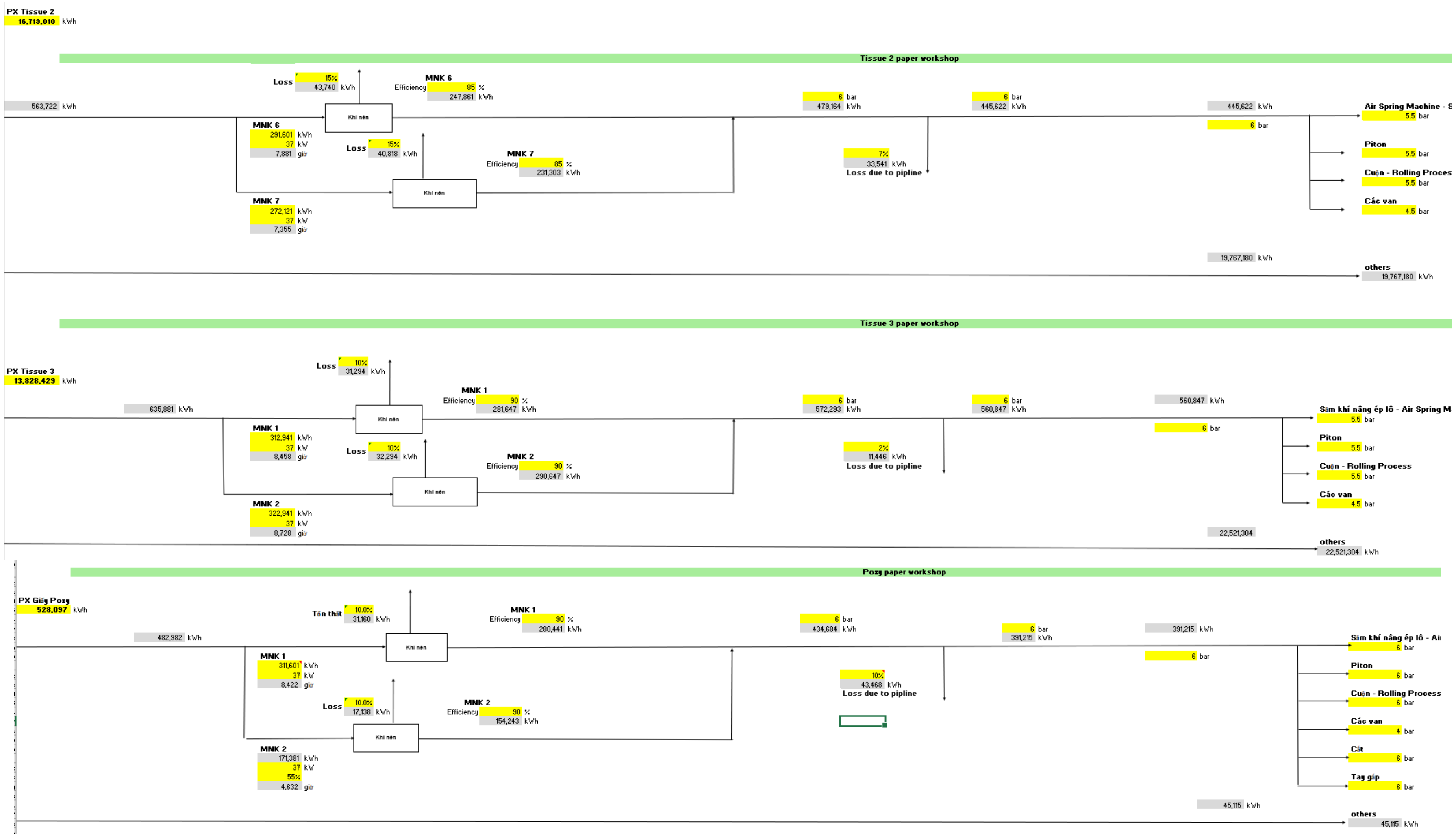


Figure 10. Air compressed supply system Workshop II, III and VI

Some comment on utility system:

Steam is an important source of energy besides electricity to provide heat for the paper drying process. Boilers and steam distribution systems and end users are surveyed, measured and evaluated for their performance as well as identifying potential energy savings. The following are boiler efficiency calculated by direct method and indirect method.

Table 4. Results of boiler efficiency calculated by direct method

Parameter	Unit	Boiler 15T.1	Boiler 15T.2	Boiler 20T 2.1	Boiler 12T2.1	Boiler 15T2.1
B_{Σ}	Tons of fuel/year	17497	17497	5360	9888	12430
D_{Σ}	Tons of steam/year	61791	61791	19830	33050	41548
Q_{t}^{lv}	kJ / kg	18945	18945	20970	18945	18945
h_h	kJ / kg	2777	2777	2785	2785	2785
h_{nc}	kJ / kg	385	385	385	385	385
ηt	%	**44,7**	**44,7**	**42,3**	**42,3**	**42,3**

Table 5. Boiler efficiency by indirect method

No	Parameter	Unit	Boiler 15T.1	Boiler 15T.2	Boiler 20T 2.1	Boiler 12T2.1	Boiler 15T2.1
1	Useful heat for process use	%	68,3	67,8	65,6	61,3	62,9
2	Heat loss by flue gas from the boiler	%	20,4	21	18,8	24,5	22,7
3	Non-recoverable condensate heat loss	%	1,7	1,7	2,4	2,2	2,3
4	Heat loss due to blowdown	%	0,9	0,9	1,0	0,4	0,4
5	Other losses	%	8,7	8,6	12,2	11,6	11,7
6	**Efficiency - η_n**	**%**	**68,3**	**67,8**	**65,6**	**61,3**	**62,9**

The heat supply system is equipped with many supporting equipment to help manage and operate the boiler more efficiently and save more energy. Input fuel has also used biomass to reduce the rate of GHG emissions as well as reduce the plant's fuel costs. However, the process of operation and management of the boiler still has a number of issues that need to be considered as follows:

- Operators have no training in boiler specialties, they operate mainly according to the experience passed down from previous skilled employees at the plant. Therefore, the operation process is not really effective;

- Biomass fuel is a by-product from wood such as sawdust, chopped wood, firewood, so the size is very different, the operation process always opens the door to bring in fuel without planning or adjusting the opening and closing of the feed door below. Therefore, the combustion process still causes fuel loss;

- Biomass fuel accumulates in piles outdoors without a roof, on rainy days, the fuel absorbs water to increase humidity and reduce the efficiency of the combustion process.

- The 20T2.1 boiler discharge rate is still high, which leads to high boiler discharge losses causing increased fuel consumption; This amount of boiler discharge water has not been utilized by the factory to recover heat.

- The oxygen concentration of the 12T2.1 boiler is 15% at a very high level. The oxygen levels of the remaining boiler s, which fluctuate at an average of about 9%, can still fall below 6% if the management process is good. High oxygen concentrations are also the cause of reduced boiler efficiency and increased fuel consumption;

- The flue gas temperature of the 15T2.1 boiler is high, causing large heat loss along the flue gas line, which is the cause of reducing boiler efficiency and increasing fuel consumption;

- The CO concentration in the flue gas of the 15T.1 boiler is 895ppm, which is very high, indicating low fuel combustion efficiency, uneven distribution of fuel in the combustion chamber, so the contact between combustion air and fuel is inefficient.

- Condensate from steam traps on the piping system discharges directly into the environment and has not been recovered.

- The pressure relief valve system at households is a type of pressure relief valve without temperature reduction, the steam after the pressure reduction becomes an overheating vapor, reducing the heat exchange efficiency in the drying batch.

- The operation of scattered boilers is inefficient, consuming a lot of costs for boiler maintenance, boiler start-up, boiler maintenance and boiler operation labor costs.

The air compressor system operates stably and the cos power factorφ is quite high. The phase current of the air compressors has very little deviation and is within the allowable threshold. However, the harmonic level of air compressors with inverter installation is very high with the highest value of 58.13% exceeding the permissible threshold. Most air compressors operating at full capacity do not have an inverter installed and the idle time is very low, accounting for less than 10%. The power measurement results of the air compressors are mentioned in Figure 4. 6 above.

In addition, the factory has 4 air compressor rooms, but only air compressor room No. 1 is designed with a piping system that directs the hot air of the air compressor to the environment. The rest of the compressor rooms are arranged in workshops or open outdoor areas with corrugated iron roofs, but there are still some disadvantages as follows:

The installation area in the workshop is affected by the waste heat from the dryers along with the exhaust temperature from the hot air of the factory, which is an increase in the inlet temperature of the air compressor, resulting in the air compressor needing to consume an additional amount of electricity to cool the inlet air to meet the operation of the air compressor. In particular, the outdoor air compressor for workshop VI with a corrugated iron roof will consume the most energy in summer when the outside ambient temperature rises to about 40°C. In addition, hot air will increase the temperature regardless of the environment around the air compressor and workshop, affecting the health of workers. Currently, the hot air from the air compressor is measured at about 30°C while the ambient temperature is relatively low at about 19°C – 22°C.

Air compressors placed outside the open space in the workshop or outdoors will often increase the dust density at the air inlet air inlet of the air compressor, which will hinder the circulation leading to the inlet air will have a higher temperature than normal and the air compressor must also increase its capacity to get air inlet.

1.4 Key areas/equipment/system have been audited

The energy audit was implemented whole plant including measurement of equipment/ system with key energy consumption as stated in Table 4.

List of key areas/equipment/system have been audited is presented in the table below:

Table 6. List of key areas/equipment/system have been audited

No.	Key areas / equipment / system	General Information	Reviews, comments
1	Whisk system	The beater system has a total of 8 machines. Each workshop is arranged with 2 threshing machines with an installed capacity ranging from 30kW to 185kW to serve the loading needs of each production stage. The threshing system is operated to avoid peak hours from 9:30 a.m. to 11:30 a.m. and from 5 p.m. to 8 p.m. every day except Sunday because there are no peak hours on Sundays. The beater is responsible for loosening the pulp before it is transferred to the crusher.	The threshing machines are working very stably. The power factor is quite high, all above 0.8. The highest harmonic level of 12.5% is also within the stable threshold. It is necessary to check and recalibrate the phase for the whisk at the Workshop III. The threshing machines are operating at a low load level compared to the installed capacity but have not installed an inverter. If operating in low load mode for too long, it is necessary to install an inverter for machines operating in low load mode to reduce power loss
2	Crusher System	The factory has 24 crushers with an installed capacity ranging from 75kW to 350kW to serve the load needs of each production stage. The crusher system is operated to avoid peak hours from 9:30 a.m. to 11:30 a.m. and from 5 p.m. to 8 p.m. every day except Sunday because there are no peak hours on Sundays. The mill will produce loosening according to the standard concentration and grind before the pulp is	The crushers are working very stably and the power factor is at an average level. The highest harmonic level of 5.88% is also within the permissible threshold. The phase current of the mills has very little deviation because the highest difference value is 8.11% and is within the allowable threshold. In addition, the crushers all operate at low loads relative to the installed capacity. There are some crushing equipment that has been equipped with a soft start system, which also limits power loss. Some machines are not equipped with soft start as well as inverter. It is necessary to

		transferred to the mixing tank and the pre-milling tank	check the condition of low load operation for long or short periods of time
3	Paper Shredder System	The Yankee dryer machine system is installed in the Workshop V, Workshop I, Workshop II and Workshop III at the factory and operates 24 hours a day. This system consists of main motors such as drying, rolling, pumping, fan, vacuum to produce different required papers	The Yankee dryer lines are operating very stably and the power factor is quite high, Branch 3 of yankee dryer 09 is at the average level. The current between the phases of the symmetrical cylinders is changed by the highest difference value of 9.5% and is within the allowable threshold. The motors of the Yankee dryer line are almost all installed with inverters, so the harmonic level of the motors is mostly over 10%. However, there are some branches of the Yankee dryer line with a harmonic level that is too high (over 30%) exceeding the permissible threshold for motors with inverters such as cultural Yankee dryer with a harmonic level of up to 36%, branch 4 Yankee dryer 09 and branch 3 Yankee dryer 11 with a harmonic level of over 40% and sometimes over 50%.
4	Agitator Motor System	The system can be stirred during the powder preparation stages at the stages before and after the crushing system, in the mixing/mixing tanks to avoid the phenomenon of powder depositing at the bottom of the die as well as the ingredients are mixed evenly to the standard. Agitator motors have a variety of capacities depending on the capacity or demand in each area.	The hydraulic stirring system works relatively stably and the power factor of the stirring system in Workshop III is very high, while in Workshop I it is average. The phase current of the hydraulic stirring system has a very small difference because the highest difference value is 7.7% and is within the allowable threshold. These stirring systems are all equipped with inverters, but the harmonic level of these two systems is still too high and exceeds the permissible threshold.
5	Lighting System	the demand for light is not much and the spending is concentrated in office areas, corridors and some working positions at the	The light quality in some areas exceeds the lighting standards, most of the areas with excess light are due to the outdoor light element from the

		equipment. Those areas are designed and arranged in accordance with the needs of the collaborator, so there are many types of lights with different capacities used. In addition, areas that need more light will be equipped with a handheld flashlight. The lighting system operates about 10 a.m. – 12 p.m. a day.	open areas and the cells that take light from the outside of the factory. The factory still has many areas that do not meet the demand for light when working, In addition, the factory has used all LED lights to replace low-efficiency and energy-intensive lamps, as well as taking advantage of light cells from around and on the roofs of workshops to maximize energy savings for the factory's lighting system.
6	Air Conditioning System	The factory uses air conditioning mainly in office areas and areas where electrical cabinets and substations are arranged. Many types of air conditioners are used at the factory such as Funiki, Sumikura, Nagakawwa, etc. Factories often use air cooler cooling systems.	the air conditioning system operates stably. Employees are very conscious during use such as the lowest temperature when in use is 25 ^{o}C for the office area and 23 ^{o}C for the electrical cabinet and substation area, turning off when not in use.
7	Pump and Fan System	Pump and fan systems are used a lot in factories with many different types and capacities depending on the needs in that area. Because these systems do not have separate power lines, the audit team cannot perform detailed measurements. Only the fan system of the boiler is arranged separately, so the measurement results of the fan system of furnace 15T.1 at boiler workshop 1 and furnace 12T2.1 at boiler workshop 2	Boilers 15T.1 and 12T2.1 are operating while the remaining boilers are in standby and backup mode. The fan system of these two furnaces operates stably, the power factor is quite high, and the phase current does not differ much. The fan system of both furnaces is installed with an inverter, so it always operates in power-saving mode when the load is low or idle for a short period of time. However, the harmonic level of both systems is very high and the lowest value is 28.33%. The high harmonic stage will consume energy and reduce the performance of the motor. Therefore, it is necessary to adjust and install a harmonic filter for this system
8	Heat Consumption System	The company has 3 tissue paper production workshops and 1 fine printing paper production workshop, of which	The total heat consumption for the drying stages of the whole plant in 2023 is converted to electricity equal to 130,372,148 kWh. In which, the heat

		workshop I consists of 10 lines, workshop II consists of 2 lines, workshop III consists of 2 lines (each line corresponds to 1 cross machine) and workshop V consists of 1 line (corresponding to 18 batches of pre-drying surface glue and 10 batches of drying after surface glue). These drying batches are supplied with steam drying heat from the boiler system at the factory.	consumption for Yankee Drying Batches at Workshop I accounted for the largest proportion (33.8%) in the whole factory, followed by the drying stages at workshops II (25.9%); workshop V (22.0%) and workshop III (18.4%). Through the survey, the expert group also found that the steam consumption rate (tons of steam/ton of product) of workshop I was the largest at 3.4 and the rest of the workshops ranged from 2.1-2.5. The reason why the steam consumption of workshop I is much larger than the rest of the workshops is because the air dryer of the paper shredding system of this workshop does not work
9	Power Supply System	The power is sent to the electrical cabinets located in the factory, which in turn are divided into smaller cabinets. The voltage of 35 kV from the grid is converted into a voltage of 0.4 kV for the electricity systems in the factory. In order to ensure the stability of the power grid and ensure that the power factor requirements are met, the company has arranged the installation of power factor compensation cabinet systems at substations or electrical cabinets of workshops. The cosφ coefficient of most substations is over 0.90.	Most substations operate at low loads, the power factor at substations is less than 0.9 and does not meet the demand for electricity. In addition, the phase weighing at substation No. 7 is quite high up to 13%. Therefore, it is necessary to recalibrate to avoid problems from occurring. In addition, substation No. 4 has a very high harmonic level of up to 25%, which will affect electrical safety as well as reduce the efficiency of power-consuming equipment. Therefore, it is necessary to install harmonic filtering equipment for the area of substation No. 4.
10	Heat Supply System	The company's heat supply system includes boiler workshop 1 and boiler workshop 2 with a total of 7 boilers with different capacities installed in these two workshops. In which, there are only 4 furnaces that are operated all the time to supply steam to	In general, the initial observations are energy efficient for the factory's production line. Currently, the factory has conducted and has also immediately implemented simple and management-related solutions. In addition, factories should also consider the following solutions:

		the production area and the rest of the boilers are backup. The input fuel of the boilers is coal and biomass (including sawdust, firewood, chopped chips). These boilers operate 24 hours/day. Depending on the demand for steam in the production process, the boilers are mobilized to operate	- Perform periodic boiler efficiency calculations to limit energy consumption and improve the system as soon as possible => based on the boiler efficiency calculation method mentioned in detail in the calculation sections below; - Drawing up a steam supply system diagram and planning periodic maintenance and repair of the steam system => based on the steam supply diagram mentioned in the calculation sections below;
11	Compressed air supply and consumption system	The air compressor system is equipped in all main workshops of the factory with a total of 9 machines with an installed capacity ranging from 37kW to 55kW to serve the load needs of each production stage with an operating time of 24 hours/day. The air compressor system is equipped with a drying and moisture separation system along with a compressed air tank with a capacity of 2m^3. The compressed air produced from the system is fed to the swivel, valve, and coil systems.	The air compressor system operates stably and the power factor is quite high Most air compressors operating at full capacity do not have an inverter installed and the idle time is very low, accounting for less than 10%. The factory has 4 air compressor rooms, but only air compressor room No. 1 is designed with a piping system that directs the hot air of the air compressor to the environment Air compressors placed outside open spaces in workshops or outdoors will often increase the dust density at the air inlet air inlet The installation area at the workshop that is affected by the waste heat from the dryers along with the exhaust temperature from the hot air of the factory is an increase in the inlet temperature of the air compressor

2 Methodology used to identify EE projects

2.1 How EE projects have been identified and developed

The work of Energy Audit was carried out following the circular 25/2020/TT-BCT on "Regulations on planning and reporting on the implementation of plan for economic and efficient energy use; perform energy audit", and in line with the EA guideline relating to audit, energy mapping, project development and project template, and including Onion Diagram Approach (Figure 11). For each layer of the Onion Diagram, it is important to assess whether more energy efficient solutions and practices can be adopted. Reducing energy consumption at the core layer has a cascading effect on secondary energy consumption, maximizing overall efficiency.

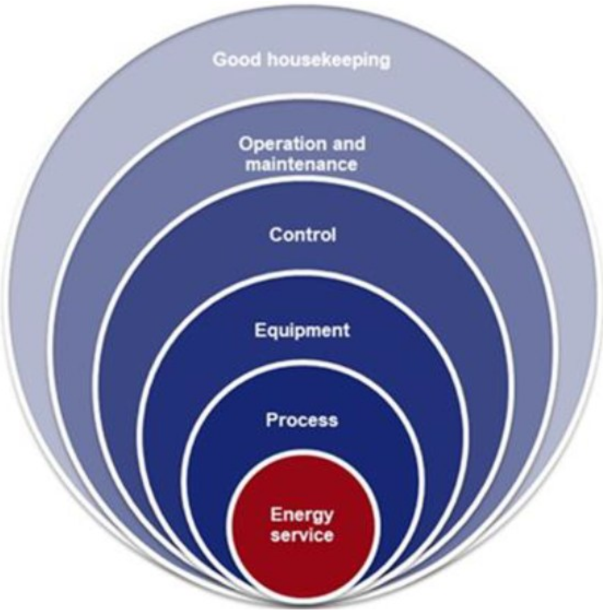


Figure 11. Onion Diagram Approach for identifying of EE opportunities

The Energy Service: The "energy service" refers to the specific requirement that a process must fulfil.

The Process: The "process" refers to the type of method chosen to deliver the energy service. Alternative processes can often be considered to improve energy efficiency.

The Equipment: The "equipment" relates to the energy efficiency of the tools and machinery used to execute the process. Some equipment may be inherently less efficient, while others are designed to optimize energy use. One way to evaluate equipment efficiency is by using the Total Cost of Ownership (TCO) approach,

considering not only upfront costs but also operational energy consumption and maintenance expenses.

The Control: The control system used to manage the process plays a significant role in achieving energy efficient operations. 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 critical for sustaining energy efficiency both in daily operations and over the long term. Focus on regular maintenance and proper operation will often lead to non- or low investment EE projects.

Good Housekeeping: A company's culture and approach to energy management insignificantly influence overall energy consumption.

The collection of data at the factory is carried out by the following main methods:

Field survey at the factory, interviews with managers, operators at each workshop, each equipment area;

- Collect data from the factory's documents such as electricity consumption and biomass consumption in recent years,... and a number of documents related to equipment characteristics, technology lines, and operation instructions.
- Use specialized measuring devices (Table 5) to measure and analyze the main energy consumption equipment, areas, and lines at the factory. The data of this period will be used for analysis and calculation
- Collecting measurement indicators at the field measuring equipment installed by the factory, however the disadvantage is that some equipment is not calibrated periodically, leading to some measurement equipment being misaligned
- Some data are calculated by Energy Balance, mass balance through other primary data collected by the methods mentioned above

Table 7. List of testing equipment

TT	Measuring device name	Code	Amount	Country of origin
1	Kyoritsu Power Analyzer	6315	01	Japan
2	Clamping Ampere	Extech EX720	01	Germany
3	Measuring equipment for measuring ambient temperature, wind speed, light, air humidity	Lutron LM8000A	01	Taiwan
4	Infrared thermometer	Voltcraft IR 900-30S	01	Germany
5	Flue Smoke Analyzer	KIGAZ 310	01	France
6	Infrared Temperature Measuring Equipment	TEXT 845	01	Germany
7	Furnace Water Analyzer	EC600	01	Sun

Energy maps have been used to develop projects using the following methods:

*** Calculated and compare KPIs**: A method of calculating power consumption by flow based on the rated capacity, running time and load factor of equipment in a production stage. The method of calculating electricity consumption according to KPIs uses the power consumption norm (kWh/ton of raw materials) and the flow of the volume of raw materials entering 1 stage to evaluate the power consumption of that stage.

The flow-based method is simple, easy to understand and easy to implement, but does not accurately reflect other factors that affect power consumption such as equipment performance or operating conditions. The KPI-based methodology provides a more comprehensive view of energy efficiency, helping to detect problems and opportunities for improvement; However, this method is more complex, requiring more data and in-depth analysis.

The reason for the difference between the 2 methods of calculating heat and electricity consumption by flow and KPI mainly lies in the energy management in the plant. Currently, the plant has only built steam and electricity consumption norms on finished products (tons of steam/ton of finished products and kWh/ton of finished products). Because Workshop I is the oldest line, the factory has not yet built electricity consumption norms for workshop I and some production stages in other workshops have not yet built norms. In addition, there are many factors that can lead to the difference between these 2 methods:

- Characteristics of paper: Different products may require different production processes, resulting in different energy consumption, even if the product volume is the same;
- Performance of the device: The performance of the device may change 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 the performance of the equipment and thus affect the energy consumption;
- External factors: The quality of input materials and equipment breakdowns can also affect energy consumption.

The difference between the 2 flow-based methods and KPIs is the energy saving potential that the plant can access

***Combining KPI calculation and analysis with temperature analysis:** Through the comparison of steam consumption/ton of product by KPI and by flow, the expert team also found that the steam consumption rate (tons of steam/ton of product) of workshop I was the largest at 3.4 and the rest of the workshops ranged from 2.1-2.5. The reason why the vapor consumption of workshop I is much larger than the rest of the workshops is because this is a drying system using old and outdated technology, whereby the amount of water that can be separated before entering the drying stage is low, leading to the moisture content of the paper before drying up to 80% while for Workshop II and III only is 68%. The steam pressure in the drying batch of Workshop I is only 1.4 bar resulting in low drying temperatures resulting in low evaporation efficiency and the utilization of heat from the evaporation steam of the drying process is inefficient. The steam pressure of the drying batch of Workshop II is 6 bar and that of Workshop III is 6.8 – 7 bar, so the drying capacity can be improved as well as the heat from the hot air released from the drying process heats the air fed into the dryer.

***Energy losses analysis:** By applying the Energy Mapping to calculate energy consumption, the audit team has developed charts showing the electricity and thermal consumption between workshops and areas in the factory. Thermal energy losses account for the highest value, far exceeding the thermal energy used in the workshops. This is a top concern because thermal energy losses account for the majority of energy sources and need to be optimized to save costs. The heat energy used for the 3 paper workshops accounts for a significant part of the energy allocation. The drying system in the workshop I can be further improved by optimizing the process or upgrading the equipment. The drying system in the workshop V has a lower thermal energy consumption than each Yankee drying system in the workshop but is still significant. Although the unknown thermal energy is not large, understanding the origin of this thermal energy will help ensure more comprehensive data.

Power allocation charts have also been developed for workshops, production processes in the workshops, thereby identifying processes that can improve efficiency or take advantage of wasted energy to reduce operating and production costs.

Specific energy consumption

* Electricity consumption rate/ton of product:

$$SEC_{electricity} = \text{(kWh/ton of product)} \frac{\text{Electricity Consumption (kWh)}}{\text{product output (tons of product)}}$$

$$= \text{(MJ/ton of product)} \frac{\text{Electricity Consumption (kWh)} \times 3{,}6}{\text{product output (tons of product)}}$$

* Heat consumption rate/ton of product:

$$SEC_{heat} = \text{(MJ/ton of product)} \frac{\text{heat energy consumption (MJ)}}{\text{product output (tons of product)}}$$

* Total consumption/ton of product:

$$SEC = SEC_{electricity} + SEC_{Heat} \text{ (MJ/ton of product)}$$

The calculation is based on factory data provided from January to December 2023. Table 6. presents the results of the calculation of consumption rates by product type.

Table 8. specific energy consumption

STT	Parameter	Electricity Consumption Rate (kWh/ton)	Heat consumption rate (MJ/ton)	Total Consumption (MJ/ton)
1	Workshop I, II, and III	757,0	6527,5	9252,7
2	Workshop V	590,9	5927,4	8054,5

The energy consumption norm applied to paper products in the period from 2021 to the end of 2025 in Circular No. 24/2017/TT-BCT for Tissue paper is 13169 MJ/ton of paper and 9455 MJ/ton of paper for fine printing paper. Thus, the energy consumption of the workshops is lower than the norm.

Based on analysis of the energy mapping and also the deep analysis of utility system, many observations were made which could have potential energy savings. The screening list have been made with 29 observations of energy using problem that coulde be check and discussed more deeply to identify the more potentials observations. The 11 most potential observations within the list will be referred to as level B projects, where the potential energy savings and investment are evaluated based on estimates if possible.

The screening list of level B projects were evaluated and 7 projects are selected for further development. These projects will be called level A projects and should be developed enough for making a decision of whether to carry out a pre-feasibility study.

2.2 EE Project evaluation

During the energy audit, after assessing the actual status at the plant, the team of experts researched, proposed and developed savings solutions by identifying the following factors:

- Amount of energy saved in a year: in the form of electricity, heat energy and assessment of the level of savings (%) compared to the current situation at the plant

- Cost savings after project implementation: this amount of cost is calculated and determined based on the reduction in consumption of input energy (such as biomass, coal, electricity, water) or due to the increase in output product capacity (paper) or cost savings due to the reduction of operating labor.

- Investment costs: this cost can be the cost of training human resources, building a management system, purchasing new replacement or repairing equipment, changing the type of energy, costs due to suspending production to implement the project, environmental costs,...

- Payback period: short-term, medium-term, long-term

- CO_2 emission reduction: the potential to reduce CO_2 emissions directly, indirectly and some projects to reduce CO_2 emissions by using clean energy.

2.3 EE Project prioritisation

When selecting energy-saving solutions at enterprises, the following criteria have been discussed in order of priorities from high to low as follows:

- Energy-saving efficiency

+Reduction in electricity/fuel consumption (%).

+Ability to improve energy efficiency.

- Investment costs and payback time

+Total initial investment cost.

+Payback period (short-term, medium-term, long-term)

+Long-term financial benefits (savings in operating and maintenance costs, electricity/fuel bills

- Impact on production/business activities

+Will it disrupt production

+Does it affect the quality of the product/service

- Technical feasibility

+Is the technology suitable for the current system

+Easy to integrate into your business's production/service process

+Complexity in operation and maintenance

materials).

- Environmental Impact & Regulatory Compliance

+Reduce CO_2 emissions and environmental impact.

+Meet energy standards (ISO 50001, Law on Economical and Efficient Use of Energy).

+Enjoy financial incentives from the government or clean energy support organizations.

- Scalability and flexibility

+Is it possible to scale in the future

+ Easy to adjust to the development needs of the business?

3 EE Projects identified

3.1 Enterprises feedback

Below are the potential for energy savings in some areas, the main equipment at the factory has been discovered by experts and the factory's feedback on these solutions:

Table 9. Synthesis of findings during the audit and feedback of the factory

No.	Current Status	Location	Equipment	Energy Savings Type	Energy Savings Potential (kWh)	Investment Cost (EUR)	Solution Name	Feedback of the factory
I. Entire Factory								
1	Improve KPI Setup. The factory manages energy consumption by setting up KPIs for machines and workshops. However, some production lines show a significant discrepancy between calculated energy consumption and KPI. Identifying the cause of this large discrepancy helps improve energy management efficiency.	Entire Factory	All Equipment	Electricity	843.83	5.443,69	Solution to enhance energy management efficiency, establish an energy management system following ISO 50001 standards	Should be implemented
II. Thermal Section – Major Equipment								
2	Install steam boxes at the wet end of the paper machine. Steam boxes heat the wet paper with steam before entering the vacuum pressing stage for water removal. Since the water temperature is higher, viscosity decreases, making mechanical water removal more effective.	Workshop V	Paper Machine	Paper Machine	-	Culture Works	Install steam boxes before the wet end of the paper machine	The factory plans to switch the Workshop V production line to another, so this solution is not applicable
3	Control forced ventilation of the drying system using a dew point sensor and regulate exhaust fans accordingly.	Workshop V	Exhaust fan	Electrical energy	-	-	Install a dew point temperature sensor and control the exhaust fan airflow based on the dew point temperature.	All dryers are already equipped with an exhaust fan system for ventilation, adjusting airflow based on evaporation levels. Therefore, this solution is not applicable.
4	Seal the paper machine system to prevent cold air infiltration, minimizing	Workshop V	Dryer	Thermal energy	-	-	Seal the paper machine system to minimize heat	If fully enclosed, it would affect operations as operators would

No.	Current Status	Location	Equipment	Energy Savings Type	Energy Savings Potential (kWh)	Investment Cost (EUR)	Solution Name	Feedback of the factory
	heat loss. This solution should be implemented while ensuring the functionality of the dew point sensor and maintaining operational ease for paper handling by operators.						loss. This solution should be combined with a dew point temperature sensor to prevent condensation that could cause paper breaks.	have no space for paper handling, leading to lower work efficiency. Furthermore, the factory previously attempted enclosure, but excessive condensation occurred. Therefore, this solution is not feasible.
5	Study the reduction of paper break frequency. The causes of paper breaks may be related to condensation, raw material composition, and the chemicals used.	Workshop V	Cultural production line	Thermal energy	-	-	Reduce the frequency of paper breaks.	The factory has increased vacuum capacity and implemented an electrostatic measurement system to adjust chemical usage levels.
6	Utilize the hot and humid air emitted from the paper machine to produce hot water. The hot water can be used in the pulp refining process or other locations where hot water is needed..	Workshop V	Dryer	Thermal energy	-	-	Install a heat exchanger to reuse condensate from the dryers for additional fabric drying.	The factory has already installed a heat exchanger to optimize energy utilization as much as possible. Therefore, this solution is not necessary.
7	Recover waste heat from the hot air emitted by the paper machine in Workshop I to preheat the incoming air.	Workshop I	Paper machine	Thermal energy	-	-	Install a heat recovery system for the exhaust air from the Yankee dryer.	The production line in Workshop I consists of low-capacity paper machines with low steam pressure, and the hot air temperature after drying is only 50°C. The heat recovery system is not effective.
8	Replace the old drying cylinders of the Workshop I drying machines.	Workshop I	Drying cylinders	Electrical energy	-	-	Replace the old drying cylinders for Workshop I.	The factory is considering replacing the old drying cylinders for Workshop I.
9	Produce hot water from the excess heat of the hot air emitted by the paper machines.	Workshop I,II and III	Paper machine production line	Thermal energy	-	-	Recover excess heat from hot air for drying.	This solution is difficult to implement and has low efficiency due to the limited demand for hot water and the complexity of system design. Additionally, the hot water temperature is low because the

No.	Current Status	Location	Equipment	Energy Savings Type	Energy Savings Potential (kWh)	Investment Cost (EUR)	Solution Name	Feedback of the factory
								exhaust air temperature from the dryer is low.
III. Electrical Section – Major Equipment								
10	Improve vacuum pump systems as there are currently various vacuum pump technologies with different efficiencies. .	Entire factory	Vacuum system	Electrical energy	-	-	Evaluate and perform regular maintenance for the vacuum system.	The factory has conducted regular maintenance. It continuously monitors the performance of vacuum pumps and considers replacing underperforming ones. Workshop I has recently replaced several vacuum pumps; Workshop II and Workshop V have also undergone replacements. In 2025, the factory plans to replace all vacuum pumps in the finished product processing workshop.
11	The province has an average solar radiation of 667.9 kWh/m², with a large available roof area.	Entire factory	Workshop roof	Electrical energy	6.038.866,4 9	10.603.000	Install a solar panel system on the workshop roofs.	Should be implemented.
12	The power factor is quite low, below 0.9.	Substation s No. 5, 6, 10, and 13	Substations No. 5, 6, 10, and 13	Electrical energy	-	-	Install capacitors for substations No. 5, 6, 10, and 13 with low power factors.	
13	Install harmonic filters as the measured harmonic values are very high, ranging from 29% to 90%.	Entire factory	Substation No. 4 and the paper machines, mixers	Electrical energy	-	-	Install harmonic filters for Substation No. 4, the paper machine system in the Workshop V, Paper Machine No. 9 in Workshop I (branches 2, 3, and 4), Paper Machine System 11 (branch 2), 110kW hydraulic mixer in Workshop III and Workshops I, Air	

No.	Current Status	Location	Equipment	Energy Savings Type	Energy Savings Potential (kWh)	Investment Cost (EUR)	Solution Name	Feedback of the factory
							Compressor No. 7 (Compressor Room No. 2), Air Compressor No. 1 (Compressor Room No. 3), and Air Compressor No. 1 (Compressor Room No. 4).	
14	The current imbalance between phases is significantly high, reaching up to 19%.	Substation No. 7, defibrating machine	Substation No. 7, defibrating machine	Electrical energy	-	-	Rebalance the phases for Substation No. 7 and the 90kW defibrating machine in Workshop III.	
IV. Thermal Section – Auxiliary Area								
15	The factory has seven boilers using biomass or coal as fuel. All boilers are equipped with energy-saving devices to preheat feedwater and combustion air. However, there is no automatic control system for combustion air, meaning the combustion process is not adjusted according to the fuel type and composition. Additionally, boiler efficiency is not clearly measured. It is recommended to establish a performance monitoring system to identify potential improvements.	Boiler workshop	Air supply system	Biomass	-	-	Install an automatic control system for combustion air supply and adjust the fuel supply mode accordingly.	The factory has installed a new boiler that uses more uniform fuel and features improved air supply control, allowing better efficiency management. However, periodic boiler efficiency calculations should still be conducted following the methodology outlined in the report.
16	The steam and condensate system lacks a clear overview. Therefore, it is necessary to study its design and maintenance level, focusing on factors such as pipeline layout and design principles, insulation, steam trap positioning and maintenance, condensate recovery, etc.	Auxiliary area	Steam and condensate system	Biomass	-	-	Design and maintenance level of the steam and condensate system.	=> Develop a schematic diagram of the steam supply system based on the diagram established in the previous section of the report and create a maintenance and repair plan for the steam system on a regular basis.

No.	Current Status	Location	Equipment	Energy Savings Type	Energy Savings Potential (kWh)	Investment Cost (EUR)	Solution Name	Feedback of the factory
17	The operational efficiency of the boilers needs to be optimized. Factors to consider include fuel standardization for biomass boilers, oxygen levels, etc.	Auxiliary area	Steam and condensate system	Biomass	1.577.500	3.629,13	Adjust the flue gas oxygen level for Boiler 12T2.1.	Should be implemented.
18	Operators rely on experience, fuel sizes vary significantly, and there is no operational log for each boiler or fuel consumption rate tracking. Additionally, stored fuel tends to absorb moisture over time.	Auxiliary area	Boiler	Biomass	20.921.111	54.436,90	Fuel management solution for the steam supply system.	Should be implemented.
19	Currently, boiler blowdown is performed periodically, but there is no mechanism to recover the heat loss from the process.	Boiler	Boiler blowdown	Biomass	455.28	10.887,38	Utilize heat from boiler blowdown water of Boilers 15T2.1 and 20T2.1 to preheat feedwater.	
20	The exhaust gas temperature of Boiler 15T2 is 195-200°C. This may be due to the inefficient operation of the feedwater heater and air preheater.	Boiler	Feedwater heater/Air preheater	Biomass	2.576.111	27.218,45	Retrofit and maintain the feedwater heater or air preheater to recover heat from the flue gas of Boiler 15T2.1.	
21	The steam pressure is reduced from around 7 bar at the boiler to 1.2–2 bar at Workshop I using only a pressure-reducing valve. After pressure reduction, the resulting steam is superheated, leading to lower heat exchange efficiency. Using a desuperheating pressure-reducing valve to obtain low-pressure saturated steam would improve heat exchange efficiency for the drying process.	Boiler	Pressure reducing valve	Biomass	63.007	1.814,56	Replace the pressure-reducing valve with a desuperheating valve to improve heat exchange efficiency and steam flow.	
22	The boiler operation is decentralized and inefficient. Some boilers operate in an On/Off mode depending on	Boiler	Boiler	Biomass	21.835.555	900.572,5	Install a new 25-ton/hour high-efficiency biomass-fired boiler to replace the	Should be implemented.

No.	Current Status	Location	Equipment	Energy Savings Type	Energy Savings Potential (kWh)	Investment Cost (EUR)	Solution Name	Feedback of the factory
	steam demand, resulting in low average efficiency. Operating costs are higher due to the need for more personnel.						low-efficiency coal and biomass-fired boilers.	
V. Electrical Section – Auxiliary Area								
23	Reduce the intake air temperature in compressor rooms, as the temperature inside is always 5°C to 6°C higher than the outside temperature in an enclosed space.	Auxiliary area	Air Compressor Station 2	Electrical energy	11.03	362,91	educe the input air temperature for Compressor Room 1	Should be implemented.
24	Reduce the intake air temperature in compressor rooms, as the temperature inside is always 5°C to 6°C higher than the outside temperature in an enclosed space. Compressor rooms No. 1 and 3 are located within the paper production area, where dust levels are relatively high.	Auxiliary area	Air Compressor Station 5,6	Electrical energy	29.635	544,37	"Reduce the input air temperature for Compressor Room 3."	Should be implemented.
25	The pressure levels of the air compressors have not been critically evaluated. It is recommended to create a preliminary pressure demand mapping to assess whether pressure can be reduced in specific areas.	Auxiliary area	Compressed air consumers	Electrical energy	-	-	Manage the compressed air pressure of the consumers according to the diagram.	The factory has implemented this solution.
26	In the packaging area, each machine has a ventilation system. It is necessary to assess whether the system is properly balanced or merely operating at a fixed speed.	Packaging area	Air ventilation system	Electrical energy	-	-	Evaluate the performance of the ventilation system in the packaging area.	The ducts all have control valves for separate machine units, but the pressure has not been adjusted yet. => The factory has already implemented this.
27	Many devices are currently using outdated drive systems, which could	Auxiliary area	Older drive systems	Electrical energy	-	-	Upgrade to improve the performance of the old drive systems.	Currently, the factory is replacing the old, low-efficiency motors with new, higher-

No.	Current Status	Location	Equipment	Energy Savings Type	Energy Savings Potential (kWh)	Investment Cost (EUR)	Solution Name	Feedback of the factory
	be upgraded to improve operational efficiency.							efficiency motors, especially transitioning to using electric motors. => This solution is not applicable
VI. Wastewater treatment								
28	The wastewater treatment plant uses air blowers for aeration. The efficiency of the aeration process has not been studied, but experience suggests that controlling and optimizing the blowers often result in high efficiency.	Wastewater treatment area	Blower	Electrical energy	-	-	Control/optimize the air blower machines.	The factory controls aeration by measuring DO (Dissolved Oxygen) for each shift, seasonally, and adjusts the aeration run time accordingly. => This solution is not applicable
29	Additionally, there is potential for biogas production from wastewater. Preliminary estimates indicate that approximately 2% of the thermal energy demand could be met using biogas generated from wastewater (with a COD of 700).	Wastewater treatment area	Wastewater Treatment Tank	Electrical energy	-	-	"Produce biogas from wastewater for electricity generation/water heating."	The factory is not interested

3.2 EE Projects identified (Level B)

The table below is a summary of findings found during the inspection and measurement process (Level B)

Table 10. Gross list (level B mapping)

Gross list							
Project no.	**Name of Project**	**Energy form (gas, electricity, oil,..)**	**Investment Cost (EUR)**	**Saving**			**Simple Payback [Years]**
				Energy [kWh]	**CO2 [ton]**	**Financial (EUR)**	
1	Solution to enhance energy management efficiency, establish an energy management system following ISO 50001 standards	Electricity	5.443,69	843.83	571	59.675,05	0,1
2	Steam Supply System Fuel Management Solution	Heat	54.436,90	20.921.111	6.695	169.661,66	0,3
3	Reduced Inlet Air Temperature for Air Compressor Room 1	Electricity	362,91	11.030	7	780,06	0,5
4	Reduced Inlet Air Temperature for Air Compressor Room 3	Electricity	544,37	29.635	20	2.095,79	0,3
5	Installing solar battery systems on the roofs of factories	Electricity	6.038.866,49	10.603.000	8968	749.839,69	8,1
6	Take advantage of the heat of the 15T2.1 and 20T2.1 boiler exhaust water to heat the additional water	Heat	10.887,38	455.278	157	3.883,17	2,8

7	Renovation of water heater or air dryer for new use of boiler flue heat 15T2.1	Heat	27.218,45	2.576.111	922	20.504,56	0,8
8	Boiler Flue Oxygen Calibration 12T2.1	Heat	3.629,13	1.577.500	564	12.556,78	0,3
9	Replace the pressure reducing valve with temperature reduction to increase heat exchange efficiency and increase the feed water temperature.	Heat	1.814,56	63.007	18	575,94	3,2
10	Replacing 7 small boilers with a large boiler with a capacity of 35 tons of steam per hour combined with the installation of power generation turbines	Electricity Heat	1.088.737,95	123.732.187	40.703	281.158,73	3,8
11	Installation of a new boiler with a capacity of 25 tons of steam per hour to completely burn high-efficiency biomass to replace coal-fired boilers and low-efficiency biomass	Heat	900.572,50	21.835.555	5226	374.616,23	2,4

4 Selected EE Projects for further supports (Level A)

This section includes projects that has been chosen to be developed further (Level A)[1].

The table below is a summary of the findings found during the inspection and measurement process (Level A)

Table 11. Project: Solutions to improve energy management efficiency, build an energy management system according to ISO 50001 standard

<table>
<tr><th colspan="3">Project information</th></tr>
<tr><td>Project: Solutions to improve energy management efficiency, build an energy management system according to ISO 50001 standard</td><td>Project no. 1</td><td>Date:</td></tr>
<tr><td>Enterprise:</td><td>Auditing company: Enervi Vietnam Energy and Environment JSC</td><td>Auditor: Nguyen Xuan Quang</td></tr>
<tr><th colspan="3">Project description</th></tr>
<tr><td colspan="3">Current situation
Through monitoring and surveying the operation of the production line at the Company, it is shown that:
The company has a statistical list of equipment and machinery of each workshop, production line and auxiliary system;
The company has developed and issued a full range of procedures for operation and periodic maintenance of equipment;
The production and use of energy is paid attention to and controlled;
The company has built energy consumption norms for Workshop II, Workshop III and workshops V.
However, some new operation and maintenance processes stop at ensuring technical requirements, so the energy saving factor needs to be paid closer attention. In particular, the management of electricity consumption systems must pay attention to factors such as analyzing electricity consumption demand in regions, identifying key energy consumption areas of the plant and other factors. From there, the energy use</td></tr>
</table>

[1] Then project developed at level B is not described in a section for itself because it is included in gross list.

situation will be analyzed and evaluated to come up with a way to manage, operate and maintain in accordance with energy needs and key energy-using areas.

In addition, based on the data provided by the factory, the audit team has built an Energy Map on a plant-wide scale. Below is a summary of the results of calculating the energy consumption of stages in each production line in 2023:

Power (kWh) = **Power** (kW) × **Operating Time** (h) × **Load Factor** (%)

The formula of the KPI calculation method:

Electricity (kWh) = **Volume Flow** (tons/year) × **KPI** (kWh/ton of raw materials)

The method of calculating power consumption by flow is based on the rated capacity, run time, and load factor of the equipment in a production stage. The method of calculating electricity consumption according to KPIs uses the power consumption norm (kWh/ton of raw materials) and the flow of the volume of raw materials entering 1 stage to evaluate the power consumption of that stage.

The flow-based method is simple, easy to understand and easy to implement, but does not accurately reflect other factors that affect power consumption such as equipment performance or operating conditions. The KPI-based methodology provides a more comprehensive view of energy efficiency, helping to detect problems and opportunities for improvement; However, this method is more complex, requiring more data and in-depth analysis.

The reason for the difference between the 2 methods of calculating heat and electricity consumption by flow and KPI mainly lies in the energy management in the plant. Currently, the plant has only built steam and electricity consumption norms on finished products (tons of steam/ton of finished products and kWh/ton of finished products). Because Workshop I is the oldest line, the factory has not yet built electricity consumption norms for workshop I and some production stages in other workshops have not yet built norms. In addition, there are many factors that can lead to the difference between these 2 methods:

Characteristics of paper: Different products may require different production processes, resulting in different energy consumption, even if the product volume is the same;

Performance of the device: The performance of the device may change 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 the performance of the equipment and thus affect the energy consumption;

External factors: The quality of input materials and equipment breakdowns can also affect energy consumption.

Proposed project The difference between the 2 methods of calculation by flow and KPI is the potential for energy savings in terms of management that the plant can access. In order to optimize energy use and minimize costs, the audit team proposed the solution **"Solutions to improve energy management efficiency and build a standard energy management system ISO 50001"**

Project illustration (PFD)	
Saving	
Energy(annual): 843,827 kWh	**Financial (annual):** 59,675.05 EUR
CO_2 (annual): 571 tons	**Simple Payback (years):** 0.1
Risk Analysis	
Risk: • Requires initial investment and deployment resources. • Potential employee resistance due to lack of awareness of long-term benefits. • The payback period may be extended if the system is not maintained effectively. Risk Mitigation Recommendations: • Training and awareness raising for employees. • Ensure systems are audited periodically to maintain effectiveness.	

Table 12. Project: Fuel management solution for steam supply system

Project information		
Project: Fuel management solution for steam supply system	**Project no. 2**	**Date:**
Enterprise:	**Auditing company: Enervi Vietnam Energy and Environment JSC**	**Auditor: Nguyen Xuan Quang**
Project description		
Current situation Through the field survey and calculation of the heat supply system including boiler workshop 1 and boiler workshop 2, the expert team found the following issues: The heat supply system is equipped with many supporting devices to help manage and operate the boiler more efficiently and save energy. The input fuel also uses biomass to reduce the GHG emission rate as well as reduce the fuel cost of the factory. However, the operation and management of the boiler still has some issues to consider as follows: - The operators have not received any training in boiler engineering, they operate mainly based on the experience passed down from previous skilled workers at the factory. Therefore, the operation process is not really effective; - Biomass fuel is a by-product of wood such as sawdust, chopped wood, firewood, so the size is very different, the operating process always opens the fuel inlet without a plan or adjustment to open and close the fuel inlet below. Therefore, the combustion process still causes fuel loss;		

- Fuel management in terms of quantity: the factory does not have an operating log to record information on the daily fuel consumption volume for each individual boiler, but only records it for each workshop, so when the workshop operates 2-3 boilers at the same time, it is very difficult to accurately determine the efficiency of each boiler when there is no fuel consumption volume. Or some causes of fuel loss in management also lead to inaccurate assessment of boiler efficiency - Fuel management in terms of quality: the inspection of coal and biomass fuel also needs to be managed more closely by the factory, with a plan to periodically inspect and analyze fuel samples, to ensure the quality of input fuel is consistent and meets standards; The factory should also have plans to manage and gather fuel in a covered area, avoiding moisture, increasing fuel humidity, reducing the efficiency of the boiler's combustion. - Due to fuel characteristics: the factory uses imported Indonesian coal, this is Asian Bituminous coal, the nature of this type of coal is to release volatile matter over time, leading to a decrease in the fuel's calorific value compared to the beginning; for biomass fuel, the fuel becomes damp, moldy and releases volatile matter over time, which also leads to a decrease in the fuel's calorific value compared to the beginning.
Proposed project The expert group proposed a group of comprehensive solutions for fuel management for boilers, including: - Building a covered warehouse: reducing the impact of weather factors on product quality such as humidity, volatile substances, etc. - Controlling the input moisture of fuel: controlling the moisture of fuel before entering the factory, monitoring and controlling the moisture of fuel before putting it into the furnace. - Designing and installing a system to utilize waste heat to dry fuel.

Project illustration (PFD)	
Saving	
Energy(annual): 20,921,111 (kWh)	**Financial (annual):** 169,661.66 (EUR)
CO_2 (annual): 6,695 tons	**Simple Payback (years): 0.3**
Risk Analysis	
Risk: • Changes in fuel management can cause operational errors. • Depends on fuel source and costs may fluctuate. • It takes time to train staff and modify processes. **Risk Mitigation Recommendations:** • Build a detailed transformation roadmap and test on a small scale before going full-scale. Enhance system maintenance to ensure continuous operation.	

Table 13. Project: Reduce the inlet air temperature for the Compressor Room 1

Project information		
Project: Reduce the inlet air temperature for the Compressor Room 1	**Project no. 3**	**Date:**

Enterprise:	**Auditing company: Enervi Vietnam Energy and Environment JSC**	**Auditor: Nguyen Xuan Quang**
Project description		

Current situation

During operation, air compressors generate a lot of heat, making the air in the air compressor room always 5°C ÷ 6°C higher than the outside temperature. Meanwhile, the hot air from the air compressor has a fairly high temperature from 24°C (ambient temperature is 20°C) to 31°C (ambient temperature is 27°C).

In addition, air compressor room 1 is a closed space but air compressor number 2 has not been designed with a hot air pipe to the outside, so the temperature in the machine room is very hot. Therefore, the temperature in this air compressor area is always much higher than the ambient temperature.

During the measurement, the audit team found that the ambient temperature of the air compressor location ranged from 23°C to 29°C, much higher than the ambient temperature at the time of the survey. Thus, the power consumption for these areas would increase and cause waste of power.

Proposed project

The energy audit team proposed the solution of "**Reducing the air temperature inlet to the air compressor**" by installing a hot air exhaust pipe for air compressor No. 2 (AIR COMPRESSOR Room No. 1)

Project illustration (PFD)

Saving	
Energy(annual): 11,030 (kWh)	**Financial (annual):** 780.06 (EUR)
CO_2 (annual): 7 tons	**Simple Payback (years):**0.5

Risk Analysis

Risk:

- The energy saving effect may not be as expected if the inlet temperature is not reduced significantly.
- Air cooling equipment investment is required, which may increase initial costs.

Risk Mitigation Recommendations:

- Accurately assess current inlet temperature and possible temperature reduction potential.

Choose equipment with high efficiency and low operating costs.

Table 14. Project: Reduced Inlet Air Temperature for Air Compressor Room 3

Project information		
Project: Reduced Inlet Air Temperature for Air Compressor Room 3	**Project no. 4**	**Date:**
Enterprise:	**Auditing company: Enervi Vietnam Energy and Environment JSC**	**Auditor: Nguyen Xuan Quang**
Project description		

Current situation During operation, air compressors generate a lot of heat, making the air in the air compressor room always 5°C ÷ 6°C higher than the outside temperature. Meanwhile, the hot air from the air compressor has a fairly high temperature from 24°C (ambient temperature is 20°C) to 31°C (ambient temperature is 27°C). In addition, air compressor rooms number 2 and 3 are both located in the production space of paper production, so there is quite a lot of dust. Therefore, the air intake door will often be dirty if not cleaned periodically and regularly, which will affect the air supply process, leading to increased power consumption. During the measurement, the audit team found that the ambient temperature of the air compressor location ranged from 23°C to 29°C, much higher than the ambient temperature at the time of the survey. Thus, the power consumption for these areas would increase and cause waste of power.
Proposed project The energy audit team proposed the solution of "**Reducing the air temperature inlet to the air compressor**" by installing a hot air exhaust pipe for air in AIR COMPRESSOR Room No. 3. In addition, air compressor room No. 3 needs to be separated from the paper production workshop with a drying system so that the installation of hot air exhaust can be effective.

Project illustration (PFD)	
Saving	
Energy(annual): 29.635 kWh	**Financial (annual):** 2.095,79 EUR
CO_2 (annual): 20 tons	**Simple Payback (years):**0,3
Risk Analysis	
Risk: • The energy saving effect may not be as expected if the inlet temperature is not reduced significantly. • Air cooling equipment investment is required, which may increase initial costs. **Risk Mitigation Recommendations:** • Accurately assess current inlet temperature and possible temperature reduction potential. Choose equipment with high efficiency and low operating costs.	

Table 15. Project: Installing solar battery systems on the roofs of factories

Project information		
Project: Installing solar battery systems on the roofs of factories	**Project no. 5**	**Date:**
Enterprise:	**Auditing company: Enervi Vietnam Energy and Environment JSC**	**Auditor: Nguyen Xuan Quang**

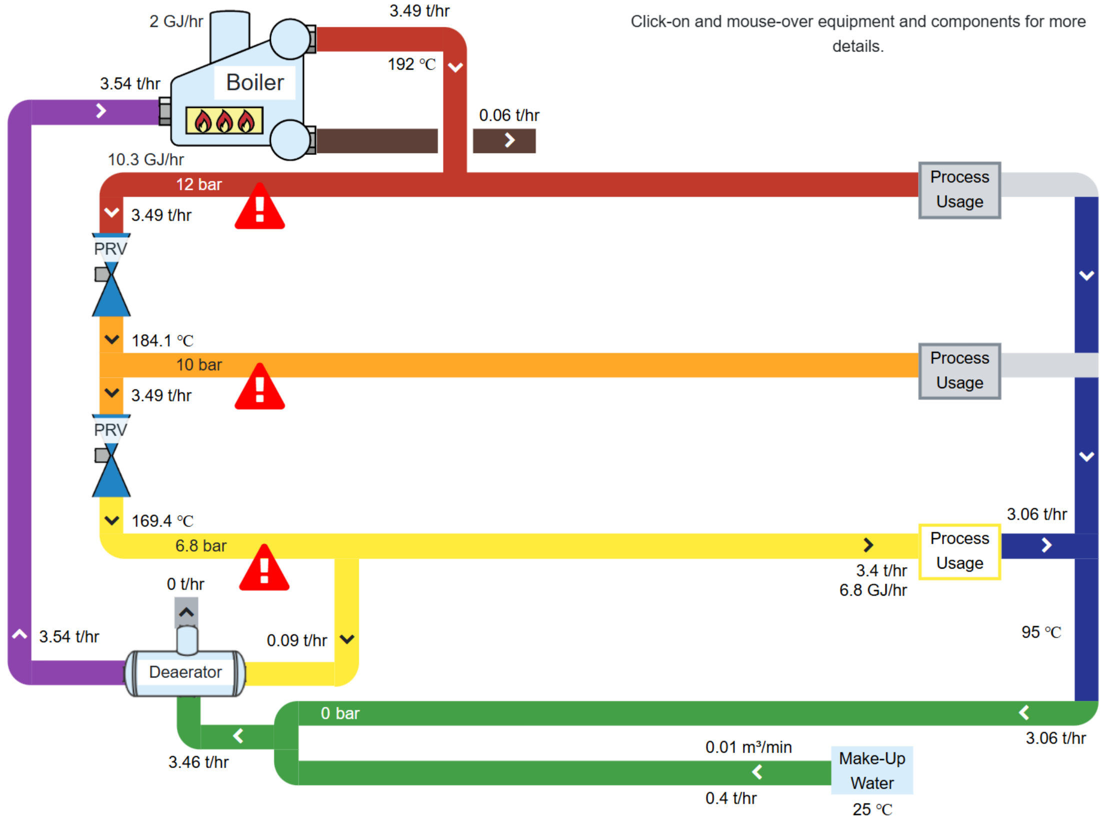
Project description
Current situation Solar power systems in Vietnam are becoming more and more popular, investing in grid-connected solar power systems helps save energy effectively. The average solar radiation in the Central and Southern provinces is about 5 kWh/m^2/day. The average number of sunshine hours per year is from 2,000 - 2,600 hours. The solar panel system is installed on the factory's workshop roof. This battery system will absorb sunlight and create clean electricity to connect to the grid to directly supply electrical equipment.
Proposed project The energy audit team proposed the solution "**Installing solar panels on factory roofs**". If the solar power system is connected to the national grid, it will save investment costs and have a lifespan of over 20 years: The system does not use batteries, so there is no need to spend on investment, maintenance, and repair costs. The system has a lifespan of over 20 years, helping to bring long-term economic and environmental efficiency. Optimal design: - Optimize output with system design using specialized software and solar radiation data, provided by NASA's reliable survey system. - Ensure the highest efficiency for faster capital recovery. - Easy operation and maintenance. - Ensure electrical safety, lightning and storms. - Fully meet EVN's electrical technical standards. To invest in a solar panel system at the company, there are 02 options as follows: - Option 01: The company invests 100% of its own capital and manages and operates it itself. - Option 02: The solar panel supplier will invest and install 100% of the panel system At the factory, then sell electricity to the factory at a price committed to be 10-15% cheaper than EVN's unit price. After operating the solar panel system for about 20 years - 25 years depending on the proposal of the management and operation company, the supplier will transfer the right to take over and operate it back to the company.
Project illustration (PFD)

Saving	
Energy(annual): 10,603,000 kWh	**Financial (annual):** 749,839.69 EUR
CO_2 (annual): 8,968 tons	**Simple Payback (years):** 8.1
Risk Analysis	

Risk: • Initial investment cost is very high (8.1 years to pay back). • System performance is dependent on weather conditions and maintenance. • Roof structure changes may be required to accommodate solar panels. **Risk Mitigation Recommendations:** • Choose a reputable supplier and carefully check the system design. Perform regular maintenance to ensure optimal operating performance.

Table 16. Project: Calibration of oxygen in flue gas of boiler 12T2.1

Project information		
Project: Calibration of oxygen in flue gas of boiler 12T2.1	**Project no. 6**	**Date:**
Enterprise:	**Auditing company: Enervi Vietnam Energy and Environment JSC**	**Auditor: Nguyen Xuan Quang**
Project description		
Current situation The 12T2.1 boiler burns a large-sized biomass coal mixture, and the fuel injection is done at only one corner, leading to fuel pile-up in one location and a fairly large area of the grate without fuel. This results in a combustion process that lacks oxygen at the required location, but the exhaust has excess oxygen due to lack of contact with the fuel. This increases heat loss along the exhaust, leading to reduced furnace efficiency and increased fuel consumption.		
Proposed project The expert group recommended that the factory should reasonably renovate the fuel input location, adjust the fuel size appropriately and adjust the air supply for the combustion process, which can help reduce the oxygen in the furnace's exhaust gas from 15% to about 9%.		
Project illustration (PFD)		



Operating efficiency of the furnace when reducing exhaust oxygen to 9%

Saving	
Energy(annual): 1,577,500 kWh	**Financial (annual):** 12,556.78 EUR
CO_2 (annual): 564 tons	**Simple Payback (years):** 0.3

Risk Analysis

Risk:

- Requires highly specialized personnel to perform calibration.
- If not done properly, it can cause combustion imbalance and reduce boiler efficiency.

Risk Mitigation Recommendations:

- Hire a professional or reputable service provider for calibration.

Regular monitoring to ensure stable system operation after calibration.

Table 17. Project: Replace 7 small boilers with large boilers with capacity of 35tph combined with installation of power turbines

Project information		
Project: Replace 7 small boilers with large boilers with capacity of 35tph combined with installation of power turbines	**Project no. 7**	**Date:**
Enterprise:	**Auditing company: Enervi Vietnam Energy and Environment JSC**	**Auditor: Nguyen Xuan Quang**

Project description

Current situation

The company's heat supply system consists of 2 boiler workshops with a total of 7 boilers with different capacities. Of which, only 4 boilers are operated in shifts to provide steam for the production area and the remaining boilers are on standby. The input fuels of the boilers are coal and biomass (including sawdust, firewood, and chopped wood). Depending on the steam demand during the production process, the boilers are mobilized into operation.

Through the survey, the expert group found the following 2 problems:

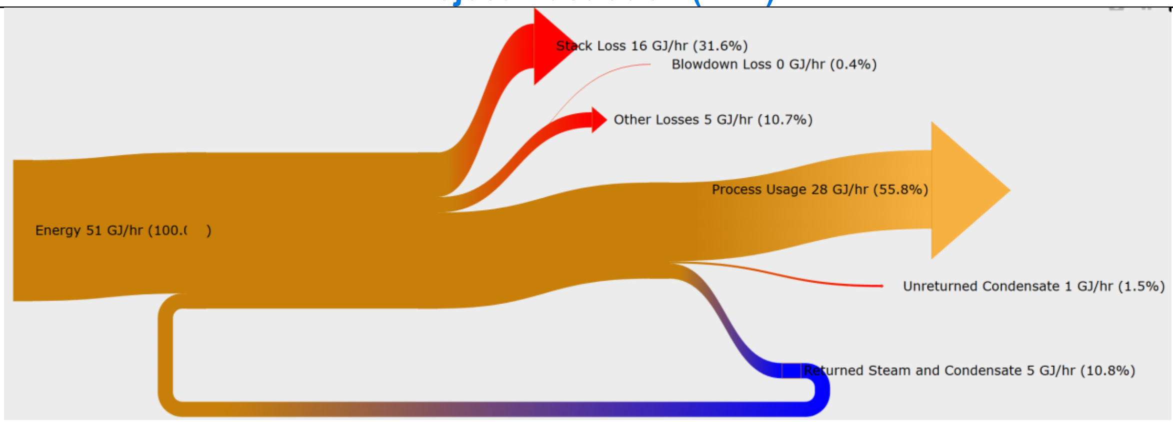
- The factory has 7 boilers, however, the factory only operates about 3-4 boilers to meet the steam demand for production, the remaining 3-4 boilers are not operating, or operate alternately for a very short time. This costs a lot of money for the process of starting the boiler and maintaining the boiler, at the same time, operating many single boilers also costs more labor, the efficiency of the boilers is not uniform, leading to a lot of fuel consumption to produce steam.
- Workshop 1 is producing saturated steam at a pressure of 8.5-9 bar, while the pressure used at the drying batch is 1.3-3.5 bar; Workshop 2 is producing saturated steam at a pressure of 11-12 bar, while the pressure used at the drying batch is 6-6.8 bar. Producing steam at a higher pressure consumes more energy while the demand for steam is low pressure.

Proposed project

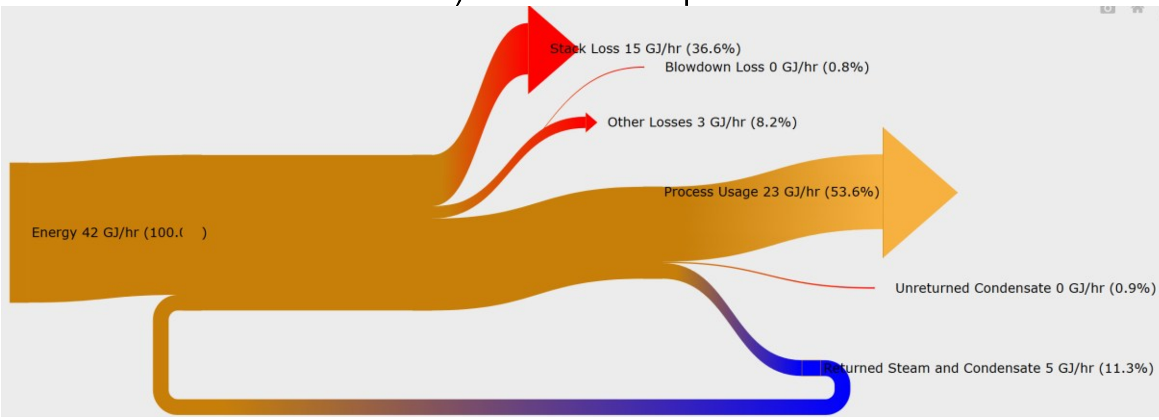
The expert group proposed to replace all 7 current boilers with a large-capacity boiler with a steam generation capacity of 35 tons of steam per hour, a pressure of 30 bar, superheated steam generation of about 300 degrees Celsius combined with the installation of a counter-pressure turbine with a power generation capacity of about 2MW with an output steam pressure of 7 bar. The turbine output steam will be fed to the paper workshops to serve the heat needs of the processes. This proposal is based on the plant's largest required steam output when expanding in the future. However, with the current state of steam use as of 2023, the following calculation is used to compare the current state with a unified steam system.

The calculation results of the solution "Replacing 7 small boilers with large boilers combined with the installation of power generation turbines**"** are shown in the Sankey diagram and the operating cost table below (calculated for the 2023 operation case is 25 tons of steam/hour)

Project illustration (PFD)

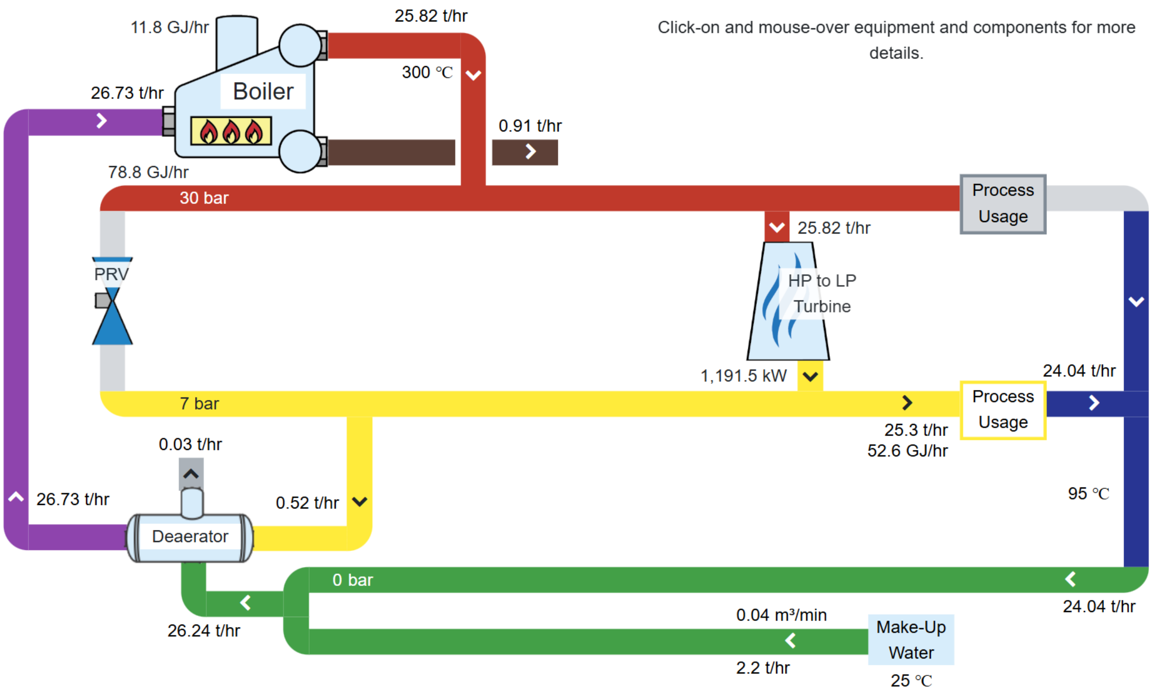


a) Boiler workshop 1

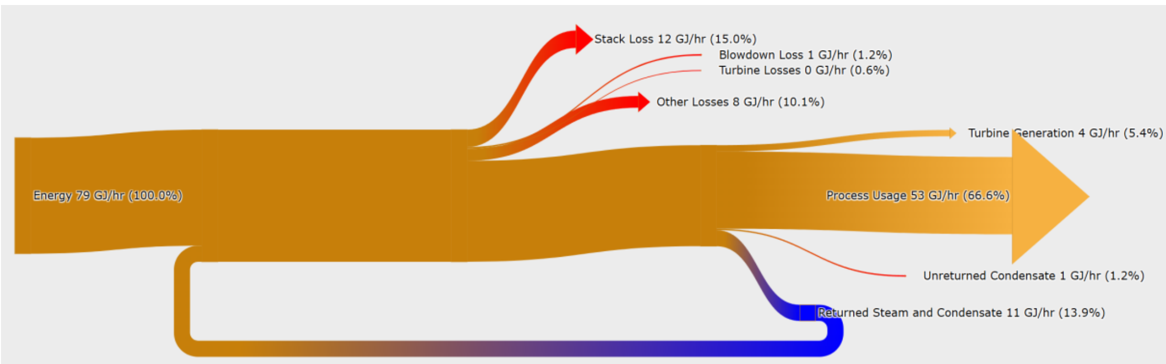


b)Boiler workshop 2

Sankey diagram of heat loss of boiler workshop 1 and 2



Schematic diagram of the replacement boiler and turbine system



Sankey diagram of heat loss of boiler system and turbine replacement

Saving	
Energy(annual): 123,732,187 kWh	**Financial (annual):** 1,088,737.95 EUR

CO_2 (annual): 40,703 tons	**Simple Payback (years):** 1.6

Risk Analysis

1. Technical risks

- Complexity in design and operation: integrating a large boiler with a power turbine requires a high degree of synchronization between the equipment. Errors in design or installation can reduce operating efficiency and increase maintenance time.
- Dependent on fuel source: fuel used must be consistent and tightly controlled to ensure high efficiency. Without quality assurance or stable supply, large boilers may operate inefficiently.

2. Financial risk

- Initial investment costs are very high: the total investment capital is large, while the expected payback period is 3.8 years, which can put financial pressure on the business if there is no reasonable financial plan.
- Fuel price volatility risk: increases in fuel costs may affect the expected economic benefits from the solution.

3. Operational risks

- High technical requirements for operating personnel: operating large boilers and turbine power systems requires highly skilled technical staff. Lack of trained personnel can lead to operating errors or reduced system performance.
- Initial downtime: Replacing 7 small boilers with large boilers will require time for installation, integration and commissioning. During this period, production may be interrupted, affecting business efficiency.

4. Environmental risks

- Potential environmental impact: if not properly controlled, the new system could cause pollution problems, such as greenhouse gas emissions or fuel ash.
- Dependent on legal regulations: strict environmental regulations must be followed. Changes in policies or regulations may pose legal risks to the project.

5. Other risks

- Actual performance may not meet expectations: If the system is not optimized during operation, economic and energy benefits may be lower than expected.
- Maintenance related risks: maintenance costs for large boilers and power turbines can be higher than for small boilers if not properly managed.

Risk Mitigation Proposal

- Detailed pre-investment assessment: conduct detailed feasibility analysis (including technical and financial risks).
- Personnel training: strengthen training of operations and maintenance team to ensure stable system operation.
- Control fuel sources: sign long-term contracts with fuel suppliers to ensure quality and stable supply.
- Performance monitoring and evaluation: install systems to measure and monitor the performance of boilers and turbines to promptly detect and correct problems.
- Build a contingency fund: establish a contingency fund to deal with unforeseen risks, especially higher than expected operating and maintenance costs.

Table 18. Project: New installation of 25 tons of steam/hour boiler, burning entirely biomass, high efficiency to replace low efficiency coal and biomass boiler

<table>
<tr><th colspan="3">Project information</th></tr>
<tr><td>Project: New installation of 25 tons of steam/hour boiler, burning entirely biomass, high efficiency to replace low efficiency coal and biomass boiler</td><td>Project no. 8</td><td>Date:</td></tr>
<tr><td>Enterprise:</td><td>Auditing company: Enervi Vietnam Energy and Environment JSC</td><td>Auditor: Nguyen Xuan Quang</td></tr>
<tr><th colspan="3">Project description</th></tr>
<tr><td colspan="3">Current situation
The company's heat supply system consists of 2 boiler workshops with a total of 7 boilers with different capacities. Of these, 4 boilers are operated (including 3 coal + biomass boilers and one coal boiler) in rotation to supply steam to the production area and the remaining boilers are standby. The input fuel of the boilers is coal and biomass (including sawdust, firewood, and chopped wood chips).
The process of burning coal and fossil fuels such as oil and gas will create a large amount of greenhouse gases, bringing many negative consequences to the environment. Specifically, the process of burning fossil fuels will create a large amount of CO2 and pollutants such as NO_2 , SO_2 , fine dust, etc. During the process of use, the exploitation, processing and distribution of coal will have a very negative impact on the natural ecosystem and the surrounding environment.
biomass also produces greenhouse gases, but plants absorb about the same amount of CO_2 during growth as they release when burned, meaning biomass can be considered a “carbon neutral” fuel source.
Currently, the boilers at the plant are operated in a decentralized manner, which is an inefficient way of operating the boilers, because:
- Some boilers operate in On/Off mode depending on the steam demand for production, consuming a lot of energy to start and maintain the boiler, and also reducing the life of the boiler structure. During a year, the factory often operates alternately between boilers to serve the maintenance and repair of the boiler. Table 7.21 below is the total operating time of the boilers at the factory .
- Low average boiler efficiency
- Operating many boilers also requires a lot of labor, leading to increased boiler operating costs.
- Implementing individual energy saving solutions for each boiler costs more investment and does not improve the overall efficiency of the system much.</td></tr>
</table>

Proposed project

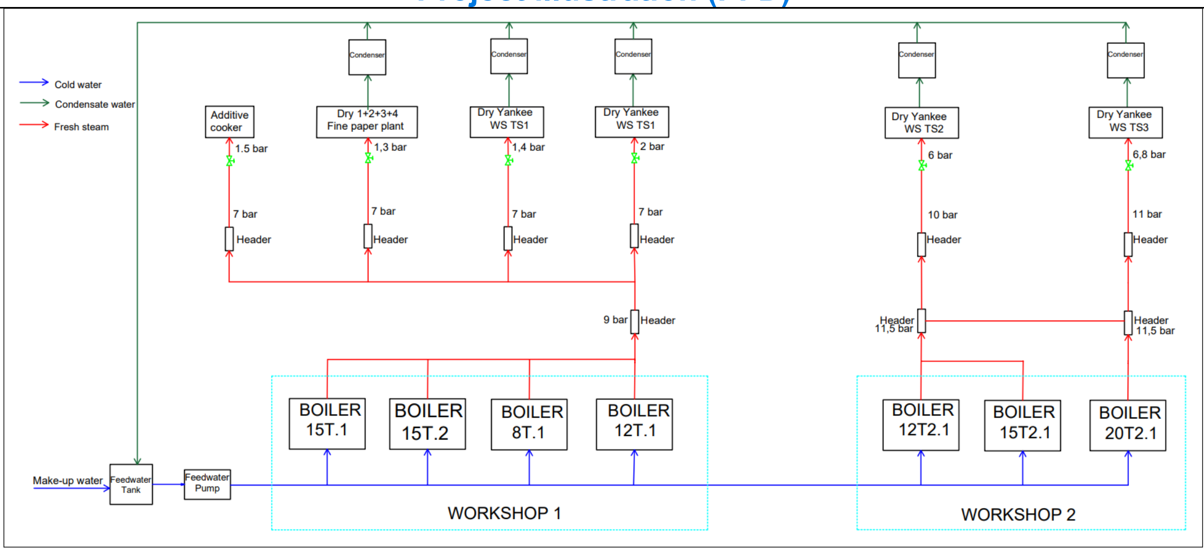
The expert group proposed the solution: "Install a new boiler with a capacity of 25 tons of steam/hour, burning entirely high-efficiency biomass, to replace the low-efficiency coal and biomass boiler."

The factory's investment in installing a large-capacity biomass-burning boiler and operating centrally will bring the following advantages:

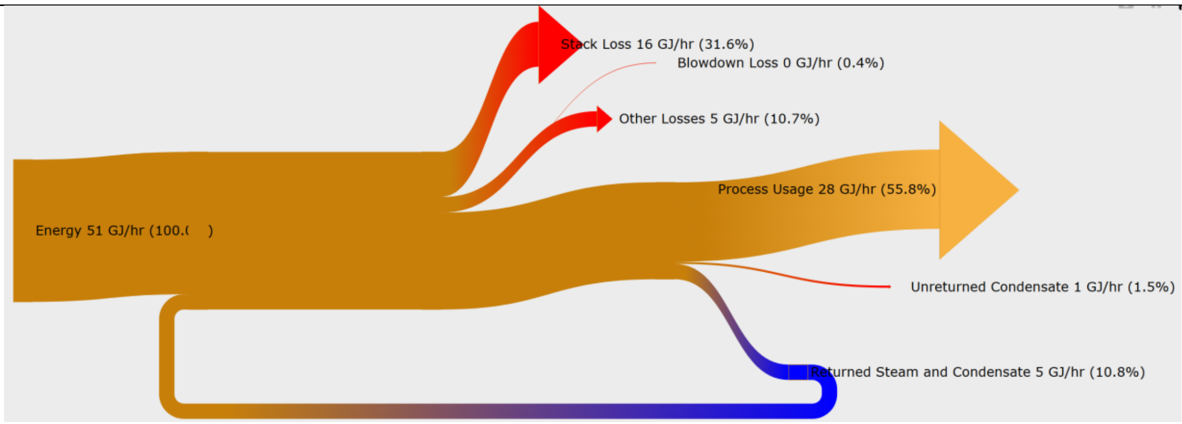
- The new 25 t/h boiler will use bark and chipped wood (chipped waste) as fuel instead of the current biomass fuel (firewood, wood chips and sawdust) and coal. Bark and chipped wood are cheap, easy to find fuels and burn more efficiently than wood and wood chips
- The current 15T.1 and 15T.2 boilers are fluidized bed boilers but are not operated in a fluidized bed manner. The new 25t/h boiler using modern step grate technology will achieve higher efficiency than the two old boilers.
- Centralized operation of large capacity boilers makes it easy to control and improve boiler operating efficiency.
- Reduce emissions of large amounts of greenhouse gases CO_2 , SO_2 , ... into the environment by eliminating coal fuel
- Investing in a large capacity boiler helps reserve capacity to serve the factory's production expansion needs.

After implementing the solution, the steam system at the factory will operate two main boilers, including a new 25-ton steam/hour boiler (tentatively called 25T.1) burning biomass at workshop 1 and a 15T2.1 boiler burning biomass at workshop 2. Three boilers 15T.1, 15T.2 and 12T2.1 operate as backup. The new 25T.1 boiler with a capacity of 25 tons of steam/hour and operating at a working pressure of 12 bar is installed on the premises of workshop 1 and connected to the steam distribution system at workshop 1 available at the factory.

Project illustration (PFD)

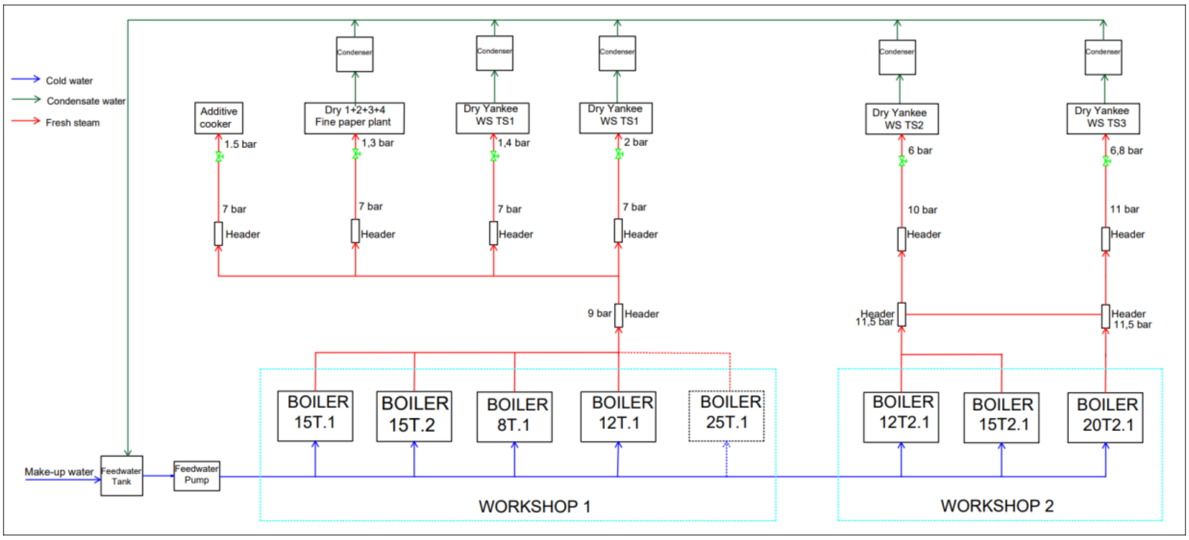


Schematic thing system system steam belong to home machine presently

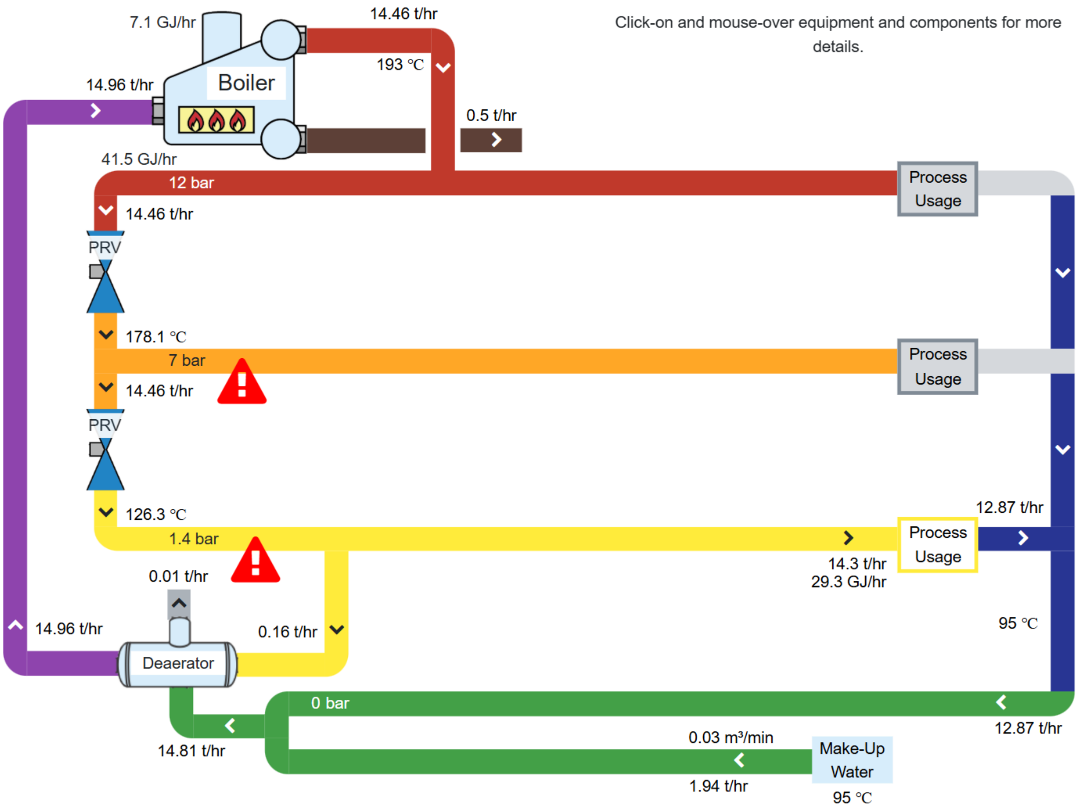


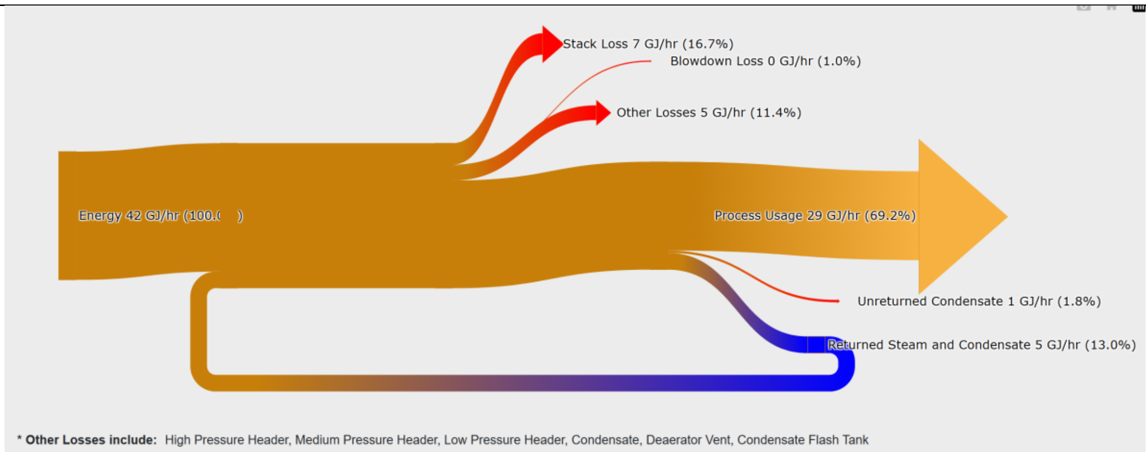
a) Boiler workshop 1

Chart Sankey damage heat loss boiler workshop 1



Steam system diagram of the factory after implementing the solution





Sankey chart of heat loss of 25 tons of steam/hour boiler after implementing the solution

Saving

Energy(annual): 78,608 GJ	**Financial (annual):** 374,616.23 EUR
CO_2 (annual): 5,226 tons	**Simple Payback (years):** 2.4

Risk Analysis

1. Technical risks

- Dependent on fuel source: fuel used must be consistent and tightly controlled to ensure high efficiency. Without quality assurance or stable supply, large boilers may operate inefficiently.

2. Financial risk

- Initial investment costs are very high: the total investment capital is large, while the expected payback period is 3.8 years, which can put financial pressure on the business if there is no reasonable financial plan.
- Fuel price fluctuation risk: increases in fuel costs may affect the expected economic benefits from

Risk Mitigation Recommendations:

- Detailed assessment before investment: conduct detailed feasibility analysis
- Personnel training: strengthen training of operations and maintenance team to ensure stable system operation.
- Control fuel sources: sign long-term contracts with fuel suppliers to ensure quality and stable supply.
- Performance monitoring and evaluation: install systems to measure and monitor the performance of boilers and turbines to promptly detect and correct problems.
- Build a contingency fund: establish a contingency fund to deal with unforeseen risks, especially higher than expected operating and maintenance costs.

Non-Energy benefits

When the project comes into operation, in addition to the economic efficiency brought to the enterprise, the project also brings socio-economic efficiency such as:

- Increase budget revenue for the state and local budgets through corporate income tax.
- Reducing thermal pollution: When high temperature exhaust gas is discharged directly into the environment, it causes thermal pollution, increasing the temperature of the surrounding air and water. This has a negative impact on the ecosystem and human health. Utilizing waste heat reduces the temperature of the exhaust gas discharged into the environment, thereby limiting thermal pollution and reducing negative impacts on the living environment.
- Extend equipment lifetime: Reduce the load on the boiler due to less fuel demand, helping the equipment operate more stably, reducing overload and rapid wear. Reduce maintenance, repair and replacement costs of equipment. The life of the boiler and related equipment is extended, improving investment efficiency.
- Improve the working environment: Excess heat emitted from exhaust gases not only heats up the production space but also causes discomfort and unsafety for workers. Reducing the heat emitted helps the working space to be cooler and more comfortable. Improve the health and productivity of workers.
- Supporting sustainable development: Optimizing energy use is an environmentally friendly solution, in line with the trend of sustainable development and corporate social responsibility. Enterprises contribute to the global sustainable development goals (SDG). Building a "green" and environmentally friendly corporate image.
- Improve resource efficiency all forms of energy are valuable resources. Waste heat, if not utilized, will become waste. Heat reuse helps optimize energy resources. Reduce waste of energy and resources. Bring double benefits: reduce production costs and improve system efficiency.
- The spillover effects of the project will promote energy saving activities and efficient energy use for key energy users, especially construction and energy industry groups.
- The project, when put into operation, will help reduce production costs, reduce product prices, increase competitiveness in the market, create jobs for local workers, thereby promoting local socio-economic development.
- For the macro economy, the project will help the company's products increase their competitiveness with traditional brick products, contributing to meeting the increasingly strong domestic construction demand instead of using traditional red bricks by using unburnt bricks, thereby contributing to a sustainable economy and reducing environmental emissions for construction activities.

If ETS in Vietnam is opened as planne, the company can has a expected annual revenue of 621.48 USD/year from selling GHG emission reduction issued by each sub-projects.

The proposed project	**Expected estimated revenue from selling carbon credit (USD/year)**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Total	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832	2,832

The price of Carbon credit is sourced from the website of "https://carboncredits.com/carbon-prices-today/".