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Innovative components and configurations for heat pumps

ZIMBA

Zero-carbon Industrial heat production by aMmonia water aBsorption heAt transformer

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Deliverable D1.3
Specifications of the end users' heat demands and wastes – v2

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Executive Summary

Deliverable D1.3 aims to define end-user requirements and identify suitable industrial sectors and configurations where low-temperature waste heat (e.g., 70 to 80 °C) and low-pressure steam demand (100 to 110 °C) coexist, thereby supporting the design and deployment of the ZIMBA AHT.

To gather end-user requirements, a structured approach was followed, including:

- a literature review to identify key industrial applications for the ammonia/water AHT,
- an online questionnaire distributed via CLAUGER sales representatives to end-users, and
- follow-up interviews with available customers to clarify and refine end-user requirements.

D1.3 is an update to D1.2 (delivered on 25 March 2025), further specifying heat demands and waste heat availability at the end-user level. Significant waste heat potential exists in the EU at temperatures ranging from 70 to 80 °C, primarily in the power generation (engine cooling), refining, chemical, paper, and food sectors.

The literature review, mainly based on commercially available water/LiBr AHT products for industrial use, confirmed that the most promising industrial sectors for AHT integration include the food, chemical, and paper industries. Typical use cases that fit the ZIMBA AHT specifications involve alcohol distillation, paper drying, and integration in district heating networks, particularly in colder regions of Europe and China.

Previous research has also shown potential for AHT in cogeneration, seawater desalination, water purification, distillation in chemical plants, and evaporation processes.

All 5 surveyed European food and beverage companies have combined heating and cooling needs, with 3 reporting significant waste heat at 70 to 80 °C, highlighting AHT integration potential: Distillerie de la Tour (0.5 to 1 MW), Distillerie de la Salle (1 to 5 MW), and Gélagri (>5 MW).

However, few industrial applications precisely match the ZIMBA AHT's operating conditions, as the driving waste heat temperature, which ranges from 72 to 80 °C, remains the major constraint. Further investigation is needed to identify processes that require steam at approximately 110 °C.

Interviews were conducted with the French companies Lactalis, Gélagri, and Distillerie de la Salle. Each interview was accompanied by a simplified process flow diagram, helping to identify potential AHT integration points. Responses from the questionnaire provided additional insights into specific process conditions and technical constraints.

The interviews revealed that steam at 100 to 130 °C is indeed required, for example, in pasteurization and CIP systems. However, this steam use is often intermittent, which poses a challenge for consistent AHT operation.

A key opportunity lies in the 87 °C return water from condensing economizers on gas-fired steam boilers. This waste heat stream could drive an AHT system, provided the integration is technically feasible.

The interviews also indicated that heat rejection at 10 to 30 °C is of limited value, as cold water is often available at similar temperatures. In some cases, this low-temperature heat could be used for preheating. If an application is found (e.g., for preheating water in a process), this would significantly improve overall efficiency.

Ultimately, the design of the ZIMBA AHT system will be driven primarily by the need for steam. While low-temperature heat rejection up to 30 °C is not always recoverable, it is not considered a major issue, as it can be discharged through cooling towers, dry coolers or other systems.

The results presented in D1.3 will feed into the next project phase, where concrete AHT integration concepts will be further explored in WP4. A continued focus will be placed on identifying suitable processes within the food and chemical industries, particularly where steam at around 110 °C is required and sufficient driving waste heat is available.

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1. Introduction

This Deliverable D1.3 focuses on identifying the process heat demands (low-temperature steam) and low-temperature waste heat available in the targeted industrial sectors. D1.3 has been elaborated in Task T1.2, which focuses on collecting end-users' requirements (Lead: OST, Partners: CLAU, CEA, POL) within Work Package WP1, specifically for designing the innovative AHT system (Lead: CEA).

The objective is to identify industrial sectors and configurations where both low-temperature steam demand and low-temperature waste heat exhaust are present.

In focus are the food and beverage, chemical, and pulp and paper industrial sectors, which require low-temperature steam.

D1.3 is linked to Task T1.3 to provide, for example, the temperatures for the AHT design.

D1.2 was established by 31 May (M6) as the first step in analyzing the end-users' requirements.

As illustrated in Figure 1, the AHT technology has three temperature levels and has the potential to produce one unit of heat at 100 to 110 °C from two units of low-temperature waste heat at 70 to 80 °C, while consuming only 0.02 units of electricity and releasing one unit of ultra-low temperature heat up to 30 °C. The heating and cooling capacities required are based on the customer's requirements.

- 70 to 80 °C hot water (heat source) – 2 units
- 100 to 110 °C steam directly (heat sink) – 1 unit
- 10 to 30 °C cold water – 1 unit

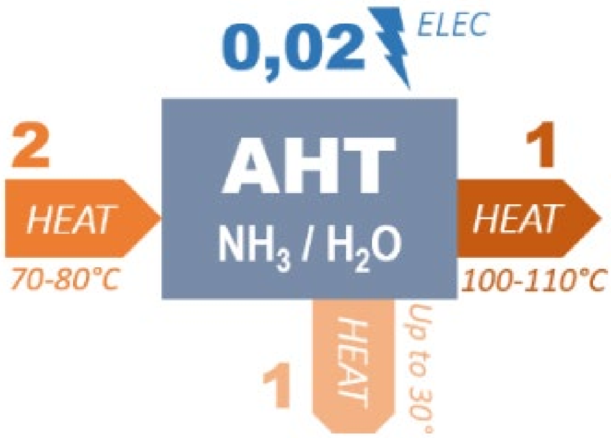


Figure 1: Illustration of the relative inlet/outlet energy fluxes requested for the operation of the ZIMBA AHT system to supply process heat at 100 °C from industrial waste heat at 70 °C with hardly any electricity consumption (CEA, 2023).

Finally, OST will explore the potential for replicating and transferring the AHT technology to other relevant industry sectors, thereby extending the impact assessment beyond the testing facility.

2. Methodology

The methodology chosen for elaborating the end-user requirements (D1.2 and D1.3) was as follows:

- Literature Review:
    - For an initial filtering of the industrial sectors, literature research was carried out using the Web of Science, Scopus, and Google Scholar databases.
    - The most important industrial sectors (OST), industrial applications, and temperature levels, among others, were summarized and reviewed (CEA, CLAUGER).
- Questionnaire:
    - An online questionnaire was created (OST, CLAUGER review).
    - The questionnaire with the survey link was sent to end-users via the CLAUGER sales representative network.
    - A standard E-mail text was created (OST) for the invitation to participate in the survey, including a brief description of the objectives and goals of ZIMBA.
    - Focus was on the industry sectors: food & beverage, chemicals, and pulp & paper.
    - The target group was engineers, sales, service, and product managers.
- Interviews:
    - Based on the survey feedback, follow-up interviews were arranged for some individual customers who were open to sharing and clarifying their end-user requirements.
- Summary/Conclusions:
    - The results of the Literature Review, Questionnaire, and Interviews were summarized in Deliverables D1.2 and the present D1.3.

3. Literature Review

The goal of the literature review was to identify the most relevant industries and applications where AHT technology could be applied. To this end, the databases Web of Science, Scopus and Google Scholar were searched.

3.1. The ZIMBA AHT, process temperatures, and waste heat potential

Figure 2 illustrates the integration of the ZIMBA AHT (Absorption Heat Transformer) technology with a circular heat system approach into a potential energy system. The AHT, based on ammonia/water, recovers low-temperature industrial waste heat (range 70 to 80 °C) to provide higher-temperature process heat (100 to 110 °C) necessary for steam production or other industrial uses and reject low-temperature waste heat (below 30 °C, ideally allowing varying cooling temperatures) to potential 5th-generation district heating systems (CEA, 2023).

A major benefit of an AHT system is that it can upgrade waste heat at a low electricity cost (Collignon et al., 2025, 2024).

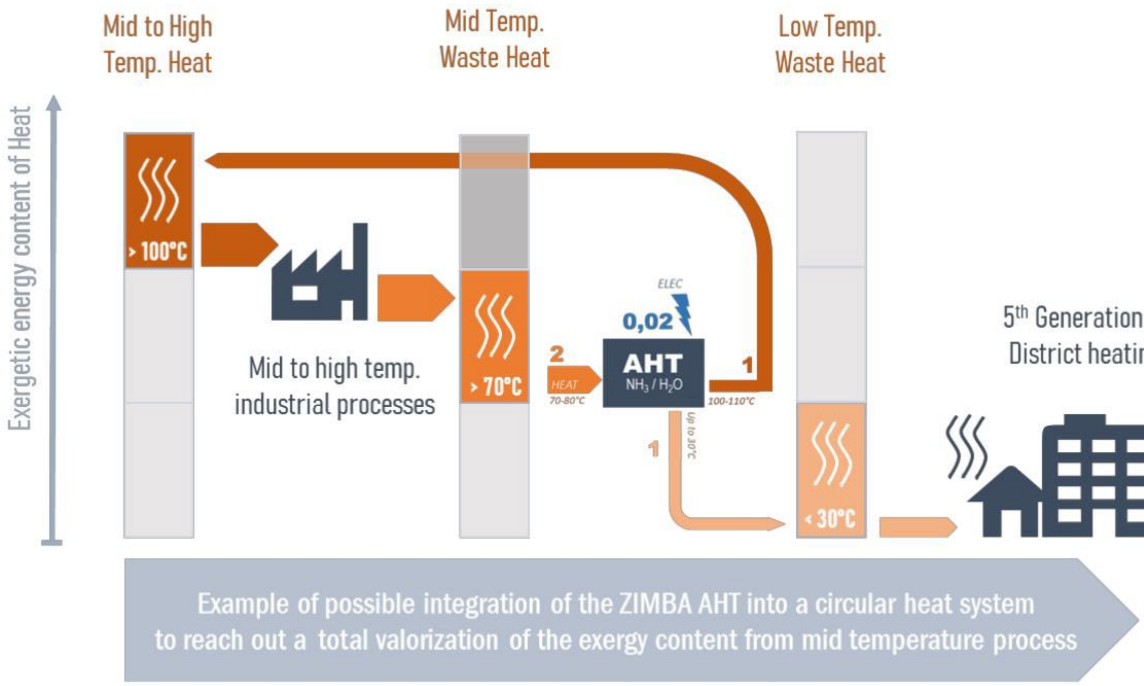


Figure 2: Illustration of potential integration of the ZIMBA AHT system into the energy system with a circularity approach (CEA, 2023).

In the AHT, three distinct temperature levels are involved. When the same waste heat is used to drive both the evaporator and generator, their temperatures are generally aligned. However, if the available waste heat cannot adequately supply both components for practical reasons, a temperature difference may occur between the evaporator and generator (Best et al., 1987). Numerous industries need process heat at high temperatures while dissipating heat at moderate to low temperatures. Figure 3 lists some typical temperature ranges of processes in the food, beverages, paper, metal surface treatment, and brick & block industries (CEA, 2023; Kalogirou, 2003).

Industrial Sector	Unit operation	Temperature range (°C)
Food	Drying	30-90
	Washing	60-90
	Pasteurising	60-80
	Boiling	95-105
	Sterilising	110-120
	Heat Treatment	40-60
Beverages	Washing	60-80
	Sterilising	60-90
	Pasteurising	60-70
Paper Industry	Cooking and Drying	60-80
	Boiler feed water	60-90
	Bleaching	130-150
Metal Surface Treatment	Treatment, electro-plating, etc.	30-80
Bricks and Blocks	Curing	60-140

Figure 3: Typical process heat temperatures in the food, beverages, paper, metal surface treatment, and bricks & blocks industries (Kalogirou, 2003).

Table 1 lists some steam requirements in the food industry.

Table 1: Steam requirements in the food industry.

Parameter	Drying	Sterilization
Steam type	Saturated or slightly superheat	Saturated or clean steam
Temperature range	100 to 160 °C	121 to 135 °C
Pressure range	0.5 to 6 bar(g)	2 to 3.5 bar(g)
Purity requirements	Industrial-grade steam or clean steam (if direct)	Clean steam (food contact surfaces or packaging)
Application examples	Fruit drying, pasta drying, pet food drying	Autoclaves, CIP, sterilizing vessels, packaging

Figure 4 illustrates the cumulative waste heat available above a given temperature level for the food, paper, chemical, and refinery sectors within the EU28 (Marina et al., 2021). Across all sectors, most of the waste heat is between 40 and 100 °C, amounting to 764 PJ/a (= 212.5 TWh/a), or 67.6% of the total waste heat below 200 °C. The 70 to 80 °C range represents a significant recovery potential for the ZIMBA AHT, especially in the refinery sector, with opportunities also present in the chemical, paper, and food sectors.

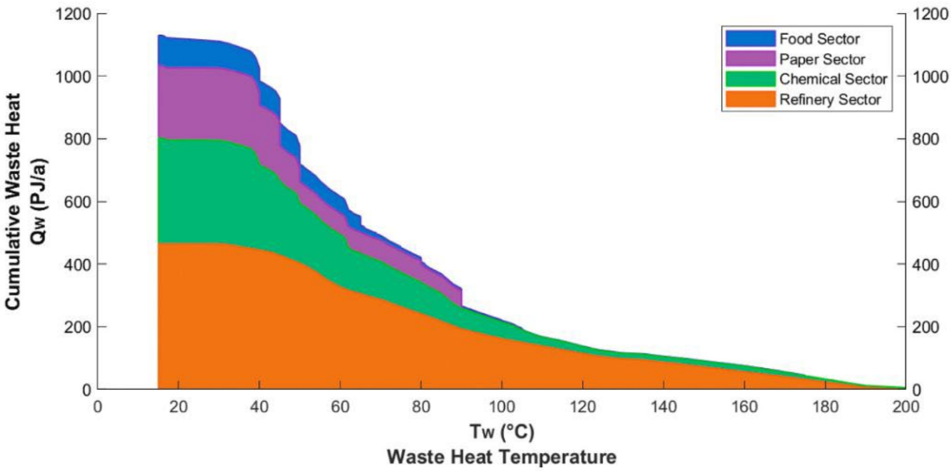


Figure 4: Cumulative waste heat <200 °C in EU28 identified in processes (Marina et al., 2021).

(Luberti et al., 2022) estimated the available low-grade waste heat in the EU based on data from 2018 (Table 2). The analysis revealed that the largest share of waste heat originated from electricity generation, primarily at temperatures between 40 °C and 59 °C for engine coolants. In addition, waste heat in the range of 60 to 79 °C was identified in power generation and the food sector.

Table 2: Waste heat potential per temperature level from power generation and industrial sectors in the EU in 2018 (Luberti et al., 2022). Highlighted in yellow is the waste heat in the range of 60 to 79 °C in power generation (1'042.2 PJ = 289.5 TWh) and the food sector (41.4 PJ = 11.5 TWh).

Temperature range (°C)	Waste heat (10^6 GJ)						
	Power generation	Industrial sectors					
		Mining	Minerals	Metals	Chemicals	Pulp & Paper	Food
<40	548.3	12.9	0.0	0.0	0.0	0.0	0.0
40–59	6441.4	60.3	0.0	0.0	39.7	94.8	127.4
60–79	1042.2	0.0	0.0	0.0	0.0	0.0	41.4
80–99	290.0	11.9	0.0	0.0	0.0	0.0	64.1
100–499	132.2	43.6	6.3	48.6	0.0	0.0	27.9
500–999	97.8	9.8	52.3	67.3	0.0	0.0	0.0
>1000	0.0	0.0	387.8	712.0	0.0	0.0	0.0
Subtotals	8551.8	138.4	446.4	827.9	39.7	94.8	260.8
		1808.0					
Grand total	10359.9						

3.2. Ammonia/water AHT

Although water/LiBr AHTs are widely applied commercially, they present several significant technical limitations. LiBr solutions are highly corrosive to metals, especially at elevated temperatures, and have high viscosity and limited solubility.

Another critical issue is the risk of crystallization that occurs when the absorber temperature rises at a constant evaporating pressure, particularly with strong solutions. To prevent operational disruptions, regular maintenance is required (CEA, 2023). Various strategies have been proposed to mitigate the crystallization issue, including the use of chemical crystallization inhibitors, enhanced heat and mass transfer, and modifications to the thermodynamic cycle (Parham et al., 2014).

In contrast, ammonia/water AHTs do not experience crystallization issues because ammonia is completely soluble in water, preventing crystallization and ensuring greater operational flexibility and reliability. Moreover, ammonia/water AHTs can deliver higher supply temperatures, up to about 150 to 160 °C, which is not achievable with water/LiBr AHT systems due to water's boiling point and crystallization limitations.

However, ammonia/water AHTs for temperatures above 80°C are very rare on the market.

An exception is the single-stage ammonia/water AGO Calforma heat transformer from AGO GmbH Energie + Anlagen (Germany), which delivers 60 to 110 °C hot water at 0.4 to 1.5 MW heating capacity using 45 to 70 °C waste heat, with a heating COP of 0.35 to 0.50 (Ayou et al., 2025). However, as of today, AGO has not sold any ammonia/water AHT due to a lack of market demand. The company would consider offering ammonia/water AHTs again if sufficient market interest emerges and a profitable commercial application can be identified. These AHT systems would be custom-made, and as such, no public information is currently available.

In experimental research of ammonia/water AHT, the test rigs by Garone et al. (2017, 2018) (Politecnico di Milano, Italy) and Haak et al. (2024) (University of Stuttgart, Germany) have been documented and experimentally characterized.

Garone (2018) and Garone et al. (2017) built an ammonia/water AHT prototype with about 4.5 kW heating capacity and demonstrated stable operation at waste heat temperatures of 60 to 64 °C and condenser temperatures of 8 to 16 °C (suitable for dry cooling in winter). Gross temperature lifts (GTL) of 15 K to 25 K were achieved, and the thermal COP ranged between 0.35 and 0.47.

Haak et al. (2024) presented initial measurement results of an ammonia/water AHT with a heating capacity of approximately 10 kW. The system is constructed using plate heat exchangers and piston diaphragm pumps. The maximum system pressure is 40 bar, enabling supply and waste heat temperatures of up to 120°C and 95°C, respectively. A heating capacity of up to 8.3 kW was achieved at a supply temperature of 115 °C with a COP of 0.384. The temperature lift was 25 K. The measurements indicated that the process is sensitive to fluctuations on the low-pressure side.

Concerning thermodynamic design, Best et al. (1987) provided the first data for ammonia/water AHTs, along with feasible combinations of operating temperatures and working fluid concentrations in the absorber and generator. Based on their modeling, the following typical temperature ranges were identified for the main system components: absorber 40 °C to 120 °C, evaporator 30 °C to 70 °C, generator 30 °C to 90 °C, and condenser 10 °C to 50 °C.

Liu et al. (2023) focused on enhancing the heating capacity of an ammonia/water AHT system by enlarging the temperature span (ΔT) of the heat source inlet and outlet. A new generator design and process were developed and analyzed using a validated process model.

More recently, Collignon et al. (2025, 2024) presented a detailed study of a steady-state equilibrium model for an ammonia/water AHT designed to upgrade low-temperature industrial waste heat. Figure 5 (left) illustrates that the AHT system has a finite operating range for a given waste heat temperature (T_{waste}), which becomes narrower as the cold sink rejection temperature (T_{cold}) increases. In particular, the lifting capability is influenced by T_{cold}. For instance, at T_{cold} = 15 °C, the AHT is effective within the T_{waste} range of 61 to 98 °C. The yellow-highlighted area indicates the operating window of the ZIMBA AHT, which is designed for waste heat sources between 70 and 80 °C and a supply temperature in the range of 100 to 110 °C. Figure 5 (right) illustrates the maximum solution temperature ($T_{sol,max}$) that can be attained in the absorber before saturation occurs. As a rule of thumb, the $T_{sol,max}$ of a single-stage ammonia/water AHT is at best T_{waste} + 30 °C (Collignon et al., 2025, 2024).

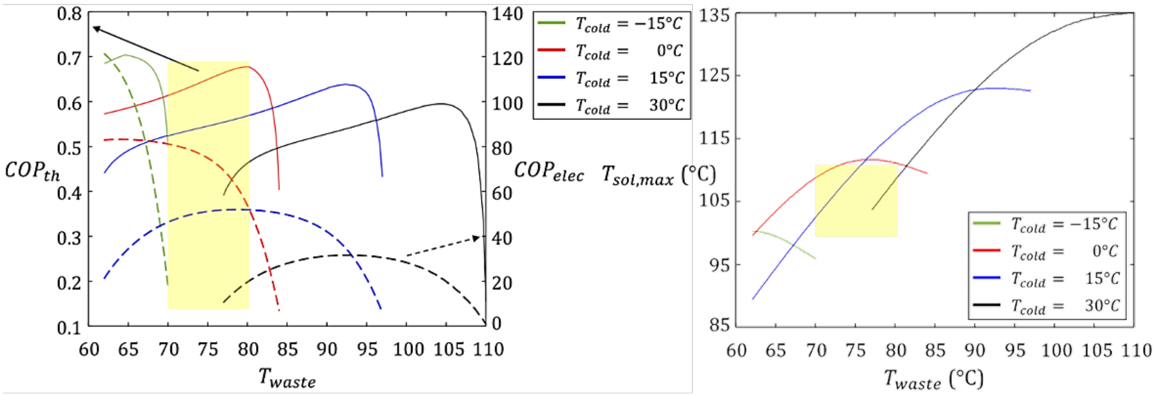


Figure 5: Operating range of an ammonia-water AHT. Estimated performance (left) and maximum solution temperature reached inside the absorber until it reaches saturation (right) as a function of the cold heat rejection (T_cold) and the waste heat (T_waste) temperatures (Source: Collignon et al., 2025). The yellow-highlighted regions indicate the operating range of the ZIMBA AHT.

For the ZIMBA AHT, the defined nominal operating conditions are:

- **Waste heat (T_{waste}) at 80/72 °C (inlet/outlet)**: Keeping the outlet temperature constant at 72 °C, a higher inlet temperature improves system performance.
- **Process heat supply at 107 °C (outlet)**: The goal is to generate saturated steam at just above 1 bar(a). The return temperature of the condensate has little impact, but increasing the steam temperature significantly increases system complexity.
- **Heat rejection (T_{cold}) below 30 °C:** Increasing the temperature difference (ΔT) is feasible if the inlet temperature remains constant (e.g., from 10/15 °C to 10/20 °C), with a limited impact on system performance. It would be highly beneficial to identify an application that can utilize the heat rejection from the AHT for the preheating of process steam.

3.3. Market overview of commercial water/LiBr AHT for industrial applications

According to the market reviews of Ayou et al. (2025) and Cudok et al. (2021), the major manufacturers of commercial single-stage water/LiBr AHTs are (Figure 6):

- Ebara Refrigeration Equipment & Systems Co., Ltd. (China)
- Johnson Controls-Hitachi Air Conditioning (Japan),
- Jiangsu Shuangliang Eco-Energy Co., Ltd. (China),
- LG Electronics (Japan),
- Thermax Ltd. (India),
- World Energy (Korea), and
- BS Nova Apparatebau GmbH (Germany).

Figure 6: Commercial water/LiBr AHT products for industrial applications.

Hitachi Zosen (Japan) and Tokyo Sanyo Electric (Japan) no longer offer AHT.

Table 3 summarizes the main technical features (Ayou et al., 2025).

Table 3: Commercially available single-stage water/LiBr AHT (Ayou et al., 2025).

Manufacturer	Heat Source	Heat Rejection	Delivered Heat	Heating Capacity (kW)	COP[a] (–)
Ebara Refrigeration Equipment & Systems Co., Ltd. [80]	Waste hot water; exhaust steam; and steam (>80 °C)	Cooling water(temperature: N/R)	Hot water or steam[b] up to 175 °C	169–8460	0.33–0.48
Johnson Controls-Hitachi Air Conditioning [82]	Waste heat (<100 °C) from engine jacket water; industrial processes; and distillation heat	Cooling water; underground water; recovery cooling water (inlet 24–32 °C)	Hot water or steam[b] up to 140 °C (70–140 °C)	150 3002475	0.45
LG Electronics [83]	Hot water at 70 °C	Cooling water at 12 °C	Hot water up to 120 °C	> 300	0.45
Shuangliang Eco-Energy Systems Co., Ltd. [78]	Waste hot water (≥ 60 °C) Exhaust steam; gas; and liquid (≥ 90 °C)	Cooling water (inlet 18–34 °C)	Hot water (130–169 °C) Steam[b] (1–6 bar)	< 8000[c] (1000–9300)	0.460.44–0.48
Thermax Ltd. [84,85]	Hot water/process condensate; geothermal water; and steam condensate from steam turbine (80–150 °C)	N/R	Hot water (110–185 °C) Dry saturated steam[b] (2–12 bar)	500–15000	0.40–0.47
World Energy Co., Ltd. [86]	Hot or drain water (at 88 °C)	Cooling water (inlet/outlet 26/32 °C)	Hot water (inlet/outlet 127/133 °C)	349–2442	0.48
BS Nova Apparatebau GmbH[d] [87,88]	Industrial waste heat (inlet/outlet 85/75 °C)	Cooling water (inlet/outlet 15/25 °C)	Hot water (inlet/outlet 111/116 °C)	448	0.48

Note: [a] thermal heating COP. [b] steam generated using separate flash tank. [c] single unit can be up to 8000 kW. [d] AHT technology provider of recent EU R&D projects [87,88]. N/R = not reported.

Ebara Refrigeration Equipment & Systems Co., Ltd. (China) offers a single-stage water/LiBr AHT delivering hot water or steam (produced separately) up to 175 °C. The heating COP is 0.33 to 0.48 with a typical temperature lift of 40 K using waste heat >80 °C (e.g., waste hot water, exhaust steam). The steam production capacity ranges from 0.3 to 15 t/h at 8 bar (heating capacity of 169 kW to 8.46 MW) (Ayou et al., 2025).

Johnson Controls-Hitachi Air Conditioning (Japan) offers single-stage water/LiBr AHT for hot water (or steam) from 150 kW to 2.475 MW at 70 to 140 °C using waste heat <100 °C. A typical heating COP is 0.45 (Ayou et al., 2019).

LG Electronics (Japan) also offers single-stage water/LiBr AHT delivering hot water up to 120 °C, with a heating capacity of more than 300 kW and heating COP of 0.45 (Ayou et al., 2025). It utilizes hot water at 70°C as a driving heat source (Ayou et al., 2019).

Thermax Ltd. (India) offers single-stage water/LiBr AHT technology, which can utilize various types of heat sources individually or in combination to deliver hot water up to 185 °C. It covers heating capacities ranging from 500 kW to 15 MW, with a typical temperature lift of 50 K (Ayou et al., 2025).

Shuangliang Eco-Energy Systems Co., Ltd. (China)'s AHT recovers waste hot water (>60 °C) or exhaust steam/gas (>90 °C) to produce 130 to 169 °C hot water or 1 to 6 bar steam with a heating COP of 0.44 to 0.48 (Ayou et al., 2025).

World Energy (Korea) offers a steam-generating AHT that delivers 133 °C (inlet) and 127 °C (outlet) steam, as well as 26 °C (inlet) and 32 °C (outlet) cooling water, utilizing 88 °C waste heat as the driving source. The heating capacity is 350 kW to 2.44 MW, and the heating COP is 0.48 (Ayou et al., 2025).

BS Nova Apparatebau GmbH (Germany) developed a single-stage water/LiBr AHT to upgrade heat to 110 to 120 °C. As part of the EU-funded PUSH2HEAT project (www.push2heat.eu), a full-scale AHT demonstrator by BS Nova will be installed in the paper mill in Cuartiere di Guarcino (Italy). The AHT will be combined with a steam generation module, in which steam is produced in a flash tank from the pressurized water produced in the absorber of the AHT. The system utilizes the cooling water from the biomass cogeneration plant (85 to 90 ºC) as a waste heat stream to generate approximately 1.5 MW of medium-pressure steam (6.5 bar(a), 162 ºC) via a flash tank and a thermocompressor. The AHT delivers 340 kW heating with a COP of 0.48 (Alonso et al., 2025).

Some industrial AHT applications above 90 °C are summarized in Table 2 (Ayou et al., 2019). For instance, Thermax AHTs deliver 135 °C for pasta drying (Baronia, Italy) and 105 °C for vegetable cooking (Renken, Germany), utilizing engine jacket water at 93 °C and 90 °C as driving waste heat sources. Although slightly above the ZIMBA target of 80 °C, this is not a major limitation.

Table 4: Deployment of AHT for industrial applications >90 °C (Source: Ayou et al., 2019).

Company Name (Country)	Manufacturer	Cycle Type	Working Pair	Temperature, T (°C)			Heating Capacity (kW)	COP (-)
				$T_{hs,in/out}$	$T_{cw,in/out}$	$T_{SINK,in/out}$ (ΔT_{lift})		
Asia Silicon Co. Ltd (China)	Thermax Ltd	Single-stage AHT	H_2O/LiBr	108/100	28/38.5	152/157 (49)	~4189	0.47[1]
Baronia Pasta (Italy)	Thermax Ltd	Single-stage AHT	H_2O/LiBr	93/75	N/R	125/135 (60)	~1202	0.46[1]
Renken Germany (Germany)	Thermax Ltd	Single-stage AHT	H2O/LiBr	90/80	N/R	95/105 (15)	~449	0.47[1]
Borregaard ASA (Norway)	Hybrid Energy AS	Single-stage CRHP	NH_3/H_2O	73/46	N/A	70/95 (22)	2000	6.1[2]
Frevar (Norway)	Hybrid Energy AS	Two-stage CRHP	NH_3/H_2O	20/14	N/A	75/95 (75)	800	2.4[2]
Løgumkloster District Heating plant (Denmark)	Hybrid Energy AS	CRHP	NH_3/H_2O	35/17	N/A	35/100 (65)	1300	4.3[2]
Alcohol Industry (Japan)	Johnson Controls HITACHI	Single-stage AHT	H2O/LiBr	N/R	N/R	107/112 (N/R)	2,475	N/R
Not Provided (N/R)	Johnson Controls HITACHI	Single-stage AHT	H_2O/LiBr	90/85	N/R	135/140 (50)	300	0.45[1]
Machinery (N/R)	Johnson Controls HITACHI	Single-stage AHT	H_2O/LiBr	90/85	27/31	133/137 (47)	150	N/R

Note: [1] – Thermal COP; [2] – Electrical COP; cw – Cooling water; hs – Heat source; ΔT_{lift} – Temperature difference between heat sink outlet and heat source inlet (Jensen, 2016); N/A – Not applicable; N/R – Not reported.

3.4. Applications of AHTs

Cudok et al. (2021) reviewed 43 AHT installations with a heating capacity of approximately 1 MW, totalling around 134 MW (see the table in Figure 7). Today, most AHT installations are in East Asian countries, with 12 in China, 2 in Japan, 1 in Germany, 1 in Italy, and 1 in the United States. Most of the reported AHT machines use the water/LiBr working fluid (40 out of 43 installations), which enables better performance than other working pairs in terms of heat exchange.

The temperatures of the installations are in the following ranges:

- T_{2_in} / T_{2_out} = 25 to 152 °C / 80 to 165 °C
- T_{1_in} / T_{1_out} = 56 to 130 °C / 75 to 105 °C
- T_{0_in} / T_{0_out} = 15 to 46 °C / 20 to 46 °C

37 of the 43 listed AHT installations operate with a driving heat temperature ($T_{1,in}$) of 75 to 110 °C, matching the target range of the ammonia-water AHT to be developed in ZIMBA. At least four AHT examples (highlighted in yellow) utilize waste heat at approximately 70 to 80 °C to supply temperatures of 100 to 110 °C, all for alcohol distillation heat recovery processes.

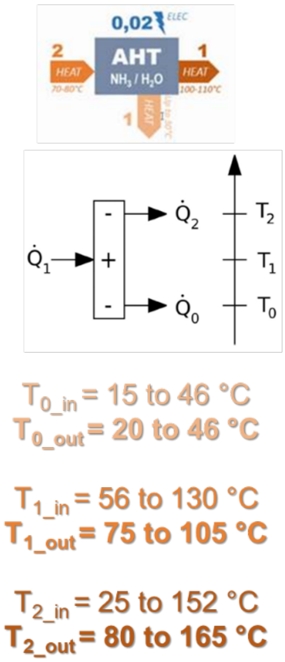


Table 1
Technical information of installations, Working pair: H_2O/LiBr, except No. 21, 4 (NaHO) and 19 (N/A), * marks assumptions based on given information, E: Evaporator, G: Generator.

				working conditions						
No.	Capacity [MW]	$T_{0,in}$ [°C]	$T_{0,out}$ [°C]	$T_{1,in}$ [°C]	$T_{1,out}$ [°C]	$T_{2,in}$ [°C]	$T_{2,out}$ [°C]	cycle	COP	references
43	1.83	32	N/A	100	N/A	N/A	148	Double	N/A	authors
42	0.55	20	N/A	130	N/A	N/A	148	Single	N/A	authors
41	0.64	32	N/A	100	N/A	N/A	130	Single	N/A	authors
40	0.89	23	29	96.1	80	139	144.5	Single	0.47	authors
39	4.68	32	N/A	56	N/A	N/A	80	Double	N/A	authors
38	0.77	32	N/A	56	N/A	N/A	90	Double	N/A	authors
37	1.04	32	N/A	115	N/A	N/A	120	Single	N/A	authors
36	0.67	32	N/A	91	N/A	N/A	165	Double	N/A	authors
35	1.8	32	N/A	97	N/A	N/A	130	Single	N/A	authors
34	42.17	32	N/A	120	N/A	N/A	158	Single	N/A	authors
33	1.2	N/A	N/A	93	75	125	135	Single	0.46	[8] authors
32	2.61	28	N/A	105	100	N/A	144	Single	N/A	authors
31	4.19	28	38.5	108	100	152	157	Single	0.47	[8] authors
30	0.45	N/A	N/A	90	80	95	105	Single	0.47	[8] authors
29	1.83	30	N/A	97	N/A	N/A	125	Single	N/A	authors
28	1.65	15	N/A	81	81	120	125	Single	0.46	[37] authors
27	2.48	25	30	78	78	107	112	Single	0.45	[38] authors
26	0.15	27	32	90	85	133	137	Single	0.48	[38,39] authors
25	5	28	30	98	N/A	N/A	110	Single *	0.47	[40,41]
24	7	28	30	98	N/A	N/A	110	Single *	0.47	[8,41]
23	7	28	30	98	N/A	N/A	110	Single *	0.47	[8,41]
22	4	N/A	N/A	80	N/A	N/A	140	Double	N/A	[42]
21	0.08	46	46	98(G) 105(E)	98(G) 105(E)	115	120	Single	N/A	[32]
20	4.1	20	26	90	85	110	130	Single	0.46	[14]
19	2	N/A	N/A	97	94.5	N/A	133	N/A	N/A	[20]
18	3.37	26.7	30.6	78.7	78.7	N/A	111.5	Single	0.48	[43]
17	1.2	N/A	N/A	78	N/A	N/A	108	N/A	N/A	[44,45]
16	N/A	22.3	N/A	88	N/A	N/A	122	N/A	N/A	[44,45]
15	1.38	22	31.4	100	100	100	136	Single	0.44	[20,46]
14	1.1	N/A	N/A	100	100	N/A	144	Single *	0.44	[20,47]
13	1.09	27	30	125	91	134	139	Single *	0.49	[20,48]
12	2.71	32	37	95	95	25	131	Single *	0.47	[20,48]
11	1.88	31	37	100	100	90	143	Single	0.48	[44,45]
10	0.35	32	37	95	85	95	120	Single *	0.49	[20,48]
9	6.78	10.7	36.6	103.3	103.3	130.8	144.9	Single	0.49	[20,47–49]
8	3.3	31	37	100	100	90	143	Single *	0.48	[20,48]
7	1.67	15	20	80	80	111	116	Single *	0.48	[20,48]
6	0.93	20	30	80	80	119	124	Single *	0.48	[20,48,50]
5	1	N/A	N/A	100	100	N/A	145	N/A	N/A	[20]
4	2.35	31	N/A	98	88	127	132	Single *	0.48	[20,48]
3	1.88	32	36	80.5	80.5	100	112	Single *	0.48	[20,48]
2	1.66	28	32	83	83	100	111	Single	0.48	[9,20,48,51]
1	2.35	26	32	98	88	127	133	Single	0.47	[20,48,50]

Figure 7: Temperature ranges of 43 AHT installations (Cudok et al., 2021). Highlighted in yellow are four examples where the waste heat is at around 70 to 80 °C and a supply temperature at 100 to 110 °C.

The applications of AHTs in the industrial sector are approximately (Cudok et al., 2021):

- 61% chemical industry (26 out of 43),
- 9% food industry (4),
- 16% different sectors (7), e.g., heavy industry and paper industry
- 14% of others with no information (7).

Typically, the heat flow at the low-temperature level (T0) is rejected to the ambient environment via cooling towers, seawater, or groundwater (Cudok et al., 2021).

Moreover, previous reviews by Parham et al. (2014) and Donnellan et al. (2015) on AHT evaluated 99 and 106 references, respectively, related to AHTs and their applications. Rivera et al. (2015) reviewed the state of the art of AHT with a focus on waste heat recovery from industrial processes, including:

- cogeneration systems,
- distillation in chemical plants,
- desalination or water purification (i.e., seawater desalination and distillation),
- evaporation processes, and
- other applications.

Several AHT prototypes have been developed with capacities ranging from 700 kW to 5 MW and with COPs between 0.15 and 0.43, as well as purified water capacities varying between 0.6 and 1.6 kg/h per kW of power supplied to the heat transformer (Rivera et al., 2015).

In the EU-funded Indus3Es project (October 2015 to April 2020), an Online Assessment Tool was developed to estimate the operational and implementation costs of AHT in industrial processes, based on the characteristics of available waste heat streams (Indus3Es, 2018). The results provided by the Indus3Es tool offer an initial indication of the feasibility of implementing an AHT within a specific industrial process.

As part of the Indus3Es project, a 200 kW AHT demonstration unit, manufactured by BS Nova, was realized at the Tüpraş oil refinery in Turkey. The system utilizes a waste heat source at 95 °C and upgrades it to 135 °C (heat rejection below 30 °C), achieving a gross temperature lift of 40 K and a COP of 0.45. The payback period for the 200-kW prototype was found to be <10 years. For a ready-to-market AHT equipment, the estimated payback period was around 6 years.

3.5. Application Case Studies for the ZIMBA AHT

This section presents case studies based on the literature screening, where the ZIMBA AHT temperatures closely align with the specifications (see Figure 1), particularly in applications such as distillation and paper manufacturing. Figures 8, Figure 9, Figure 10, and Figure 11 illustrate possible integration concepts of AHT in:

- an alcohol distillation plant (Cudok et al., 2021),
- an industrial cogeneration plant (capacity: 150 kW) (Cudok et al., 2021; Fujii et al., 2008),
- a virtual paper mill (CEPI Confederation of European Paper Industries), and
- a future 4th generation district heating network (Garone, 2018; Garone et al., 2017).

The temperature ranges of the applications are (T2: supply temperature, T1: driving waste heat temperature, T0: heat to be dissipated):

- T2 = 107/112 °C T1 = 78 °C T0 = 25/30.5 °C
- T2 = 133/137 °C, T1 = 85/90 °C T0 = 27/32 °C
- T2 = 184 °C (10 bar(g) steam) T1 = 60/80 °C T0 = 15/45 °C
- T2 = 80/70 °C T1 = 35/55 °C T0 = 10/15 °C

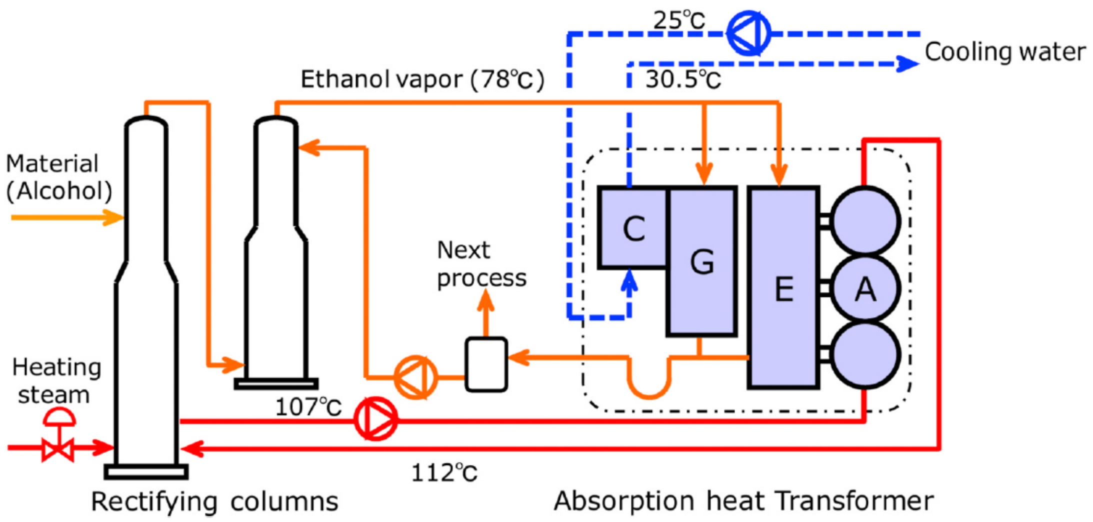


Figure 8: AHT installed in an alcohol distillation plant (Cudok et al., 2021).

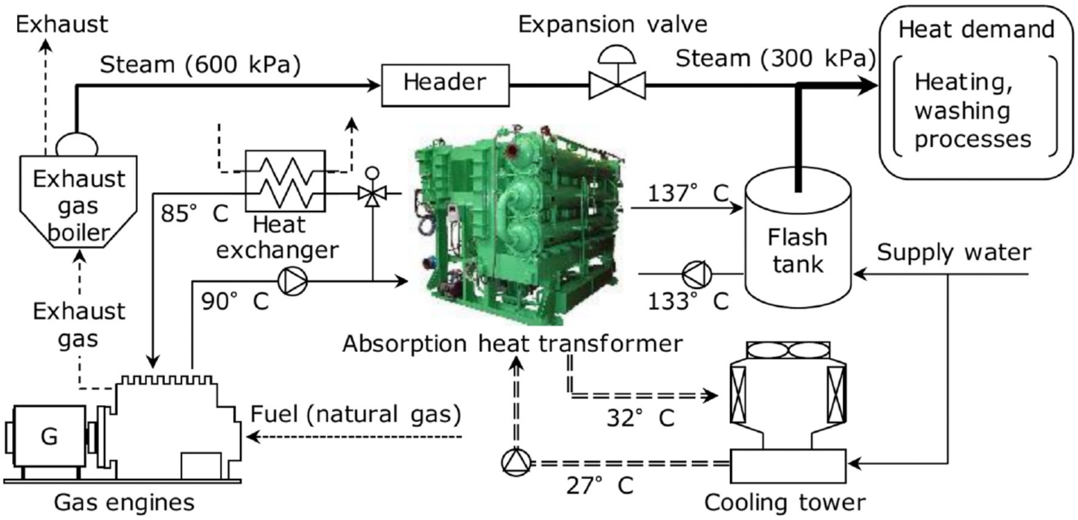


Figure 9: AHT installed in an industrial plant (capacity: 150 kW) (Cudok et al., 2021; Fujii et al., 2008).

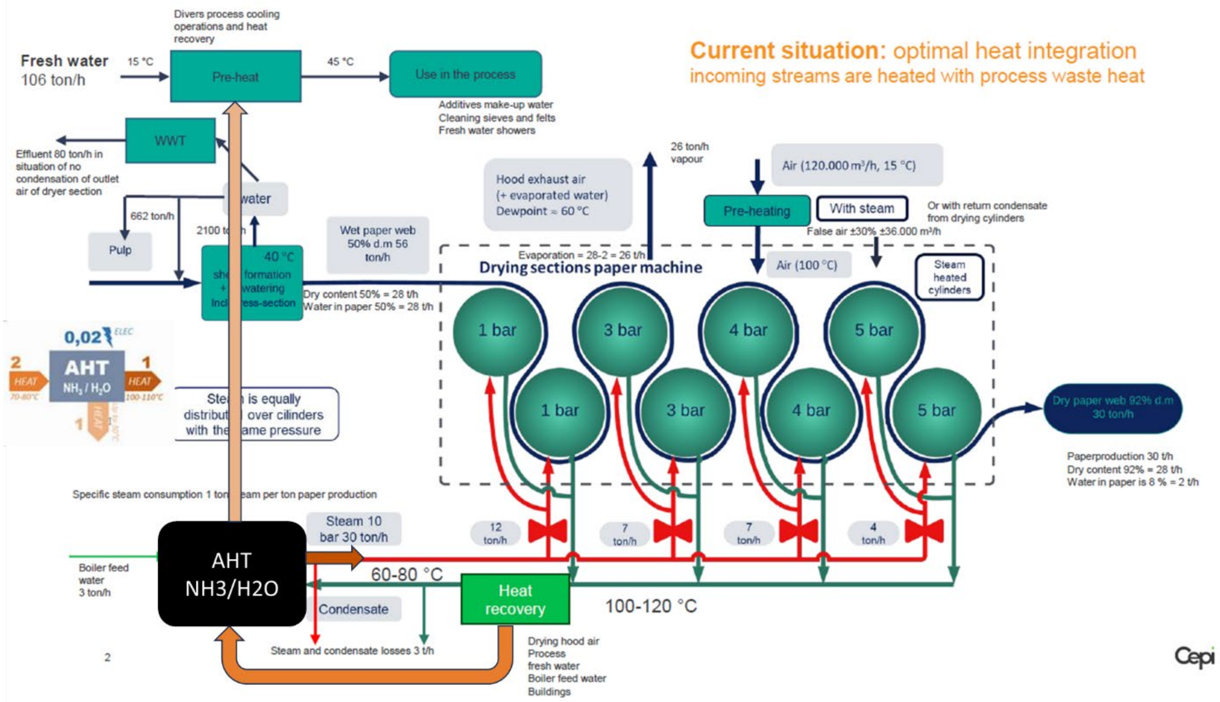


Figure 10: A possible AHT integration in a virtual paper mill (Source: CEPI).

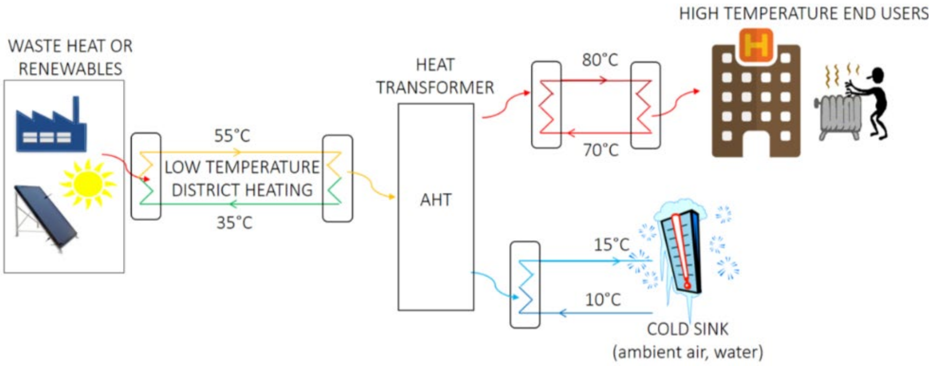


Figure 11: Integration of an AHT in future 4th-generation district heating networks (Garone, 2018).

The application of the **alcohol distillation plant** appears to be feasible for the ZIMBA AHT technology. However, it has the characteristic of an isothermal heat source, which may not be entirely representative. Challenging are the heat flows to and from the AHT. In the evaporator (E) and generator (G), there is condensing ethanol vapor, meaning no temperature glide, which is detrimental concerning COP. In the condenser (C), the temperature of the cooling water seems to be fixed (maybe due to a cooling tower that might struggle fixing the cooling temperature in summer). As a result, the benefits of using an ejector under cut-off conditions no longer apply. In the absorber (A), there is a temperature glide from 107 to 112 °C, suggesting a subcooled liquid. In comparison, the AHT in the ZIMBA projects aims to generate steam in the absorber.

The case study of the **industrial plant** may be considered too stretched for the ZIMBA AHT technology. However, it would be possible to lower the steam temperature or the heat dissipation temperature to see what the AHT technology can do.

The AHT integration in the virtual **paper mill** may be even more challenging, as it involves producing steam at just above atmospheric pressure and then adding an MVR system to increase the steam pressure to the required 10 bar(g). The 45 °C of the return cooling water could also be a challenge for the ZIMBA AHT technology.

Besides industrial applications, the integration of an AHT in **district heating systems** is also a viable consideration, especially in highly populated locations in Europe and China, where cold climates are gaining importance for district heating applications (Garone, 2018). The current trend is going towards lower supply temperatures. Nevertheless, the average supply temperatures are around 86 °C in Sweden and between 70 and 120 °C in Denmark (Garone, 2018; Garone et al., 2017). However, the application of a future 4^{th}-generation district heating network raises the issue of not producing steam, which is a key element in the ZIMBA project.

Toppi et al. (2021) highlighted a compressor-assisted heat transformer for waste-heat-powered district heating applications. Using waste heat at 50 and 60 °C and heat rejection temperature at 0 °C and -10 °C, it is possible to upgrade heat up to 120 °C with an electrical COP above 4, a thermal COP of about 0.5, and an upper pressure below 40 bar.

3.6. Conclusions from the Literature Review

Various industrial processes operate within temperature ranges that are close to the operational characteristics of the ZIMBA AHT. However, no process identified to date precisely matches the temperature requirements of the technology. The AHT concept shows promise, particularly the food, chemical, and district heating sectors, each with varying temperature needs.

Successful integration of the AHT requires suitable temperature levels, continuous thermal demand, and an excess of waste heat. These conditions are difficult to meet simultaneously. Nonetheless, the distillery sector stands out as a promising candidate. Notably, at least 4 of the 43 implemented LiBr/water AHTs documented by Cudok et al. (2021) recover waste heat in the 70 to 80 °C range to supply 100 to 110 °C, all in alcohol distillation applications.

For the ZIMBA AHT, the availability of driving waste heat at 70 to 80 °C remains the primary constraint. This temperature range is particularly prevalent in the refinery sector, with additional potential in the chemical, paper, and food industries. Waste heat in the 60 to 80 °C range is also found in power generation (engine cooling), suggesting broader opportunities for low-temperature heat recovery.

Further identification of suitable processes, particularly in the food and chemical industries, where low-pressure steam at 110 °C is required, will be a key focus. The aim is to target applications where waste heat at approximately 80/72 °C is available. If higher steam pressures are required, mechanical vapor recompression (MVR) can be employed to further boost the steam output.

4. Questionnaire

An Online Questionnaire (programmed in MS Forms) (Figure 12) for industrial companies has been created and sent to 25 CLAUGER customers via their sales representatives. The objective was to gather direct feedback from CLAUGER's customers to determine in which industries and processes the ZIMBA AHT technology best fits the end-user requirements.

The questionnaire included questions on various industries, processes, typical heat requirements, heat flows, capacities, and temperature conditions, among others. Possibly, follow-up interviews could be organized with interested customers from the food and beverage, chemical, and pulp and paper industries to further clarify the requirements of end-users.

Figure 12: Online Questionnaire for industrial companies.

The questionnaire consisted of 32 questions (some open, some with multiple answers possible):

No.	Questions
1	What is your company name? • …
2	In what industrial sectors are you active? (multiple answers possible) • Food & beverage • Chemicals • Pharmaceutical • Pulp & paper • Textiles • Metal • Minerals • Others
3	If [Others], please write some comments: • …

4	What products do you produce? (open question, write some key words) • …
5	In which geographical markets are you active? (multiple answers possible) • Africa • North America • Latin America • Asia • Europe • Others
6	If [Others], please write some comments: • …
7	What industrial processes do you have in your factory? (multiple answers possible) • Drying • Evaporation • Distillation • Cooking • Others
8	If [Others], please write some comments: • …
9	Do you have heating and cooling needs in your factory? • Yes • No
10	Which media do you use for heating and cooling? (multiple answers possible) • Water • Air • Steam • Others
11	If [Others], please write some comments: • …
12	What pressure and temperature levels do you have in your factory? (multiple answers possible) • High-pressure steam 6 to 12 bar(a) • Low-pressure steam 1 to 6 bar(a) • Pressurized hot water (80 to 100°C) • Hot water (60 to 80°C) • Warm water (30 to 60°C) • Cold water (10 to 30°C) • Chilled water (0 to 10°C) • Hot air • Others
13	If [Others], please write some comments: • …
14	What is your main energy carrier? (multiple answers possible) • Gas • Oil • Electricity • Biomass • Others

15	If [Others], please write some comments: • …
16	What heating technologies do you have in operation? (multiple answers possible) • Steam boiler (fossil fueled) • Biomass boiler • Electrode boiler • Air heater (fossil fueled) • Heat pump • Others
17	If [Others], please write some comments: • …
18	What cooling technologies do you have in operation? (multiple answers possible) • Chiller • Freezer • Cooling tower • Others
19	If [Others], please write some comments: • …
20	Do you have waste heat in excess available at 70 to 80 °C that must be rejected? (multiple answers possible) • Yes • No • No, but at another temperature level: …
21	If [No, but at another temperature level], please write some comments: • …
22	If yes, at what capacity? (multiple answers possible) • <100 kW • 100 to 500 kW • 500 kW to 1 MW • 1 to 5 MW • >5 MW
23	What cooling technology is used to reject the waste heat? • Dry cooler (ambient air) • Cooling tower • Others
24	If [Others], please write some comments: • …
25	Do you need a significant amount of low-temperature heat between 10 to 30 °C? • Yes • No
26	If yes, at what capacity? (multiple answers possible) • <100 kW • 100 to 500 kW • 500 kW to 1 MW • 1 to 5 MW • >5 MW

27	If yes, what kind of heating technology is used? • …
28	Do you have a process around 100 to 110°C that needs a significant amount of energy? • Yes • No
29	If yes, at what capacity? (multiple answers possible) • <100 kW • 100 to 500 kW • 500 kW to 1 MW • 1 to 5 MW • >5 MW
30	If yes, what kind of process? (open question, write some key words) • …
31	If yes, is the process running continuous? • Yes • No
32	Are you okay with being contacted again to discuss this in further detail? • Yes • No

5. Questionnaire Results

Out of 25 questionnaires sent, 5 companies responded (20% response rate):

- Distillerie de la Tour (www.distillerie-de-la-tour.com),
- Distillery de la Salle (www.distilleriedelasalle.com),
- Gelagri (www.gelagri.com),
- Lactalis (www.lactalis.com), and
- Isigny Sainte-Mère (www.isigny-ste-mere.com).

Here is a summary of the main conclusions from the responses:

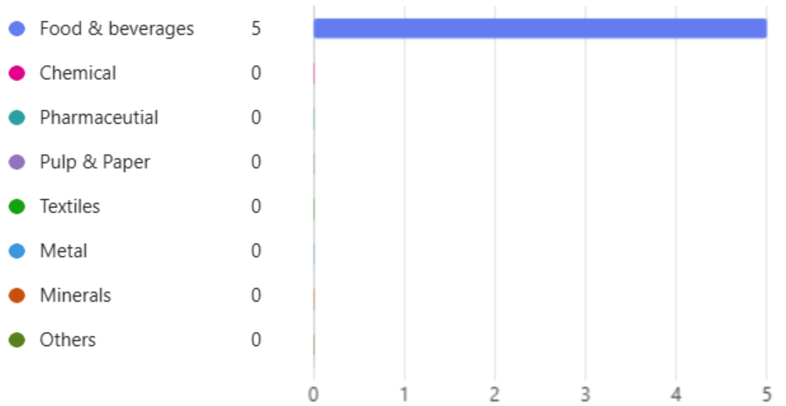
- All 5 respondents are food & beverage companies and operate within Europe
- Key industrial processes include evaporation (4), distillation (2), drying (2), cooking (1), and pasteurization (1)
- Heating and cooling media used are water (5), steam (4), air (3), and water-glycol (1)
- All companies have both heating and cooling demands, primarily hot water (60 to 80 °C), chilled water (0 to 10 °C), and low-pressure steam (1 to 6 bar)
- Main current energy carriers are gas (5), biomass (2), and electricity (2)
- Heating technologies in use are steam boilers (5), biomass boilers (2), an electrode boiler (1), air heaters (2), and heat pumps (3).
- The cooling technologies are chillers (5), cooling towers (4), freezers (4), and absorption cooling (1)
- 3 companies have significant waste heat at 70 to 80 °C:
  - Distillerie de la Tour: 500 kW to 1 MW
  - Distillerie de la Salle: 1 to 5 MW
  - Gelagri: >5 MW
- Additional rejected heat:
  - Distillerie de la Salle: water at 35 °C
  - Distillerie de la Tour: hot air at 55 °C
- Waste heat rejection technologies used include cooling towers (4), dry coolers (3), and evaporative condensers (1)
- Special low-temperature heat needs at 10 to 30 °C have Distillerie de la Salle, Lactalis, and Isigny Sainte-Mère
- All companies are open to being contacted for follow-up interviews to further specify their needs.

Table 5: Questionnaire results

<table>
<tr><th>Responses to the questions</th></tr>
<tr><td>
Q1: What is your company name?
Q4: What products do you produce? (open question, write some keywords)

ID 1: Distillerie de la Salle → Cognac
ID 2: Distillerie de la Tour → Cognac, brandy, wine, raisin must
ID 3: Gelagri → Freeze vegetable
ID 4: Lactalis → Milk, yogurt, butter, cheese, powder
ID 5: Isigny Sainte Mere → milk powder, dairy products

Q2: In what industrial sectors are you active? (multiple answers possible)



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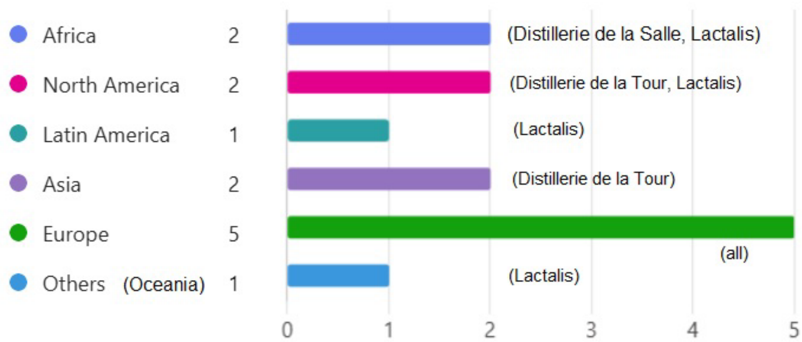
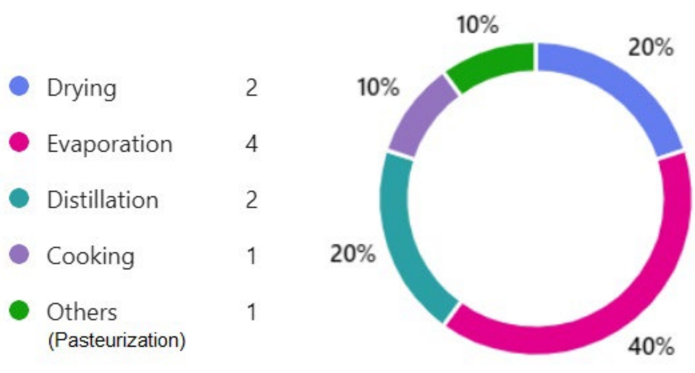
<tr><td>
Q5: In which geographical markets are you active? (multiple answers possible)



</td></tr>
<tr><td>
Q7: What industrial processes do you have in your factory? (multiple answers possible)



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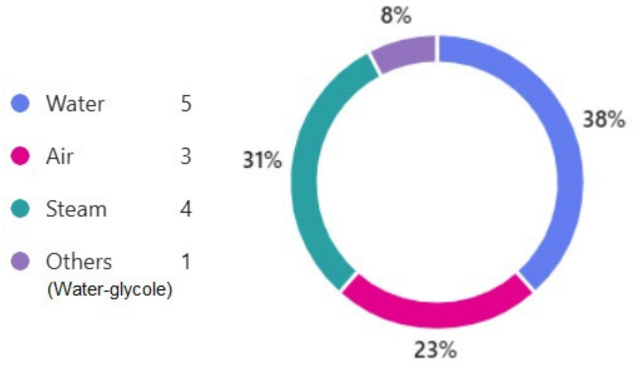
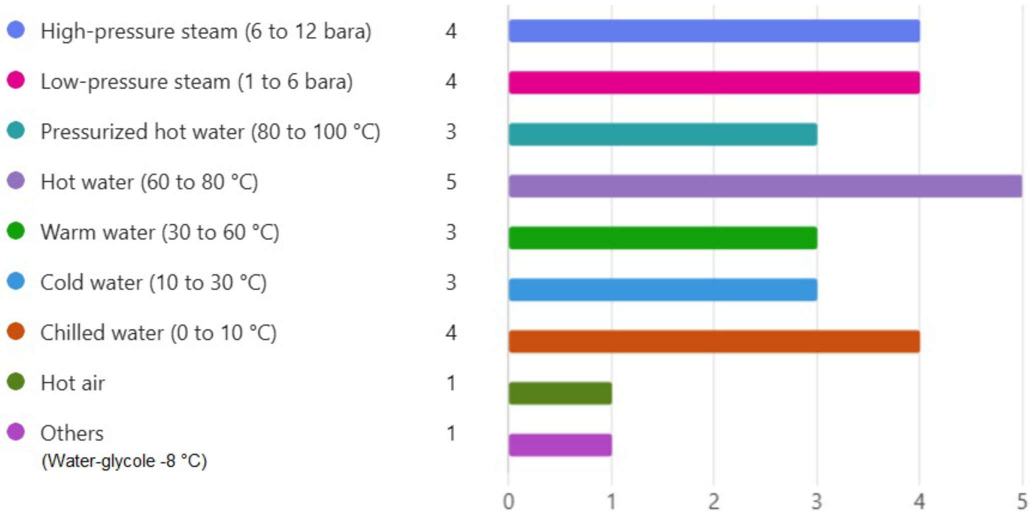
</table>

Q9: Do you have heating and cooling needs in your factory? Yes (5x)

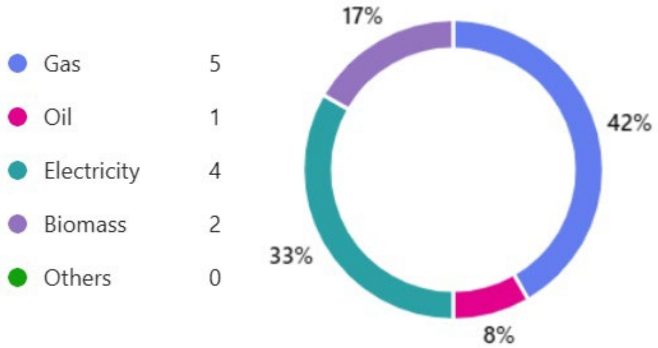
Q10: Which media do you use for heating and cooling? (multiple answers possible)



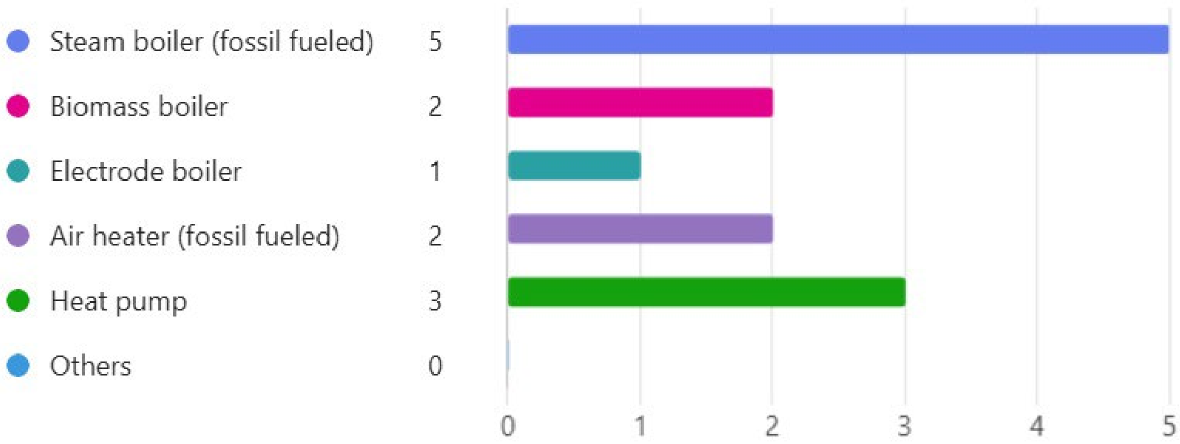
Q12: What pressure and temperature levels do you have in your factory? (multiple answers possible)



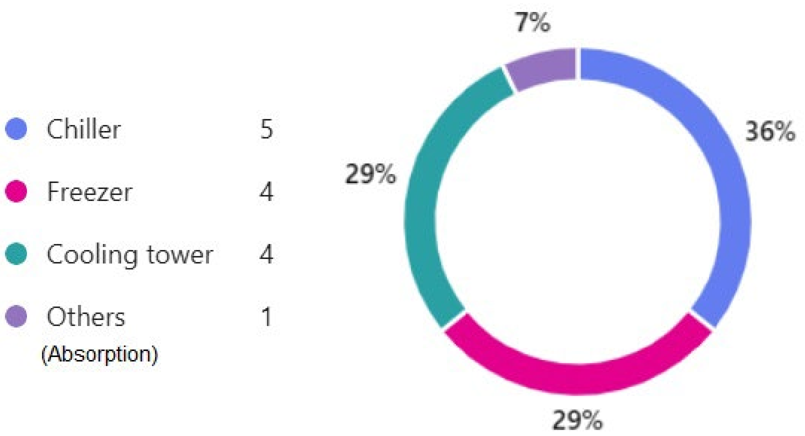
Q14: What is your main energy carrier? (multiple answers possible)



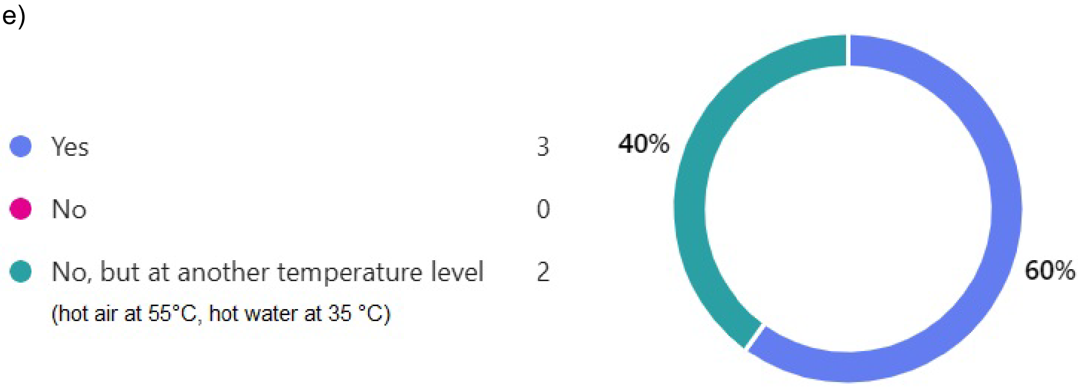
Q16: What heating technologies do you have in operation? (multiple answers possible)



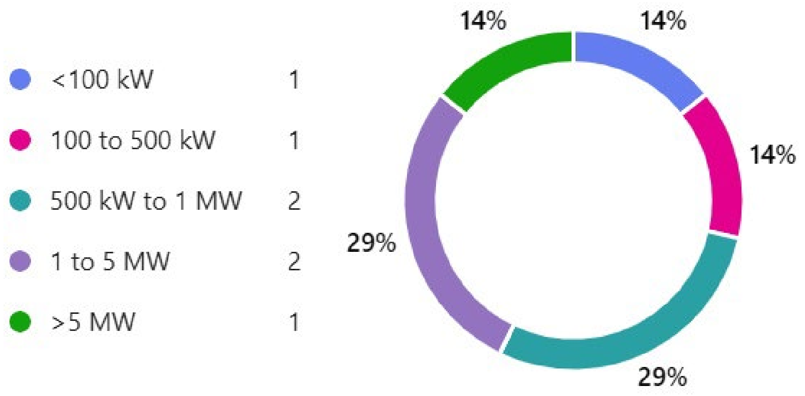
Q18: What cooling technologies do you have in operation? (multiple answers possible)



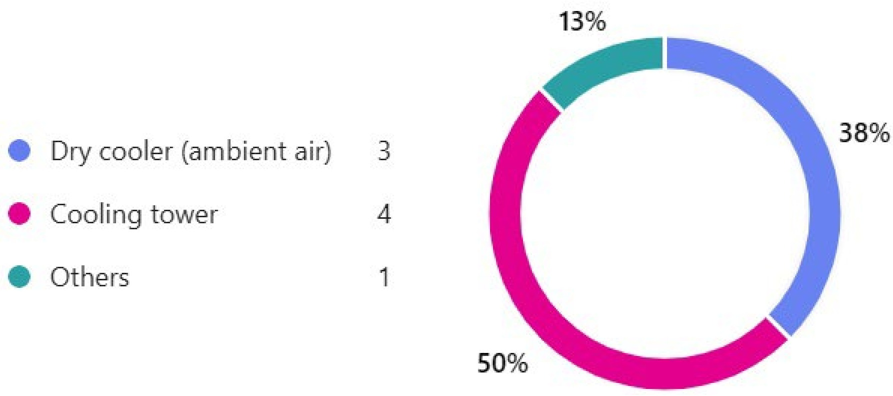
Q20: Do you have waste heat in excess available at 70 to 80 °C that must be rejected? (multiple answers possible)



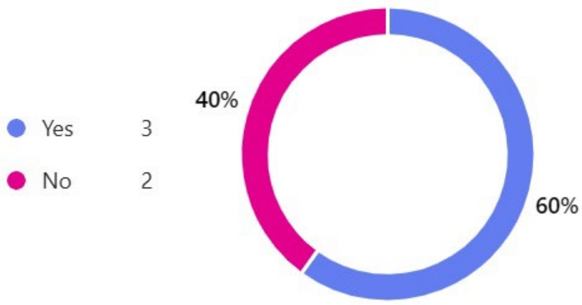
Q22: If yes, at what capacity? (multiple answers possible)



Q23: What cooling technology is used to reject the waste heat?

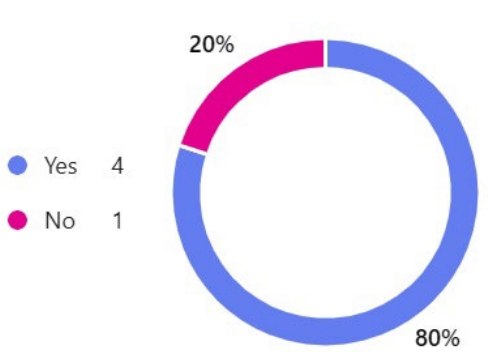


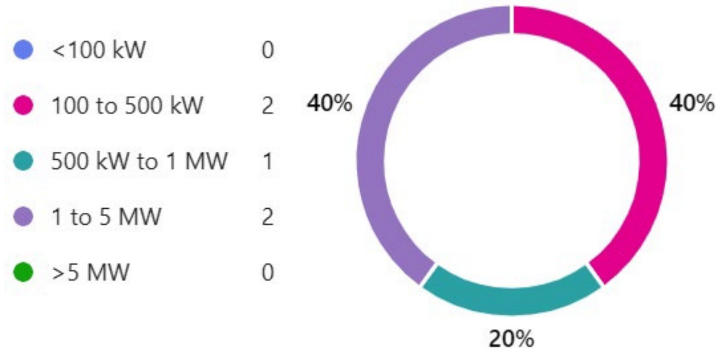
Q25: Do you need a significant amount of low-temperature heat between 10 to 30 °C?
Q26: If yes, at what capacity? (multiple answers possible)



Q27: If yes, what kind of heating technology is used? → heat recovery (2)

Q28: Do you have a process around 100 to 110°C that needs a significant amount of energy?
Q29: If yes, at what capacity? (multiple answers possible)

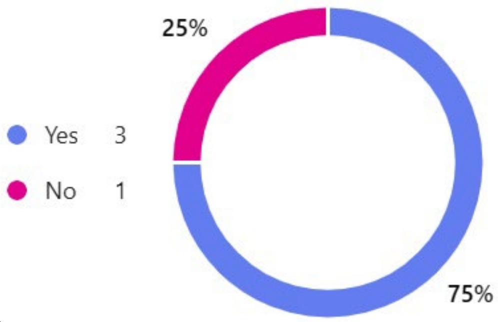




Q30: If yes, what kind of process? (open question, write some key words)

- Steam distillation
- Pasteurisation
- Pre-heating air, milk heating, etc.

Q31: If yes, is the process running continuously?



Q32: Are you okay with being contacted again to discuss this in further detail? Yes (5 x)

6. Interview Results

As part of Deliverable D1.3, interviews were conducted with 3 out of 5 companies participating in the online questionnaire and open to sharing more detailed insights into potential integration opportunities for AHT (Absorption Heat Transformer) technology. The interviewees had a technical background and were able to describe the energy situation and process flow diagrams.

The aim of the interviews was to collect key information regarding

- Process Description
- Temperature ranges
- Heating and cooling capacities
- Media used (e.g., steam, water)
- Potential integration points for AHT technology

The interviews were conducted on the following dates:

- 19 May 2025: Lactalis – Heat Recovery in a Steam Boiler with Dual Economizers (www.lactalis.com)
- 20 May 2025: Gélagri – Vegetable Processing with Blanching (www.gelagri.com)
- 28 May 2025: Distillerie de la Salle – Cognac Distillation (www.distilleriedelasalle.com)

6.1. Interview 01: Lactalis – Heat Recovery in a Steam Boiler with Dual Economizers

Lactalis is a globally active dairy company that processes milk from cows, sheep, and goats into a range of products, including butter, cheese, soft cheese, yogurt, ice cream, and milk powder.

Process Description

Production plants primarily use steam and hot water as energy sources, with steam generated by gas-fueled boilers. Spray dryers are used for producing milk powder. In France, the plants are mainly equipped with steam boilers; the others are equipped with hot water boilers. In the rest of the world, steam boilers are the primary source of heat.

Temperature Ranges and Media

Thermal processes such as drying, evaporation, and pasteurization require:

- Steam (low-pressure 1 to 6 bar(a) and high-pressure 6 to 18 bar(a))
- Hot water (heated from 75 °C to 105 °C)
- Cold and chilled water (0 to 30 °C)
- Glycol-water mixtures down to -8 °C

All production plants are equipped with a Cleaning-in-Place (CIP) station. Acid and caustic soda solutions are heated from 15 °C to 85 °C within 2 hours using heat exchangers.

Figure 13 illustrates a gas-fired steam boiler equipped with two economizers (heat recovery heat exchangers) in the flue gas exhaust. The 1st economizer preheats the boiler feed water to 144 °C before it enters the boiler. The 2nd economizer (condenser) is an optional unit that condenses flue gases and heats a separate water loop connected to a 10 m³ buffer tank. This loop uses city water at 12 °C, which is heated to 87 °C.

Heating capacity

The estimated heating capacity of the 2nd economizer is approximately 370 kW, calculated as follows: 75 K × 5 m³/h × 4.12 kJ/kg K = 370 kW.

Note: This 2nd economizer is not installed in all systems.

Potential AHT System Integration

There is an intermittent steam demand at 100 to 130 °C for pasteurization and CIP stations. While steam is not used continuously, CIP is required across all plants, involving the heating of acid and soda solutions to 85 °C in 10 to 20 m³ tanks. This results in large flow volumes but non-continuous consumption, and in some cases, the distance between steam production and usage points is significant. All cheese production sites require a steady supply of hot water at 75 °C to 85 °C.

The 87 °C waste heat recovered by flue gas condensation in the 2nd economizer of the steam boiler presents a valuable opportunity for AHT integration, particularly for steam generation.

The 10 to 30 °C temperature range is of limited value, as incoming city water is already within this temperature range. In some plants, water loops operating at 30 °C to 35 °C are used for climatization and space heating, particularly in areas of cheese production that require continuous air exchange and high hygiene standards. The air used for climatization could be preheated in the AHT condenser. However, these systems are typically operated only in winter. In this case, the heat could be rejected to a dry cooler, for example.

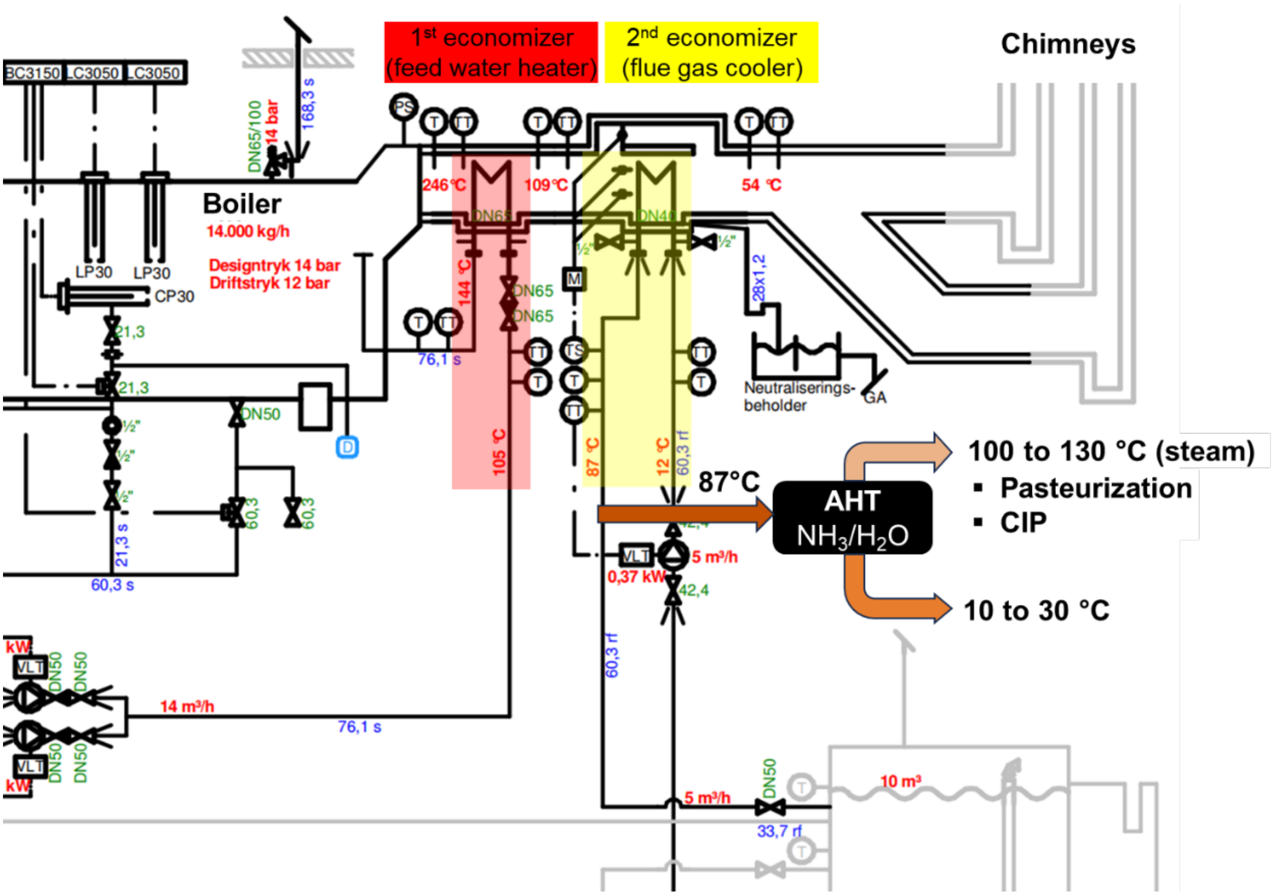


Figure 13: Schematic of a gas-fired steam boiler with two economizers in the flue gas exhaust. The 1st economizer preheats boiler feed water from 105 °C to 144 °C. The optional 2nd economizer recovers additional heat by condensing flue gases, heating a separate water loop (12 to 87°C) connected to a 10 m³ buffer tank. Indicated is a potential integration point of an AHT.

6.2. Interview 02: Gélagri – Vegetable Processing with Blanching

Gélagri specializes in vegetable processing, with blanching as the core thermal process. The facility operates seven blanchers.

Process Description, Temperature Ranges, and Heating and Cooling Capacities

Vegetables are first cleaned and then heated to 90°C in the blanchers by steam injection.

Steam at 140 °C is produced by two steam boilers with capacities of 10 t/h and 8 t/h (total thermal capacity 10 MW). Additionally, hot water at 95 °C is generated and pumped/sprayed onto the vegetables.

During blanching, part of the water evaporates, and a mixture of air and steam at 70 °C to 80 °C is extracted through hoods and vented. The used process water, including water from cleaning, exits the blanchers at 20 °C to 25 °C.

After blanching, the vegetables are cooled from 90 °C to 10 °C and then frozen to -18 °C.

Cooling is provided by two chillers (rated at 10 MW and 3 MW) with a total cooling capacity of 13 MW. The quantity of waste heat available at 70 °C to 80 °C is currently unknown; however, measurements are planned.

The waste heat from the chillers is recovered to heat city water from 45 °C to 50°C for various uses, such as workshop heating, cleaning processes, or boiler feedwater preheating.

A project is currently under evaluation to install an electric-driven vapor compression heat pump to raise the water temperature to 90 °C.

Potential AHT System Integration

Figure 14 illustrates a potential integration point for an AHT. It would use the 70 °C to 80 °C air/steam exhaust from the blanchers as a driving heat source, enabling the generation of steam at 100 °C to 110 °C. The heat rejection from the AHT could contribute to water preheating (e.g., from 20 °C to 30 °C).

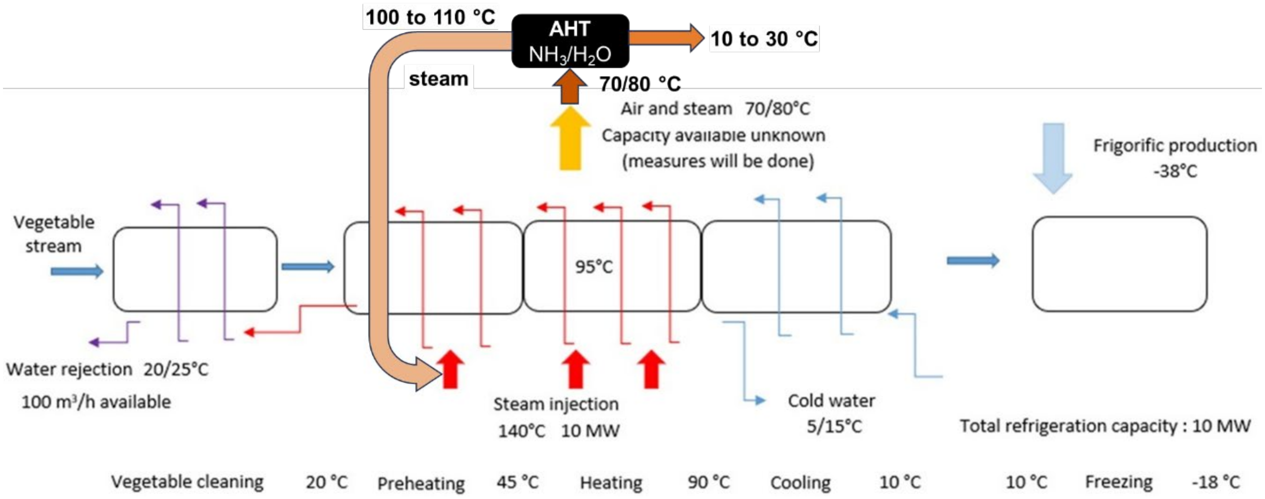


Figure 14: Schematic of a potential integration point of an AHT at Gélagri producing vegetables.

6.3. Interview 03: Distillerie de la Salle – Cognac Distillation

The Distillerie de la Salle produces Cognac using the traditional *Alambic Charentais* double-distillation method. The site operates 21 distillation units: 18 stills of 2.5 m³ each, equipped with a 100 kW gas burner, and 3 stills of 10 m³ each, with a 400 kW gas burner. This results in a total thermal capacity of 3 MW.

Process Description

The distillation process is batch-based, with two 10-hour batches produced daily. The wine is heated in the stills from 75 °C to 100 °C. The alcohol in the wine evaporates and is condensed using a heat exchanger with cooling water at 5 to 9°C, producing a distillate at 13 to 17 °C. An on-site water pond supplies the cooling water. Two distillation steps are required. After the first cycle, a wine residue (vinasse) remains at about 95 °C and is evacuated for further use. The second distillation cycle uses the first distillate as input.

Cooling and Heat Recovery

- Cooling system: A 100 m³ tank of water is chilled to 6 to 8 °C by a 300-kW chiller and used to produce the distillate.
- The cold water is heated up to 75 to 85 °C via heat exchange with alcohol and stored in a separate 100 m³ tank.
- Heat reuse: The 75/85 °C water is heated up to 85 °C with the 95 °C vinasse. The 85 °C water is used to preheat incoming wine for distillation. After preheating, the water is discharged into the pond at a temperature of 50 to 55 °C.

Potential AHT System Integration

The existing heat recovery loop, where water is heated by vinasse and reused to preheat wine, presents an integration point for an AHT. With the hot water tank at 75 to 85 °C, the pond at 5 to 25 °C and a steam/wine heat exchanger, the AHT system could produce steam at around 110 °C to heat the wine to temperatures between 75 °C and 100 °C.

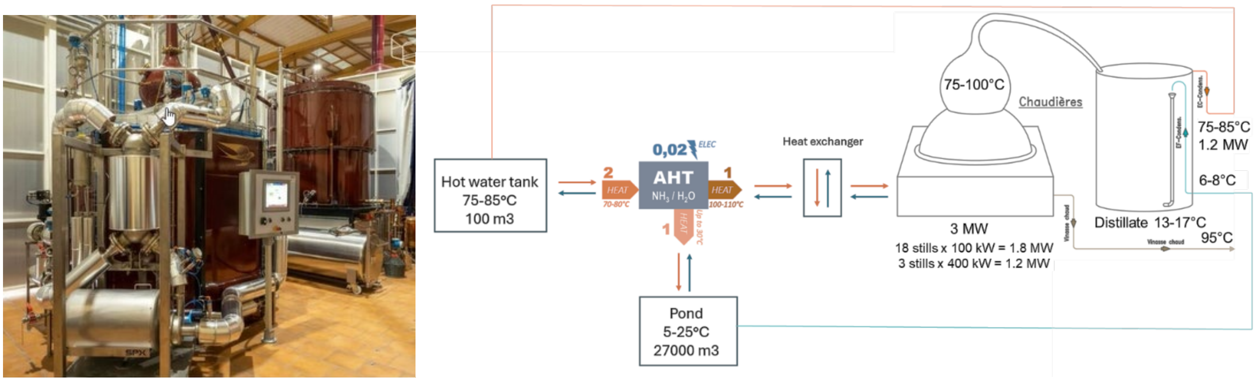


Figure 15: Schematic of the Cognac production process at the Distillerie de la Salle with a potential integration point of an AHT (Left: Photo of the type of heat exchanger, Source: Sarazin, 2025).

6.4. Conclusions from the interview results

The three interviewed food & beverage companies (Lactalis, Gélagri, and Distillerie de la Salle) each exhibit potential integration points for an Absorption Heat Transformer (AHT) system.

Lactalis does not have a constant steam demand, but certain processes like pasteurization and CIP (Cleaning-in-Place) stations require temperatures between 100 and 130 °C for over half a day. This could provide sufficiently stable conditions for the operation of an AHT. Additionally, the 87 °C waste heat recovered from flue gas condensation in the 2nd economizer of the steam boiler represents a valuable opportunity for AHT integration, especially for steam generation. However, further studies and information are needed to assess the feasibility of integration, including factors such as the distance between steam production and usage points, and the potential use of rejected heat at around 10 to 30 °C.

For Gélagri, the available waste heat from the air and steam exhaust of the blanchers, at 70/80 °C, is currently unknown. Measurements will be necessary to assess the feasibility and relevance of integrating an AHT system.

Distillerie de la Salle has a significant amount of heat available at 75/85 °C in an existing heat recovery water loop that could be used to supply the AHT system. The AHT could potentially upgrade this medium-temperature water to a higher temperature level. Its integration seems promising and may contribute to substantial energy savings. Further investigation is needed to assess this potential in more detail.

Continued focus will be placed on processes that require steam at around 110 °C and have sufficient waste heat available.

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8. Degree of progress

The degree of fulfillment of the task activities in relation to what is outlined in the DoA is 100%.

9. Dissemination level

The dissemination level of this Deliverable D1.3 is public.