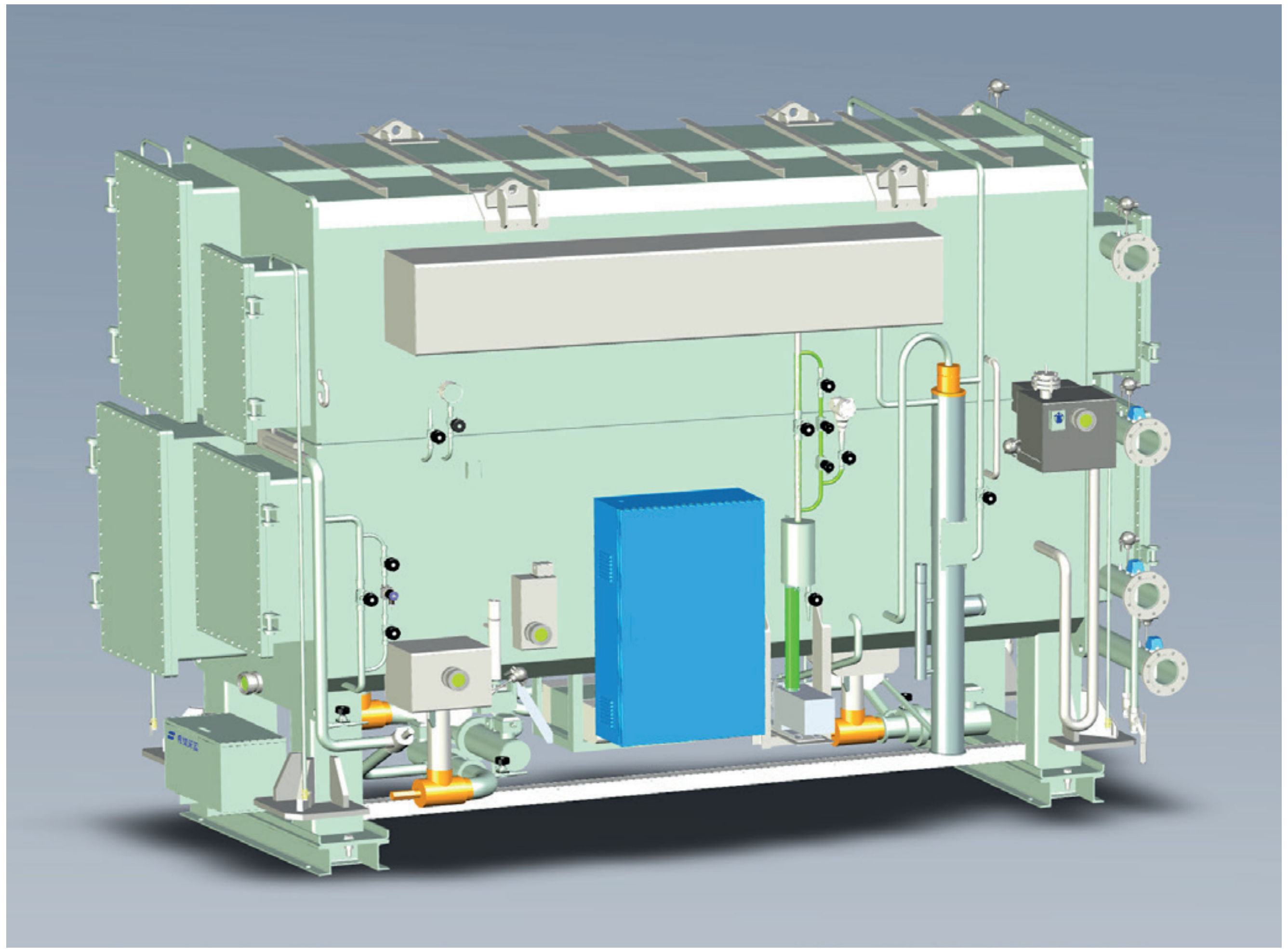
Maximum efficiency for biomass heating plants

Heat recovery via absorption heat pumps and active flue gas condensation

SCHMID energy solutions

Schmid - Moving grate boiler UTSR-1600 visio



3-D model of an absorption heat pump by STEPSAHEAD

Additional energy gain at constant fuel input – maximized heat recovery through absorption heat pumps

Optimized heat recovery from flue gases can massively increase the efficiency of biomass heating plants. By using combined flue gas condensation systems and absorption heat pumps, 20 – 40 % more heating energy can be generated from the same amount of fuel.

The flue gas from biomass combustion contains about 10 – 25 vol. - % water vapour depending on the fuel moisture. A lot of heat is stored in this water vapour, which is released again during condensation. Approximately 670 kWh of heat is released per ton of water vapour condensed.

For condensation, the flue gas must be cooled below its dew point temperature. Depending on the fuel moisture and residual oxygen content in the flue gas, this temperature is approximately 45 – 60 °C. The colder the flue gas can be cooled in the flue gas condensation system, the more condensation heat can be recovered.

In practice, the return flow of the heating network is often used to cool the flue gas condensation system. Its temperature often lies in the range of 55 – 60 °C and thus close to or above the dew point temperature.

Under these conditions, the water vapour in the flue gas cannot or only insufficiently condense, and the flue gas condensation system is limited in its performance or not functional at all.

Schmid energy solutions and STEPSAHEAD aim to maximize the efficiency of biomass heating plants. Through active flue gas condensation supported by an absorption heat pump, efficiency is increased, additional heating energy is utilized, and the dependency on the return flow temperature is reduced.

Advantages with Schmid’s combustion control system Revolution adaptive

The latest combustion control system Revolution adaptive by Schmid energy solutions is particularly advantageous in combination with condensation systems. It maintains low residual oxygen levels without operator intervention, even with varying fuel qualities. This improves flue gas condensation by raising the water dew point, leading to higher heat yields. Consequently, absorption heat pumps can be economically operated with 105 °C warm water boilers instead of hot water boilers. Therefore, external inspection with additional investment and operating costs as well as maintenance efforts can be avoided.

Cooperation between Schmid energy solutions and STEPSAHEAD

In February 2024, Schmid energy solutions and STEPSAHEAD agreed to collaborate to establish active flue gas condensation on Schmid boilers to maximize their heating efficiency.

STEPSAHEAD absorption heat pumps for active flue gas condensation have been successfully used in heating plants and industrial facilities for years.

More about Revolution adaptive

More about STEPSAHEAD

Energy gain in the energy flow diagram

For the representation in the energy flow diagram, a biomass boiler with a rated heating power of 1’000 kW is considered.

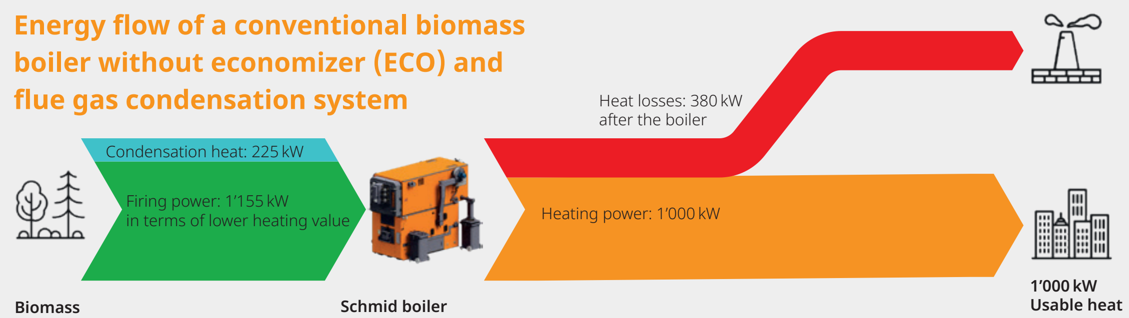
A conventional biomass boiler without an economizer (ECO) and flue gas condensation system requires approximately 1’155 kW of firing power for 1’000 kW of usable heat output. Losses of 155 kW occur due to radiation and chemical losses, primarily from the hot gases exiting the boiler. The latent heat of vaporization of the moisture in the flue gas, amounting to 225 kW, remains unused without an ECO and flue gas condensation system.

An ECO additionally provides about 70 kW, and an active flue gas condensation system with an absorption heat pump provides another 205 kW of usable heat output. This is achieved at a constant firing power (fuel input of 1’155 kW).

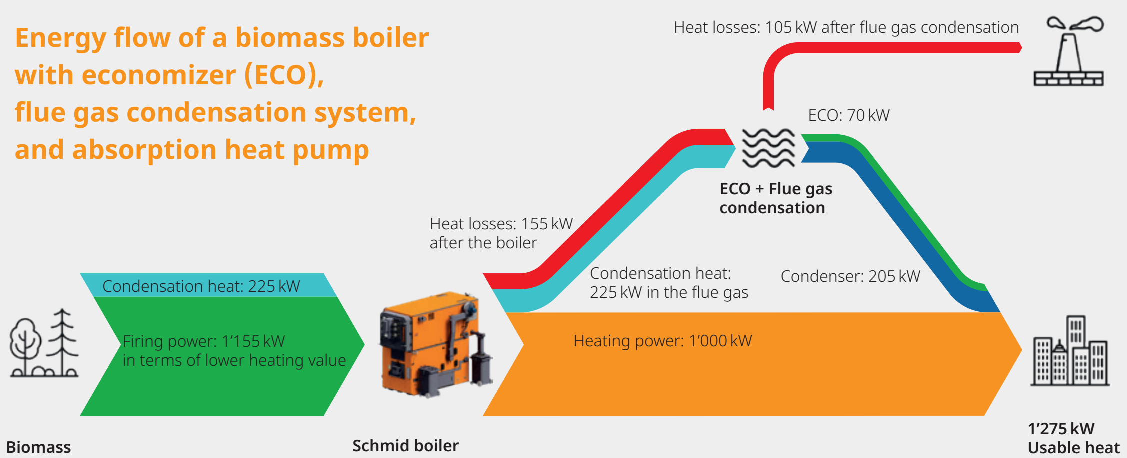
Hence, this highly efficient system delivers 1’275 kW of usable heat to the district heating network from 1’155 kW of firing power (in terms of lower heating value), corresponding to an efficiency of approximately 110 %.

Efficiencies above 100 % are possible because the lower heating value does not consider the condensation heat of the water vapour in the flue gas (225 kW) by definition. Relative to the higher heating value (1’380 kW), the efficiency is approximately 93 % (1’275 kW / 1’380 kW).

Energy flow of a conventional biomass boiler without economizer (ECO) and flue gas condensation system



Energy flow of a biomass boiler with economizer (ECO), flue gas condensation system, and absorption heat pump



Benefits of an absorption heat pump

Heat pumps can be used to transfer the low-temperature heat generated in a flue gas condensation system to the return flow of the heating network if the return flow temperature is too high for reliable flue gas condensation. This allows the low-temperature heat to be raised from, for example, 48 °C to 63 °C and integrated into a return flow with, for instance, 55 °C.

Schmid energy solutions and STEPSAHEAD utilize an absorption heat pump to elevate the condensation heat.

Unlike a compression heat pump, which requires an electrically driven compressor, the absorption heat pump is based on an absorption/desorption cycle using lithium bromide salt and water. It is driven by warm or hot water (≥ 105 °C). Consequently, compared to a compression heat pump, the absorption heat pump consumes very little electricity (< 1 % of the heat output).

The warm/hot water for driving the absorption heat pump is provided by the biomass boiler. The driving heat, together with the low-temperature heat from the condensation system, is used to warm up the network return flow and deliver heating energy to the network. Thus, there are no significant heat losses.

Efficiency and performance enhancement, reduction of operating costs

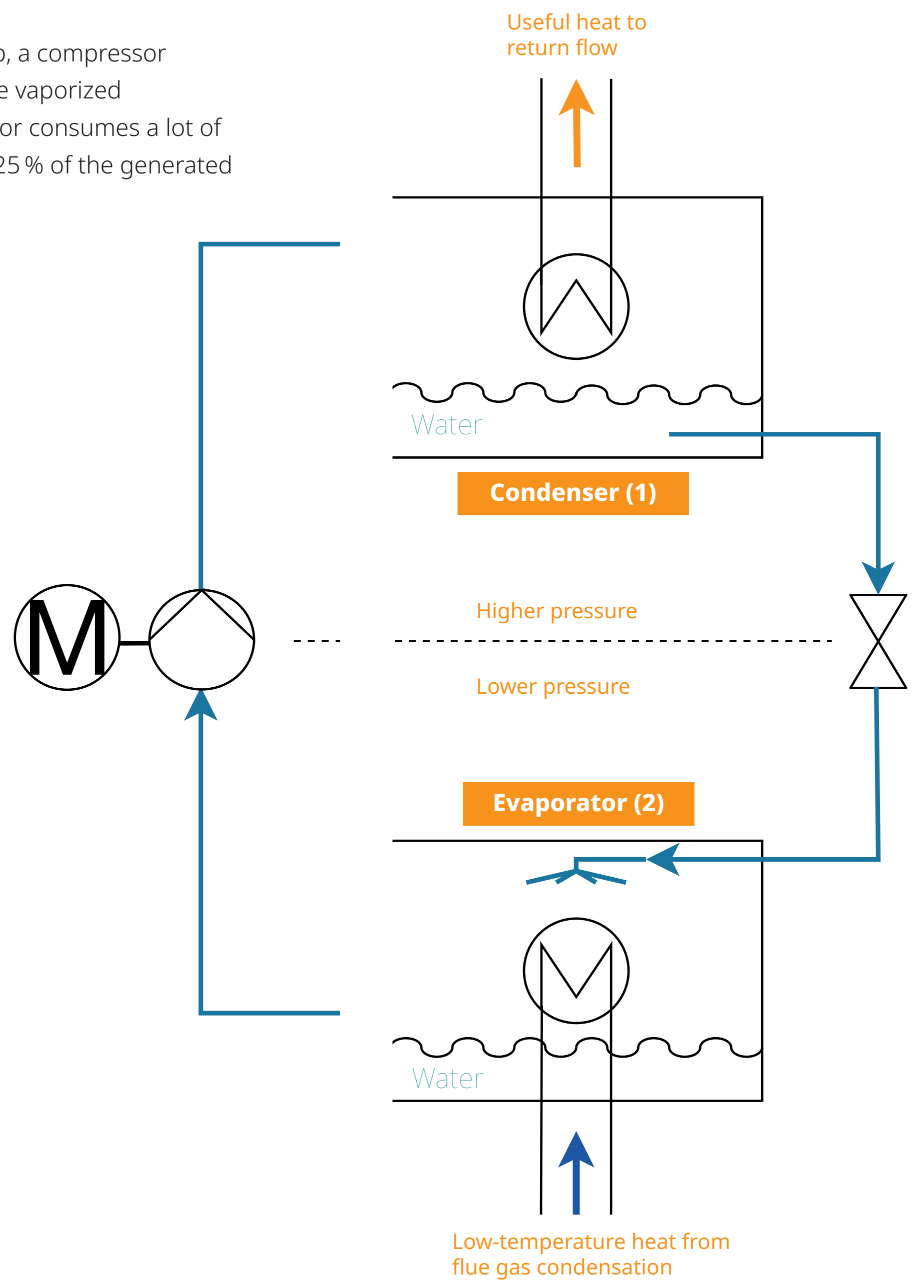
- Significant increase in biomass utilization efficiency
- 20 – 40 % more heating energy from the same amount of fuel - improvement of the heating plant's performance
- Reduction in fuel costs per unit of produced heating energy
- Low additional maintenance and upkeep effort
- High part-load capability of the absorption heat pump (up to 10 % of the rated capacity)

Environmentally friendly

- Electricity consumption < 1 % of the heat output of the absorption heat pump (compression heat pumps > approx. 25 %)
- Safe working fluids: water and lithium bromide salt
- Operation of the absorption heat pump under vacuum: No leakage in case of a leak
- Resource conservation through reduced biomass consumption
- Reduction of visible steam emissions from the chimney due to efficient flue gas condensation
- Quiet operation of the heat pump

Principle of operation of a compression heat pump

In a compression heat pump, a compressor increases the pressure of the vaporized working fluid. The compressor consumes a lot of electrical energy (> approx. 25 % of the generated heat output).



1. Partial function of the heat pump
Heat transfer

Heat pumps are used to transfer heat from a lower to a higher temperature level.

They use evaporation and condensation of a working fluid for transferring the heat.

Condenser (1):
Heat is released, and the working fluid condenses. This process is similar to what happens on a cold glass of a beverage, where moisture from the air condenses, releases heat to the glass, and slowly warms it up.

Evaporator (2):
Heat is added, and the working fluid evaporates. This process is comparable to boiling water on a stove.

2. Partial function of the heat pump
Achieving different temperature levels for heat supply and heat release

Heat pumps operate with two pressure levels, influencing the evaporation and condensation temperatures of the working fluid:

Analogy: Water boils at 100 °C at sea level but at 90 °C at 3000 meters above sea level (reduced air pressure).

Condenser (1):
Higher pressure = higher condensation temperature. The working fluid condenses at a high condensation temperature, releasing heat.

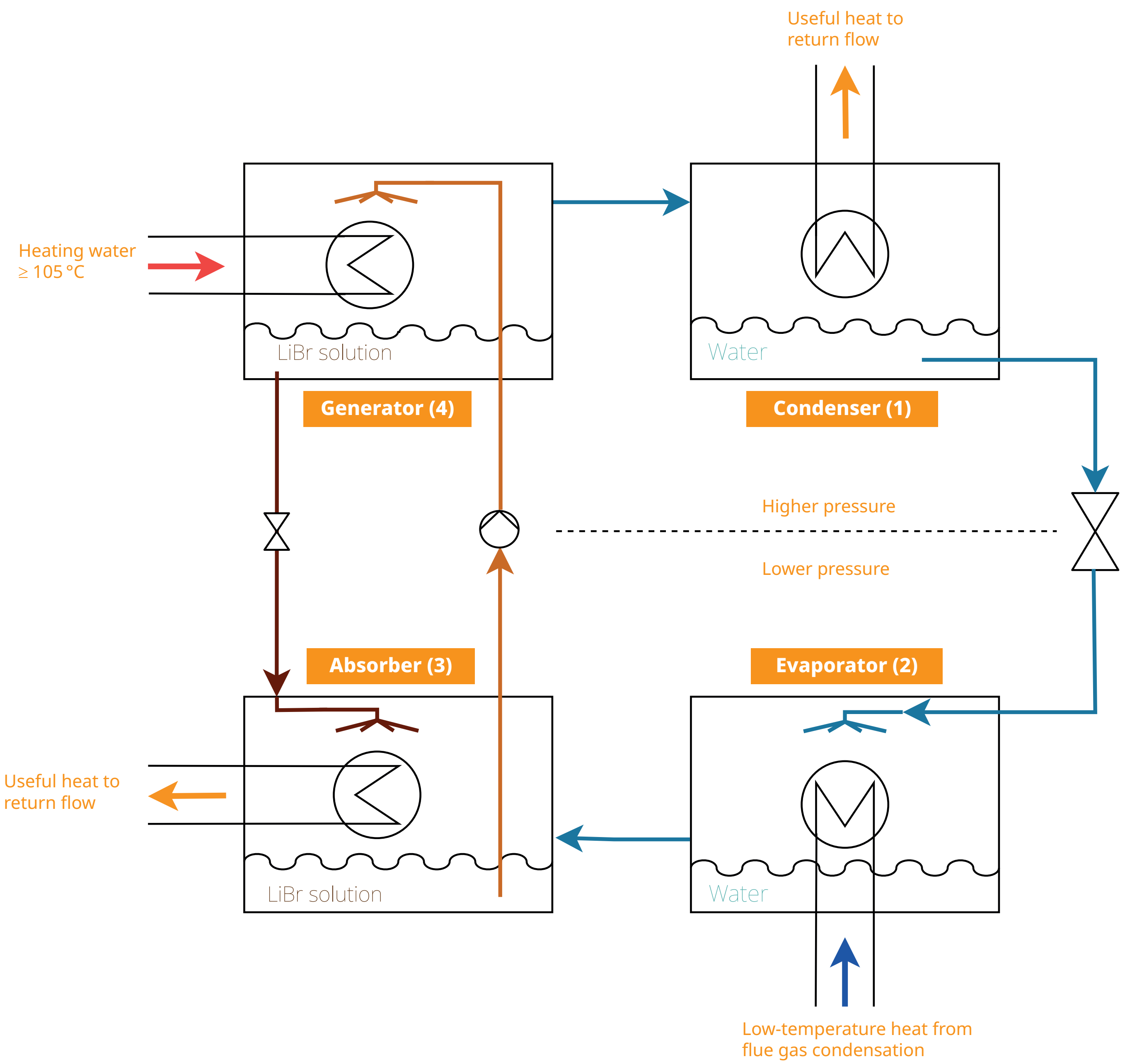
Evaporator (2):
Lower pressure = lower boiling temperature. The working fluid evaporates at a low boiling temperature, absorbing heat.

Heat pump cycle

To keep the pressure low in the evaporator, the working fluid vapour must be transferred to the condenser and compressed to a higher pressure. Energy is consumed to move the working fluid vapour from low to high pressure.

The heat pump cycle is thus closed, allowing heat to be lifted from a lower temperature level (evaporator) to a higher temperature level (condenser) through the use of different pressure levels in the evaporator and condenser and the addition of driving energy.

Principle of operation of a lithium bromide absorption heat pump



An absorption heat pump is a type of heat pump that is driven by heat (warm/hot water) from a biomass boiler. Therefore, it consumes very little electricity.

A lithium bromide absorption heat pump uses water and water vapour as working fluids at two different pressure levels.

A closed absorption and desorption cycle with a water-lithium bromide (LiBr) solution, in combination with a small pump, acts like a compressor.

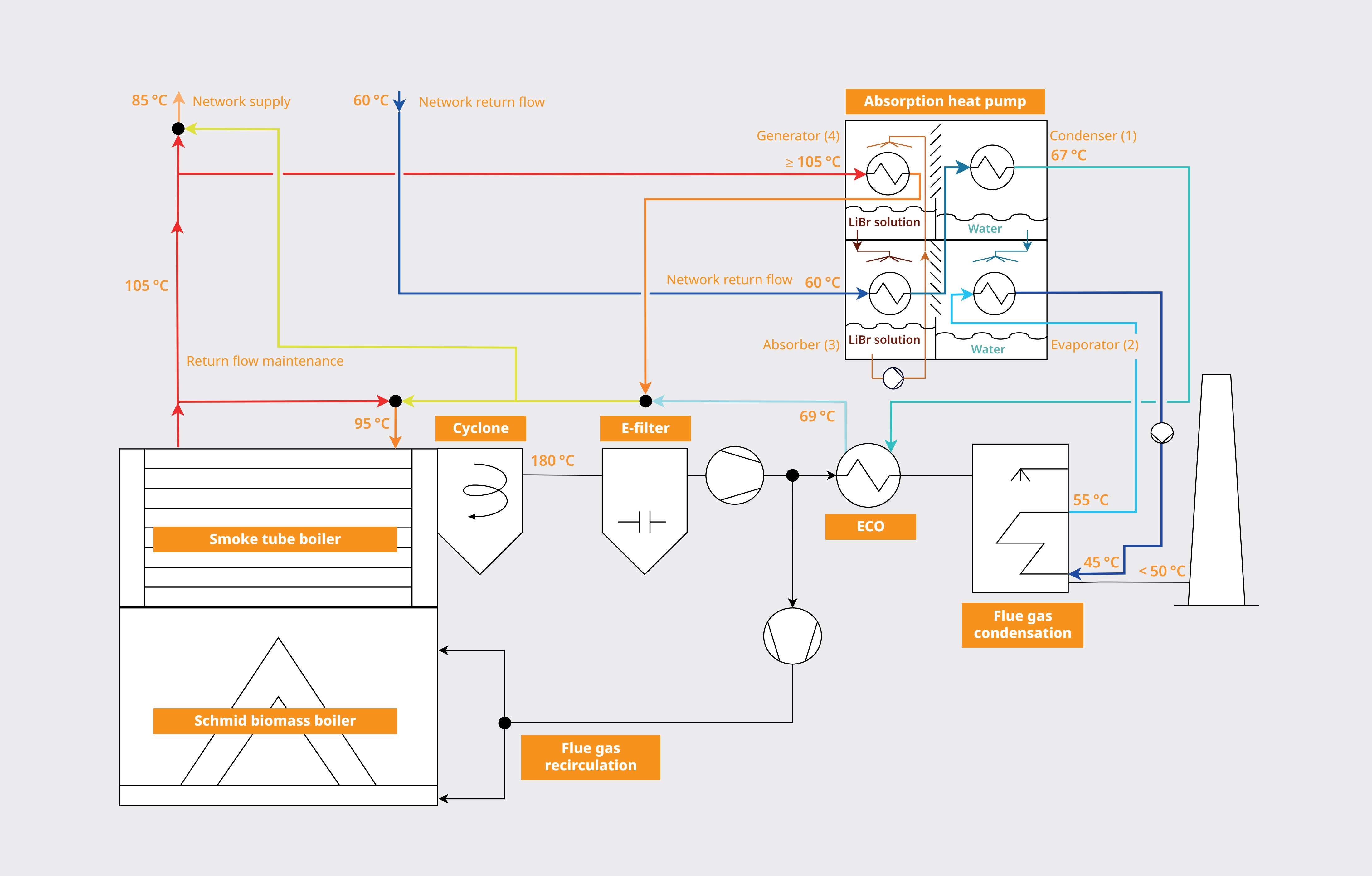
The working fluid (water vapour) is thus brought from a low-pressure level to a higher pressure level. This is done through the following steps:

Absorption in the absorber (3):
Concentrated LiBr solution absorbs water vapour that is produced in the evaporator (2). This process is similar to salt absorbing moisture from the air.

A pump increases the pressure of the LiBr solution diluted with water and transports it to the generator (4) at a higher pressure level. Increasing the solution's pressure with a pump consumes much less electrical energy than increasing the pressure of a vapour with a compressor.

Desorption in the generator/desorber (4):
To maintain the process, the LiBr solution must be reconcentrated. This is done by heating the solution to release water vapour. Heating water at ≥ 105 °C, supplied by the biomass boiler, is used for this purpose.

The reconcentrated LiBr solution is then returned to the absorber (3).



Integration of the absorption heat pump in a Schmid biomass heating plant

The integration of the absorption heat pump occurs in three water hydraulic circuits.

The absorption heat pump, in conjunction with the Revolution adaptive combustion control system, requires a minimum driving temperature of 105 °C. Higher driving temperatures, up to 150 °C, allow for greater temperature lifts and lower condensation temperatures, which are energetically advantageous. However, driving temperatures above 105 °C require a certified hot water boiler, leading to increased investment and operational costs. Using a hot water boiler with a supply temperature of ≤ 105 °C is economically and organizationally advantageous, especially for systems up to approximately 3 MW. For larger systems, the use of a hot water boiler with supply temperatures up to 150 °C may be interesting.

Hydraulic circuits
(Temperatures are project-specific examples)

Heating network return flow:
The heating network return flow (60 °C) goes through the absorber (3) and the condenser (1) of the absorption heat pump, where it is heated by approximately 7 °C. It absorbs the low-temperature heat from the flue gas condensation as well as the driving heat from the desorber (4). After passing through the absorption heat pump, return flow passes through the economizer and is then fed into the Schmid biomass boiler. A buffer storage tank can also be integrated into the systems at a suitable location.

The heating water is finally heated in the biomass boiler to 105 °C (or up to 150 °C with a hot water boiler).

Schmid biomass boiler flow:
A portion of the heating water from the biomass boiler flow is used as driving energy at 105 °C (or up to 150 °C with a hot water boiler) and fed into the desorber (4) of the absorption heat pump. The heating water cooled in the absorption heat pump is then reintegrated into the return flow to the biomass boiler. The other portion of the heating water from the biomass boiler supply either goes to the buffer tank or is mixed with water from the heating network return flow to the desired supply temperature, for example, 80 – 90 °C.

Cooling circuit for flue gas condensation:
The flue gas condensation system is connected to the absorption heat pump via the cooling circuit. This circuit continuously provides sufficiently cold water at 45 °C for the cold end of the flue gas condensation system, which is returned to the evaporator (2) of the absorption heat pump at about 55 °C.

The flue gas is cooled from approximately 180 °C at the boiler outlet to around 50 °C at the flue gas condensation system outlet.

In multi-boiler systems, due to the good partial load operability of the absorption heat pump, several boilers can often be connected to one absorption heat pump. The flue gas streams can either be combined into one flue gas condensation system, or the cooling circuit from the evaporator (2) of the absorption heat pump can be split into multiple flue gas condensation systems and recombined before entering the absorption heat pump.

To ensure the high efficiency of a heating system with an absorption heat pump, flue gas condensation system, and biomass boiler, careful design and dimensioning are required in the first step. Our specialist team, in collaboration with the client, handles the design, planning, and installation.

High profitability

Rapid amortization and high profitability are the goals of every investment. The economics of the active flue gas condensation system with an absorption heat pump depend on the following criteria:

- Full load hours per year
- Network return and supply temperatures (seasonal cycle)
- Fuel moisture content (seasonal cycle)
- Heat sales price
- Depreciation period and interest rate of financing

Other costs, such as electricity, additional maintenance, and service costs, are low and therefore play a minor role in the system's overall profitability. However, these costs are included in our economic analysis. Additionally, costs for building modifications, electrical installation, and hydraulic integration have been considered.

Example

Nominal boiler capacity:	3’200 kW
Average fuel moisture content:	M 50
Network return temperature:	58 °C
Target supply temperature:	90 °C
Flue gas dew point temperature (after boiler):	60 °C

Without an absorption heat pump, flue gas condensation in this configuration is minimal or non-existent.

Additional 880 kW of power at full load

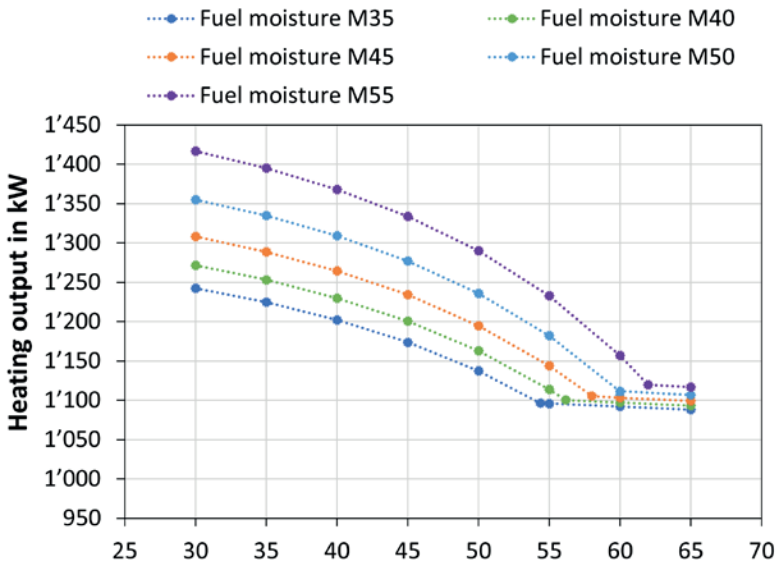
However, with active flue gas condensation combined with an absorption heat pump, the flue gas is cooled to 46 °C in the condensation unit, and the condensation heat is utilized, providing an additional 880 kW of power at full load.

Amortization example

Interest rate:	3 %
Heat sales price:	CHF 0.100 / kWh (EUR / kWh)
Full load hours:	3’000 hours
Amortization time:	< 5 years
*Investment return:	> 10 % per year
Full load hours:	4’000 hours
Amortization time:	< 4 years
*Investment return:	> 17 % per year
Full load hours:	5’000 hours
Amortization time:	< 3 years
*Investment return:	> 24 % per year

*Over 10 years of plant operation.

The total heat output of a biomass boiler with a nominal capacity of 1’000 kW and active flue gas condensation depends on the flue gas temperature at the outlet.



Retrofit for existing biomass heating plants

Existing biomass heating plants (single or multi-boiler systems) can also be retrofitted with an active flue gas condensation system and an absorption heat pump to maximize energy efficiency and generate more useful heat with the same fuel consumption.

For a successful retrofit, optimal integration of the existing biomass boiler, hydraulic system, and new components such as the economizer, condensation unit, and absorption heat pump is crucial. Therefore, careful design and dimensioning of all components and necessary modifications to existing systems are required. Our expert team collaborates with the client to handle the design, supply, planning, installation, and required modifications and maintenance.

Our Services

- Consultation on various options including cost-benefit analysis
- Design, planning, and delivery of the biomass heating plant including economizer, flue gas condensation, and STEPSAHEAD absorption heat pump
- Coordination and execution of installation in collaboration with the client
- Commissioning and handover to the operator, including training
- Maintenance package

Interested in an quote?
Schedule an appointment now.
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In collaboration with:
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