HEAT PUMPS

Solutions for the decarbonisation of the pulp and paper industry

Energy Efficiency Solutions Forum (EESF)

With the contribution of

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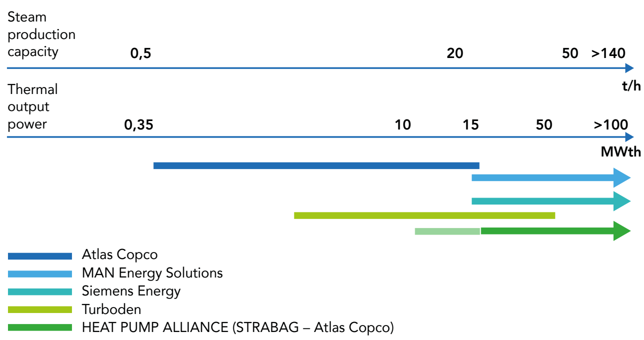
The pulp and paper sector is committed to achieving climate neutrality in Europe by 2050. This requires reducing emissions in our production processes by the implementation of energy-efficient technologies and the effective use of fossil-free energy sources.

Cepi's Energy Efficiency Solutions Forum (EESF) aims to accelerate the development and implementation of carbon-reducing technologies and solutions in our sector. We accomplish this by forging new partnerships and collaborating with developers and suppliers of energy efficiency technologies, as well as providers of fossil-free energy.

Among these technologies providing energy efficiency are heat pumps.

Heat pumps can significantly reduce the energy required for paper drying. The efficiency of a heat pump is defined by its Coefficient of Performance (COP), which is the relationship between the power input and the useful heat output of the heat pump at given operation points.

A joint working group of EHPA and Cepi members concluded that a COP of at least 3 (i.e. 67% energy savings) is achievable both with standardised and engineered heat pumps, for the combination of the heat pump, the steam compression and an optimised paper production process. Close cooperation between suppliers of paper machines and of heat pumps can even lead to energy reduction with heat pumps in the highly demanding tissue production processes. This paper describes how.



	Standardized / Industrialized	Engineered / Standardized	Engineered
LP Steam Mass Flow [t/h]	0,5 - 4	6 - 10	15 - 140
Heat input (max) [MWth]	0,35 - 2,7	4 - 7	10 - 100

Available (single unit) heat pump capacities

Integrating the heat pumps

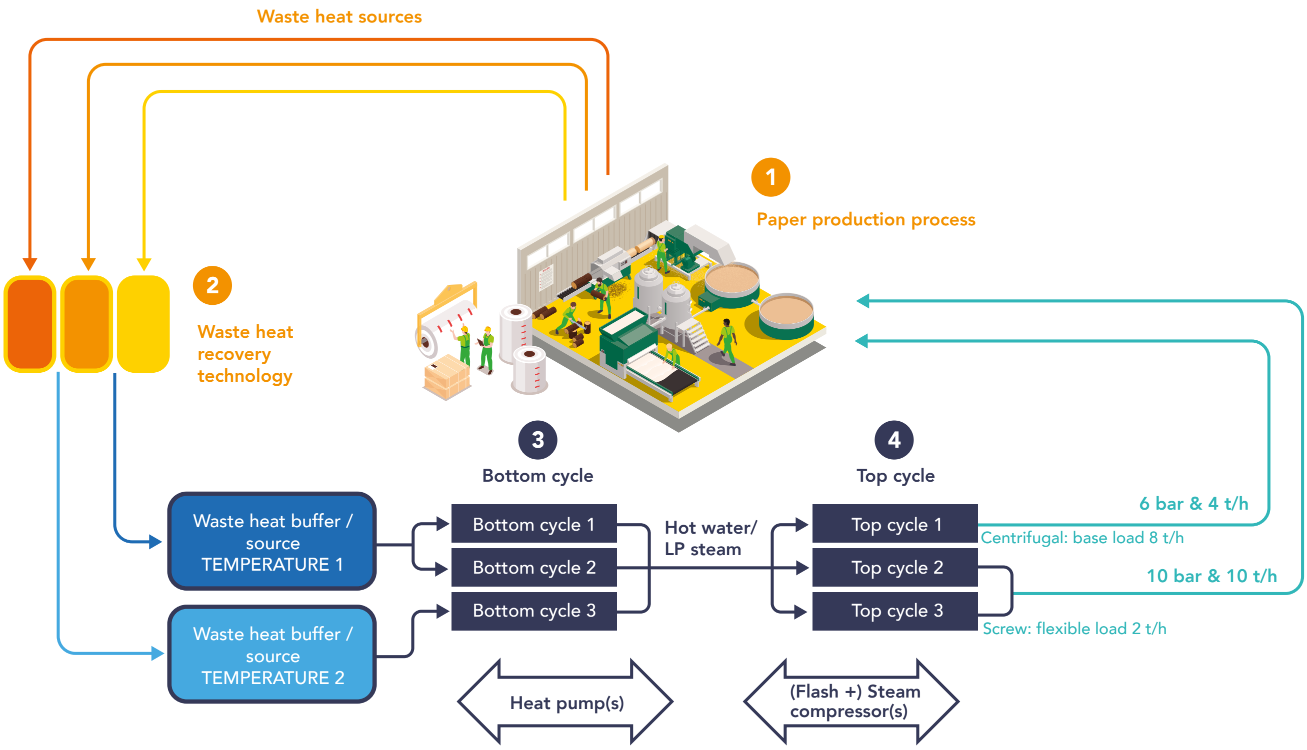
The optimal integration of heat pumps generally consists of the following elements:

1. **Optimisation of the paper production process.** Minimising the temperature lift required by the heat pump leads to higher heat pump efficiencies. It can be achieved by sourcing from higher temperature 'waste heat' sources (e.g. dewpoint of drying hood vapour ≥ 60°C) or reducing the required process temperature or steam pressure.

2. **Heat recovery.** Recovery of the latent and sensible heat of the drying hood wet outlet air flow into a 'warm water' stream. Although each mill will require a different system, it is advised to standardise the heat exchanger units and consider including Cleaning in Place (CIP) systems due to contaminations in the vapour. Different systems may need to be used for recovering latent heat and sensible heat.

3. **Steam generation – bottom cycle.** A heat pump lifts the temperature of the warm water to generate low pressure steam. Table A provides an overview of the available capacities. While single or multiple standard heat pumps are increasingly available for capacities below 10MWth, capacity needs above this threshold make custom designs for each process interesting and economically feasible.

4. **Steam generation – top cycle.** In the top cycle the low-pressure steam is compressed to higher pressures as required for each process. This may be done by a combination of multiple steam compressors that serve the different steam demands in the process. A full scalable option is achieved with a combination of screw and centrifugal turbo compressors. For small and medium-sized solutions, the screw compressor is a reliable solution: it is very flexible and efficient at each pressure level. The centrifugal compressor has a better efficiency. Different types of centrifugal compressors are available: radial inline or integrally geared compressors.



Controlling steam capacity with heat pumps

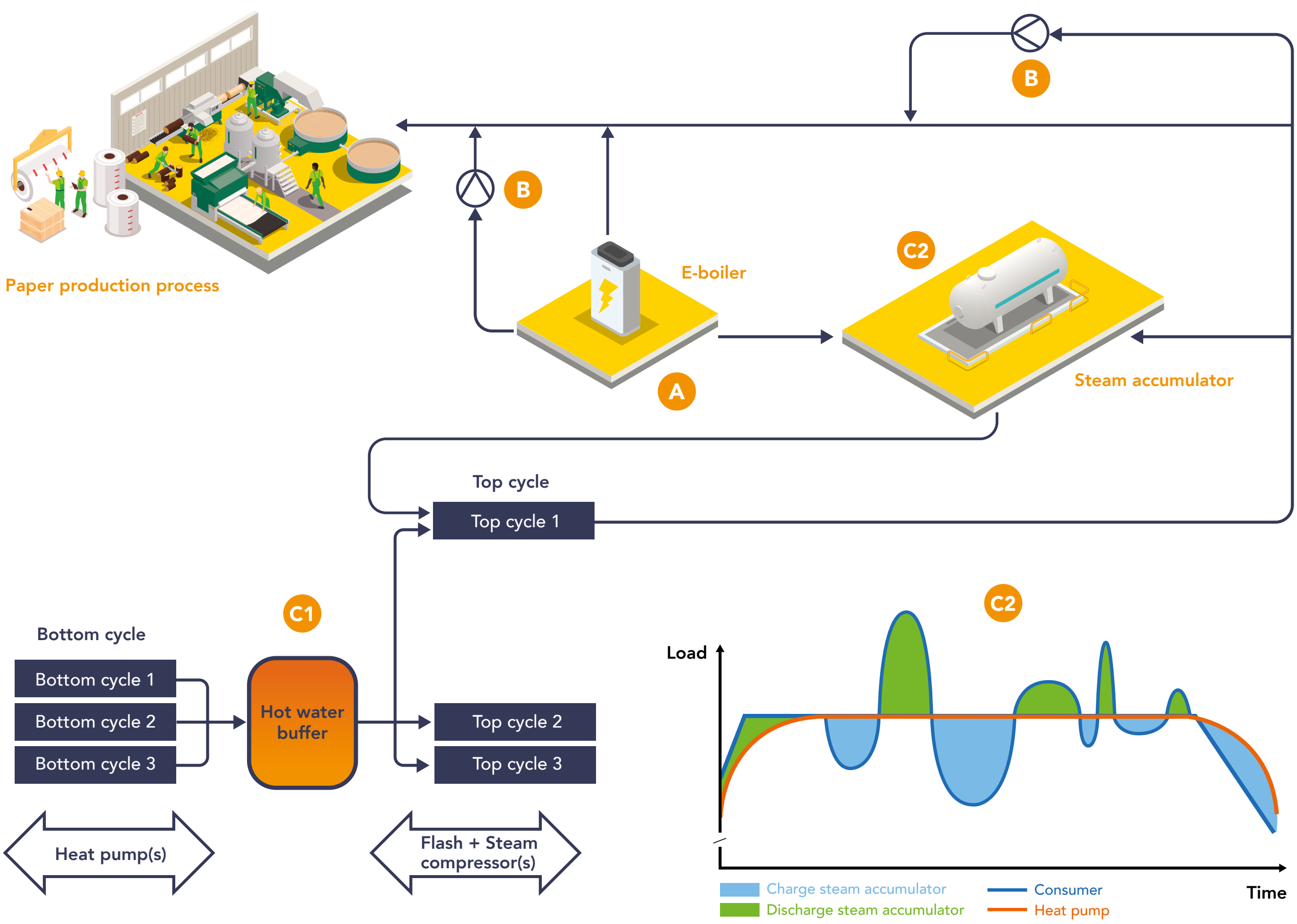
Heat pumps and steam compressors have slower reaction times compared to reducing valves in current steam systems. They also run most efficiently in base load, with a certain control range in which the efficiency is reduced. Typical turndown to 50% (screw compressor) or to 70% (turbo compressors) of full load power can be realised at moderate efficiency loss. If the paper plant has a wide range of steam demand, it is advised not to cover all possible load scenarios with a single heat pump or steam compressor solution. Instead, cascaded heat pumps / steam compressors of different sizes and/or hybrid combinations of heat pumps, E-boilers and thermal storage may be applicable, depending on the specific requirements of the individual paper mill:

A Combine a standard or engineered heat pump / steam compressor for base load with an E-boiler in part load, for dynamic control. An E-boiler could also be used for start-up steam. At capacities below 10 MWth the use of standard compressors is recommended for cost efficiency.

B For the higher capacities: use the centrifugal compressor in base load combined with a more flexible screw compressor to handle the fluctuations.

C Include buffers for hot water and/or steam:

- **C1** **a hot water buffer** between the bottom and top cycle. This is a cost-effective solution that also allows more waste heat sources to be used by connecting them to several heat pumps that can then work in parallel, all providing feed to the hot water buffer for the top cycle.
- **C2** **a steam accumulator** in the top cycle (Figure D). A steam accumulator allows faster control compared to hot water storage. It can store the steam during ramp down or stop, and can supply steam during start-up for peak demands. Use of a steam accumulator also decreases the required design capacity to e.g. 90% of the maximum mass flow. The steam accumulator requires the steam fed at a somewhat higher temperature than what it releases. It can also be fed with steam from an E-boiler.



Integrating heat pumps in tissue production processes

Tissue production processes have the challenge of high steam pressures (as 'blow-through steam' to remove condensate from the Yankee cylinders) and relatively low capacity (not allowing engineered solutions). The working group identified the following opportunities to make heat pump implementation feasible:

- Replace the thermo-compressor by a mechanical compressor.
- Develop tissue production solutions that don't need 18 bar steam pressure.
- The thermocompressor can be replaced by mechanical compression.
- Reduce the required steam pressure, which is to be compensated by increasing the Yankee cylinder size to keep the same drying capacity. An improved hood temperature can compensate for any steam pressure decrease.
- Electrical heating of the hood inlet air (instead of combustion air) can significantly reduce the required amount of air (up to dewpoint of 90°C).

These adjustments lead to about 10% higher tissue machine prices as well as higher buildings.

Key take-away's:

- **The large industrial heat pump technology is a widely proven technology, with some references for system components running for decades in industry.**
- **A complete electrification of process heat / steam generation in the paper industry is possible, but also baseload / hybrid systems are a good first step.**
- **Increasing the temperature of the heat source to as high as possible temperature levels is the main way to reach high efficiencies (COP) of a heat pump system. The drying hood is preferably optimised to achieve highest dew point of the drying air.**
- **Investigate what pressure is really needed at the point of use. It is most efficient to change the steam network layout requiring an upgrade of the steam grid to allow lower pressures.**
- **In existing plants (brownfield), infrastructural costs are often much higher than the cost of the heat pump system.**
- **Running a heat pump in base load offers more standardisation thus cost reduction potential. However, it requires additional equipment for flexible steam generation to cover the dynamics.**
- **Improved economics require a balance between standardised and site-specific elements as well as a balance between investments and total operating costs.**
- **Most of the high temperature heat pump suppliers work with natural refrigerants.**

Case studies

In 2023, Turboden, a Mitsubishi Heavy Industries group company, signed a contract with a European company in the pulp and paper industry. It will install an innovative heat upgrade system, based on the integration of a large heat pump and a mechanical vapour compressor (from AtlasCopco). With renewable electricity, low temperature waste heat (10 - 20°C) is upgraded to produce 12 MWth of superheated steam at 170°C for the paper production process.

The project is expected to start by the end of 2024.