SPIRIT

# Deliverable 4.3

# Heat pump integration tool

Drafted by: Moritz Schmidberger

Date: 02/03/2026

Grant agreement No: 101069672

Project start date: 1st September 2022

Duration: 54 months

Funded by the European Union

| BASIC INFORMATION ON THE DELIVERABLE | |
|---|---|
| **DISSEMINATION LEVEL** | Public |
| **DUE DATE OF DELIVERABLE** | 31/05/2025 |
| **ACTUAL SUBMISSION DATE** | 02/03/2026 |
| **WORK PACKAGE** | WP4 - Repeatable concepts and modular design |
| **TASK** | T4.4 Heat pump/process integration tool development |
| **TYPE** | Documentation |
| **NUMBER OF PAGES** | 26 |

Funded by
the European Union

| Report of Contributors | | | | |
|---|---|---|---|---|
| | **Name** | **Organisation** | **Role/ Title** | **E-mail** |
| **Report leader** | Moritz Schmidberger | (TLK) | Engineer | Moritz.schmidberger@tlk-energy.de |
| **Contributing Author(s)** | Ina Machleid | (TLK) | Engineer | |
| **Reviewer(s)** | All consortium partners of WP4 | | | |
| **Final review and quality approval** | S. Spoelstra | TNO | Project coordinator | **simon.spoelstra@tno.nl** |

| Date | Version | Description |
|---|---|---|
| 01/03/2024 | 0.1 | First draft |
| 10/09/2025 | 0.2 | First revision |
| 23/02/2026 | 1.0 | Final version |

# DISCLAIMER OF WARRANTIES

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101069672 (SPIRIT).

This document has been prepared by SPIRIT project partners as an account of work carried out within the framework of the EC-GA contract no. 101069672.

Neither Project Coordinator, nor any signatory party of SPIRIT Project Consortium Agreement, nor any person acting on behalf of any of them:

(a) makes any warranty or representation whatsoever, expressed or implied,

(i). with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or

(ii). that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or

(iii). that this document is suitable to any particular user's circumstance, or

(b) assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if the Project Coordinator or any representative of a signatory party of the SPIRIT Project Consortium Agreement has been informed of the possibility of such damages) resulting from your selection or use of this document or any information, apparatus, method, process, or similar item disclosed in this document.

# PROJECT PARTNERS

**TNO**: NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK

**DTI**: TEKNOLOGISK INSTITUT

**DLR**: DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV

**EHPA**: EUROPEAN HEAT PUMP ASSOCIATION

**MYK**: NV MAYEKAWA EUROPE SA

**SINLOC**: SINLOC-SISTEMA INIZIATIVE LOCALI SPA

**EURAC**: ACCADEMIA EUROPEA DI BOLZANO

**EHP**: EUROHEAT & POWER

**DTU**: DANMARKS TEKNISKE UNIVERSITET

**TVP**: TVP Solar

**TIS**: TIENSE SUIKERRAFFINADERIJ N.V.

**TLK**: TLK ENERGY GMBH

**GEA**: GEA Refrigeration Germany GmbH

**SPIL**: Spilling Technologies GmbH

**SKPS**: Smurfit Kappa Paper Services B.V.

**SKC**: SMURFIT KAPPA CZECH SRO

**SP**: STELLA POLARIS AS

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

# ABBREVIATIONS AND ACRONYMS

**CAPEX:** Capital Expenditure

**COP**: Coefficient of Performance

**CC**: Composite Curve

**GCC**: Grand Composite Curve

**HP(s)**: Heat pump(s)

**HTHP(s)**: High-temperature heat pump(s)

**NPV**: Net present value

**PBT**: Payback time

**SPIRIT**: Implementation of sustainable heat upgrade technologies for industry

# TABLE OF CONTENTS



# LIST OF FIGURES



Funded by the European Union

# 1. INTRODUCTION

This task will focus on creating a heat pump tool, which can be used to design, dimension, and optimize the most relevant heat pump cycles concerning thermodynamic performance and economic key-performance indicators.

Description of tasks: A web-based tool is being developed to support the early integration of heat pumps in industrial processes. It enables easy design and optimization of various heat pump systems based on thermodynamic and economic criteria. The concept and the layout of the three-part web tool will be presented in the following. As part of this deliverable, the **1st web tool Pinch Analysis Tool** is fully implemented and available. With the online pinch analysis software, a user can quickly and easily identify how much efficiency potential there is in unused waste heat flows in their industrial operation and how they can optimally integrate heat pumps. The tool is online and can be found here: https://tlk-energy.de/en/tools/pinch-analysis-online

Building on this foundation, the **2nd web tool, the Heat Pump Design Tool**, enables users to design a heat pump that fits the requirements identified in the pinch analysis. The tool can also be used independently to configure a heat pump cycle, explore different refrigerants, adjust operating parameters such as condensation and evaporation temperatures, and evaluate performance through the coefficient of performance (COP). If combined with the pinch analysis, the tool directly integrates the heating and cooling demands of the process and displays the heat pump within the thermodynamic diagrams and the Grand Composite Curve. The tool is online and can be found here: https://tlk-energy.de/en/tools/industrial-heat-pump-design

The **3rd web tool, the Economic Evaluation Tool**, forms the final step of the workflow. It calculates the economic and environmental impacts of implementing the defined heat pump. Based on default or user-specified values for electricity prices, gas boiler efficiency, and gas prices, the tool provides results on electricity usage, investment and operating costs, return on investment, and $CO_2$ savings compared to a conventional gas boiler. All relevant indicators are summarized in a results table, giving the user a clear overview for decision-making. This tool is directly linked when a heat pump has been created in the heat pump designer. Unlike the other two tools, it is not a standalone tool and can only be used in combination with a heat pump.

# 2. PINCH ANALYSIS

Pinch analysis is a systematic method for optimizing energy efficiency in industrial processes, particularly by maximizing heat recovery. The goal is to reduce the use of external energy sources—such as steam for heating or water for cooling—as much as possible. Instead, the hot and cold streams already present in the process should be linked in a way that allows them to exchange heat directly with each other.

Hot streams that need to be cooled can release heat, while cold streams that need to be heated require heat input. The core idea of pinch analysis is to match these hot and cold streams efficiently so that external energy demand is minimized.

A central concept in this method is the so-called pinch point. This is the point in the process where the minimum allowable temperature difference $\Delta$Tmin between hot and cold streams occurs. It divides the system into two regions: Above the pinch point, no external cooling should be used, since there is excess heat. Below the pinch point, no external heating should be applied, as the heat demand in this region should ideally be met through internal heat recovery.

Using pinch analysis, one can determine the minimum external heating and cooling requirements, as well as design the optimal heat exchanger network. The result is an energy-efficient process with maximum heat recovery and minimal energy input.

The application is divided into three parts. In the first part the user enters data into the Stream Table.

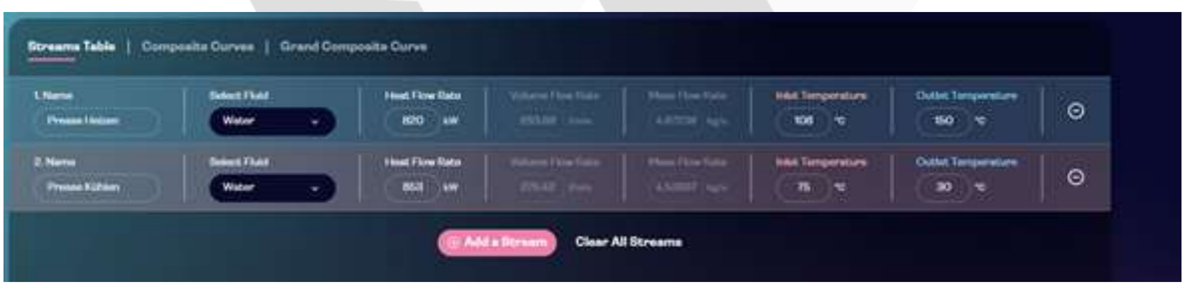


**Figure 1 - Pinch Analysis streams table**

The default view shows a process flow to be cooled down and a process flow to be heated up. These can be given their own names. Furthermore, the medium of the process flow can be selected, currently the choice between water, air, exhaust gas, silicon oil and water-glycol mixture are possible. The heat flow must then be entered. Alternatively, a new process flow can be added, in which case the user can decide whether to specify heat flow, volume flow or mass flow. Finally, the inlet and outlet temperature must be entered, which determines whether the flow requires heat or releases heat.

If you click on “Add a stream”, further streams can be added. You will then be guided through a screen where you can enter all the necessary information:

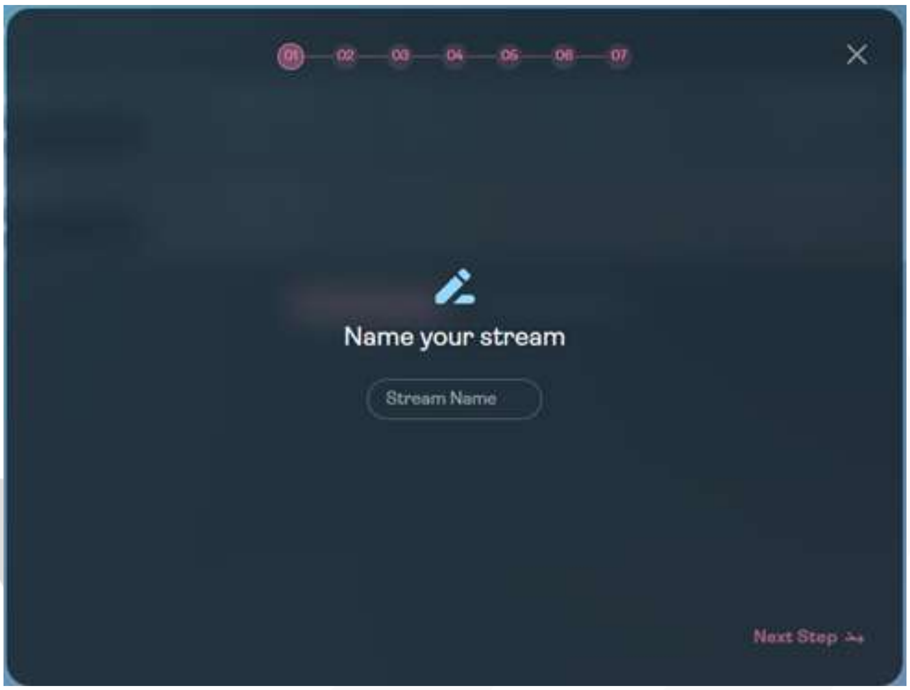


**Figure 2 -Pinch Analysis input stream name**

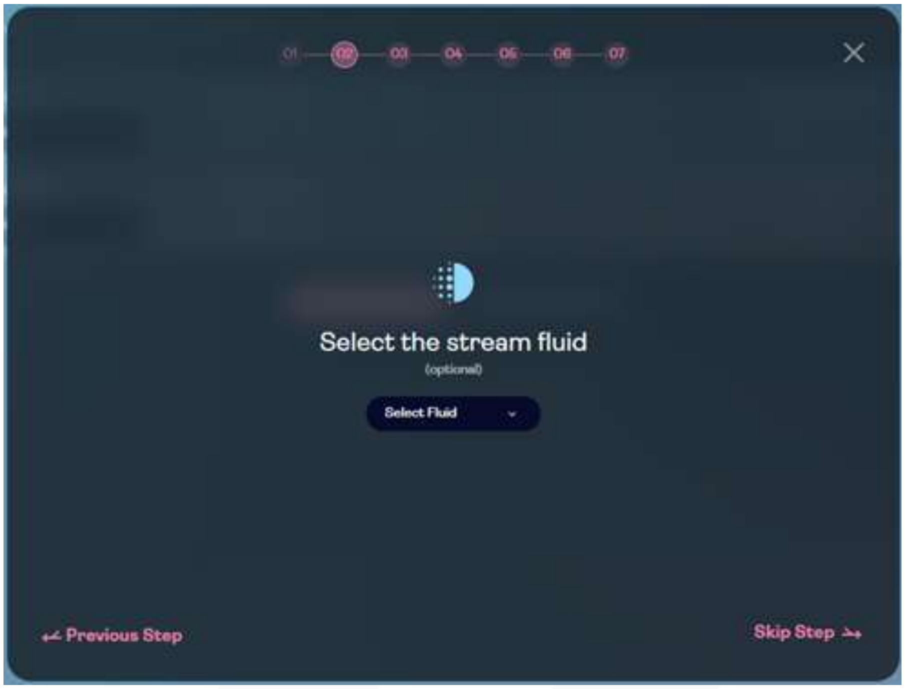


**Figure 3 - Pinch Analysis input of the fluid**


**Figure 4 - Pinch Analysis input heat flow rate**


**Figure 5 - Pinch Analysis input volume flow rate**

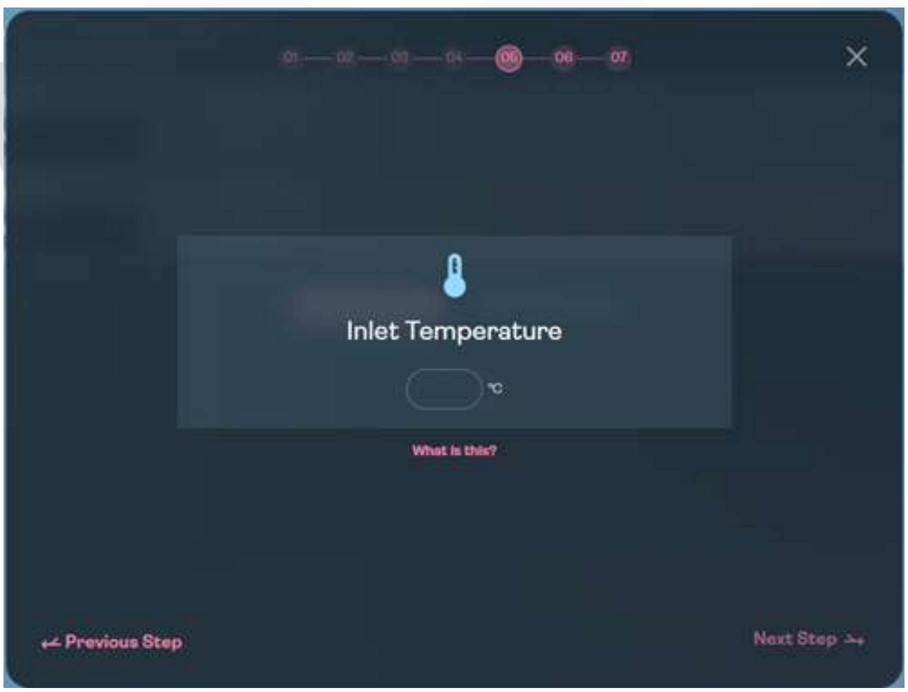


**Figure 6 - Pinch Analysis input inlet temperature**


Figure 7 – Pinch Analysis input outlet temperature

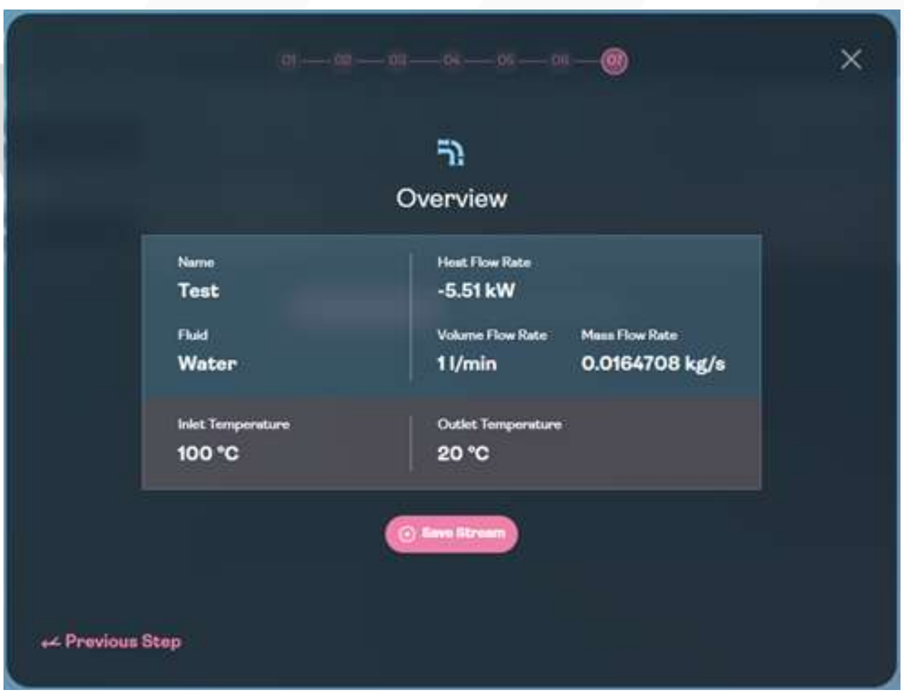


Figure 8 – Pinch Analysis input overview

The process is now looked at further with the following example of two streams that need to be heated up and two streams that need to be cooled.


Figure 9 - Pinch Analysis streams table

Clicking on "Composite Curves" takes you to the next step:

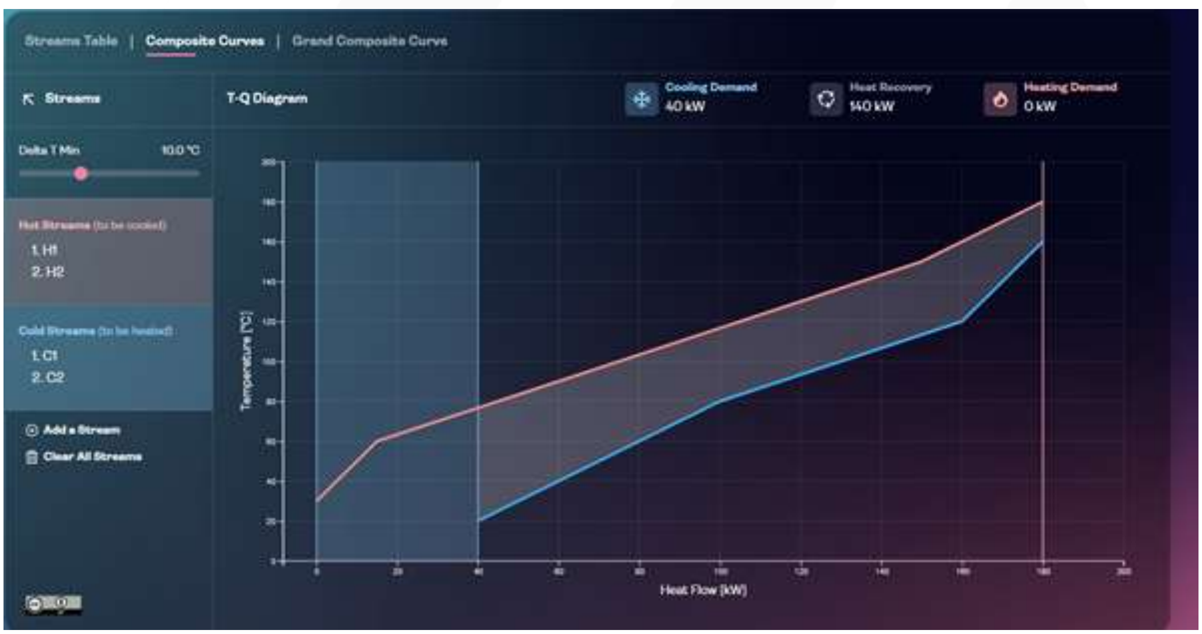


Figure 10 - Pinch Analysis composite curve

In this view, the user can now adjust the delta T min. Based on this setting, the composite curves are displayed in the T-Q diagram. The diagram now shows a "hot" composite curve in red, which results from the hot process streams. The same applies to the "cold" composite curve which is displayed in blue.

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

To construct the composite curves, the first step is to adjust the stream temperatures to account for the minimum allowable temperature difference $\Delta$Tmin. This is done by shifting all hot stream temperatures downward by $\Delta$Tmin /2 and all cold stream temperatures upward by the same amount. This ensures that the thermal driving force is maintained in the analysis.

Next, all unique stream temperatures (after adjustment) are collected to define a set of temperature intervals. For each of these intervals, the total heat capacity flow rate Cp is determined by summing up the Cp values of all hot or cold streams that are active within that specific temperature range. These total Cp values determine the slope of the curve segments. Specifically, since the heat transferred (Q) is calculated as Q = Cp $\times$ $\Delta$T, the slope of each segment on a temperature vs. heat (T-Q) diagram is 1 / Cp.

The composite curve is then built step by step: starting from zero cumulative heat (Q = 0), the heat exchanged in each interval ( $\Delta$Q) is calculated and added based on the total Cp and the temperature difference of the interval. This is done for both the hot and cold streams, resulting in two separate curves, the hot composite curve, which moves downward in temperature as heat is released, and the cold composite curve, which moves upward as heat is required.

The point where the two curves come closest together, typically separated by $\Delta$Tmin, represents the pinch point of the process. This point is critical for determining the minimum heating and cooling requirements and for designing an optimal heat exchanger network.

You can hover over the various curve areas with the mouse to see which currents occur in this curve segment. You can see this by a dot lighting up on the left in the list of currents.

The diagram also shows the areas on the left and right that represent the external cooling and heating demand. In this example, 40 kW must be cooled externally, and 0 kW must be additionally heated. This means that 140 kW can be saved by cleverly combining the process flows. It is also still possible to add flows in this screen.

Funded by the European Union

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Clicking on “Grand Composite Curve” takes you to the last step:

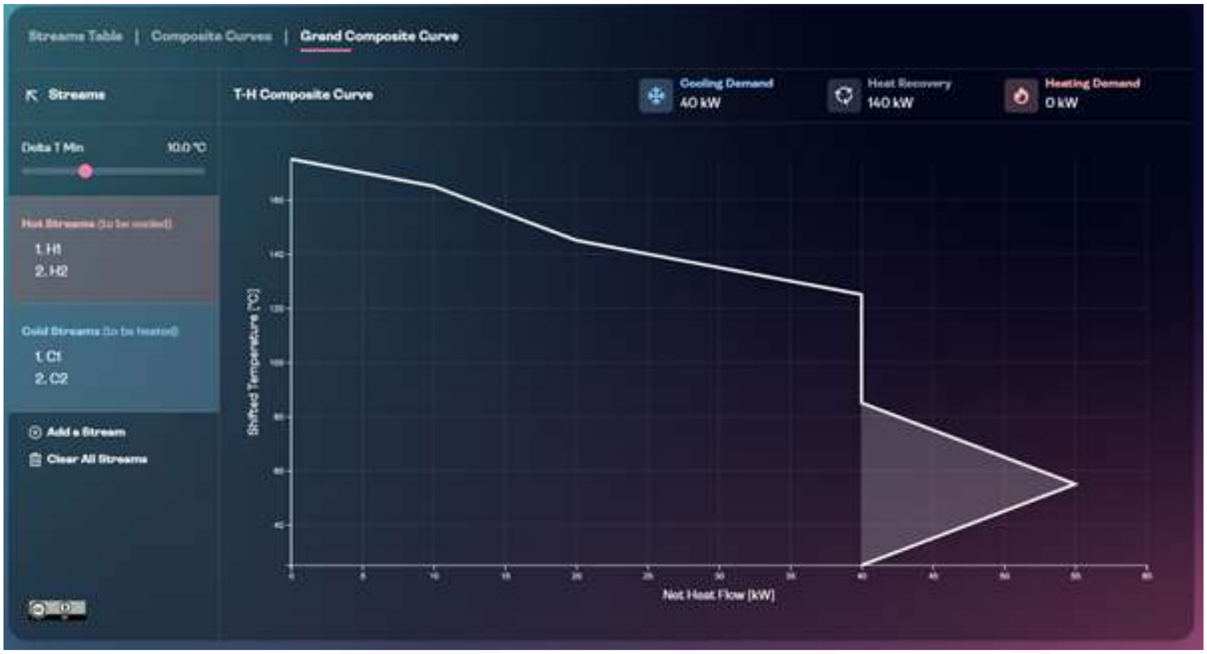


**Figure 11 - Pinch Analysis grand composite curve**

The Grand Composite Curve (GCC) is a valuable tool in pinch analysis that provides a clear overview of the net heat surplus or deficit within a process across different temperature levels. Unlike the composite curves, which show cumulative heat for hot and cold streams separately, the GCC shows the net heat flow in each temperature interval, offering direct insight into where heating, cooling, or internal heat exchange is needed.

To construct the GCC, the process begins in the same way as with composite curves: by adjusting the stream temperatures for the minimum temperature difference $\Delta$ Tmin. Hot stream temperatures are shifted downward by $\Delta$Tmin /2, and cold stream temperatures are shifted upward by $\Delta$Tmin /2. This ensures that the temperature differences used in the calculations reflect realistic heat exchange limits.

Next, a list of all distinct adjusted temperatures is compiled to define temperature intervals. Within each interval, the total heat capacity flow rate Cp is determined separately for the hot and cold streams that are active in that temperature range. By subtracting the total Cp of hot streams from that of the cold streams, the net heat flow ($\Delta$Q) in that interval can be calculated as ($\Sigma$Cp,cold - $\Sigma$ $\Delta$Cp,hot) $\times$ $\Delta$T.

Funded by the European Union

These $\Delta Q$ values represent the net heat balance for each interval. Starting with an assumed heating requirement (often chosen so that the minimum value in the cumulative heat cascade is zero), the heat surplus or deficit is calculated cumulatively from the top of the temperature scale down. The result is a heat cascade diagram, which is then rotated and plotted on a temperature vs. heat (Q-T) diagram to form the Grand Composite Curve.

The shape of the GCC reveals key design information: flat segments indicate potential for internal heat exchange, upward jumps show where external heating (e.g., steam) is needed, and downward jumps indicate where external cooling is required. The pinch point is seen as the point where the curve touches the vertical axis—indicating zero net heat flow at that temperature level.

The $\Delta Tmin$ can also be adjusted here and additional currents can be added. Here too, you can see which currents have been calculated in this segment by hovering over the curve areas.

This gathered data is then used for the 2nd web tool to determine where a heat pump can be implemented, as well as the design of the heat pump itself.

Funded by the European Union

# 3. HEAT PUMP DESIGN

As the second part of the three-part web application, the Heat Pump Design Tool has been developed to support the early integration of heat pumps into industrial processes. While the first tool, Pinch Analysis Online, identifies the efficiency potential of unused waste heat and determines where heat pumps can be beneficially integrated, this second tool takes the next step: it allows users to design the heat pump itself and match it to the process requirements.

The tool can be used in two ways. Based on the results of the first web tool, a heat pump can be designed that aligns precisely with the heating and cooling demands of the process. This ensures that the integration is directly linked to the pinch analysis and overall process energy balance. Alternatively, the tool can also be used independently: users may configure a heat pump without pinch results and directly evaluate its performance in terms of the coefficient of performance (COP). This dual functionality makes it suitable both as a process-integration tool and as a stand-alone simulation environment.

The workflow in the Heat Pump Design Tool follows a clear sequence of user inputs:

1. Refrigerant selection – The first step is to choose the working fluid for the cycle.
2. Cycle configuration – The user decides between:
    a. a simple cycle, where superheating and subcooling can be entered manually, or
    b. a cycle with internal heat exchanger, where the effectiveness of the internal heat recovery can be specified.
3. Compressor efficiency – In both configurations, the isentropic efficiency of the compressor must be defined. This parameter is always available and can be adjusted via a slider.
4. Temperature settings – Using sliders, the user adapts the condensation and evaporation temperatures to the desired operating conditions. Depending on the configuration, additional inputs such as subcooling, superheating, or heat exchanger effectiveness are adjusted here as well.
5. Integration with pinch analysis (optional) – If a pinch analysis has already been carried out, the user can define the heating power of the heat pump according to the pinch results. In this case, the corresponding heating and cooling streams are displayed in the T–h diagram and the designed heat pump is also visualized within the Grand Composite Curve (GCC).

Funded by the European Union

If you click on "Add heat pump", a new configuration can be added. You will then be guided through a screen where you can enter all the necessary information:


Figure 12 - Heat Pump Design input name

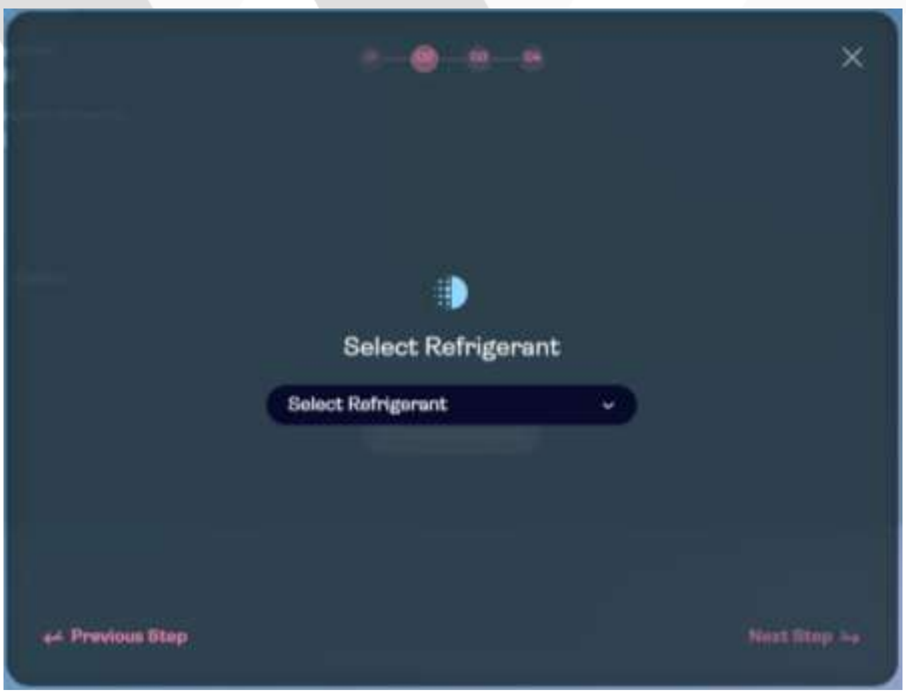


Figure 13 - Heat Pump Design input refrigerant

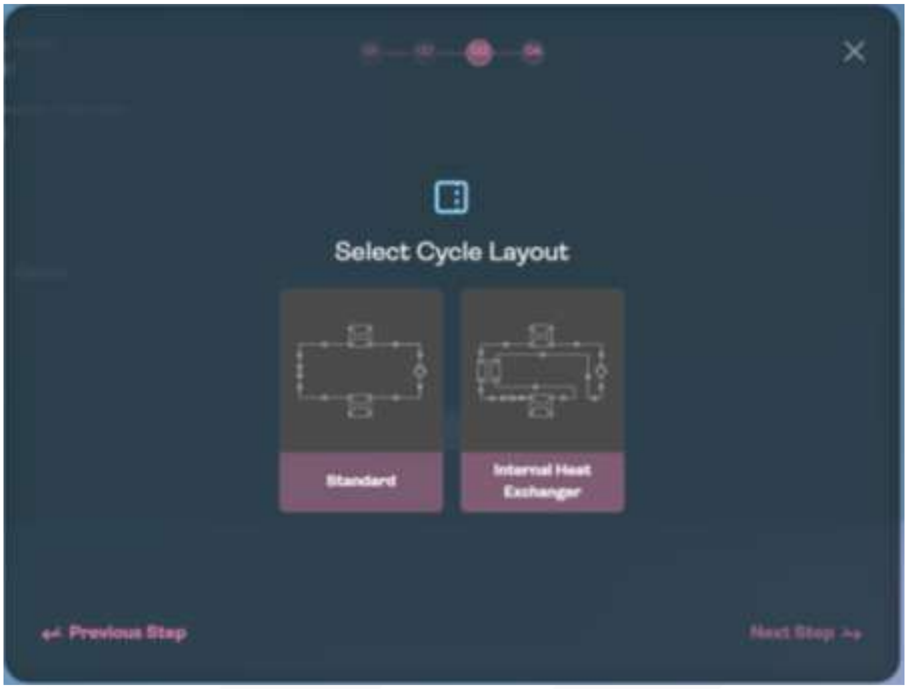


Figure 14 - Heat Pump Design input cycle configuration


Figure 15 - Heat Pump Design input overview

Funded by the European Union

Once the setup is complete, the tool displays the T–h diagram of the chosen refrigerant and cycle configuration. This provides a clear visualization of the thermodynamic behavior of the system. The representation in the T-h diagram makes it possible to plot the corresponding streams from the pinch analysis, thereby creating a direct link between the two tools.

At the same time, the COP for the defined cycle is shown in the top left corner of the interface, giving immediate feedback on the theoretical efficiency of the chosen setup. This actual COP is defined as the quotient of the usable heat and the power consumed. For heat pumps, this is calculated as the heat on the sink side divided by the sum of the heat supplied on the source side and the heat dissipated on the sink side. Isentropic efficiency is thus included in the calculation.

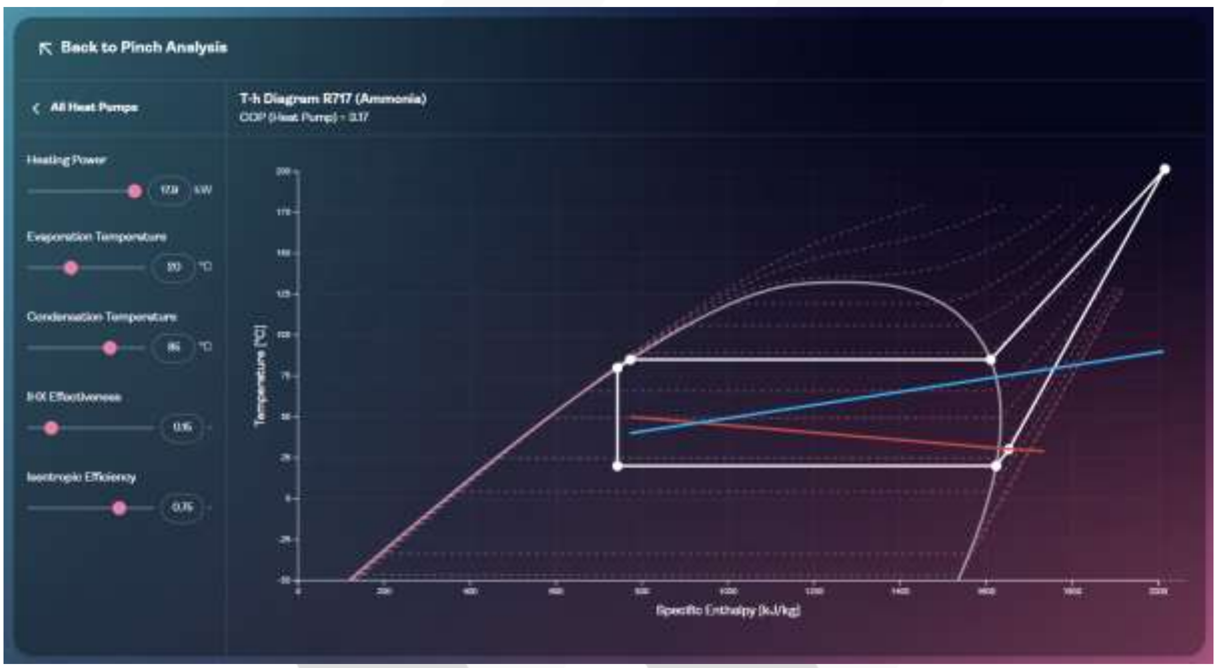


**Figure 16 - Heat Pump Design T-h-diagram**

The Heat Pump Design Tool guides the user step by step through refrigerant choice, cycle definition, efficiency parameters and operating conditions, and offers seamless integration with pinch results. This enables both precise process integration and flexible stand-alone heat pump simulation. When the user returns to the grand composite curve of their pinch analysis, they can see how the heat pump is integrated into their complete process.

Funded by the European Union

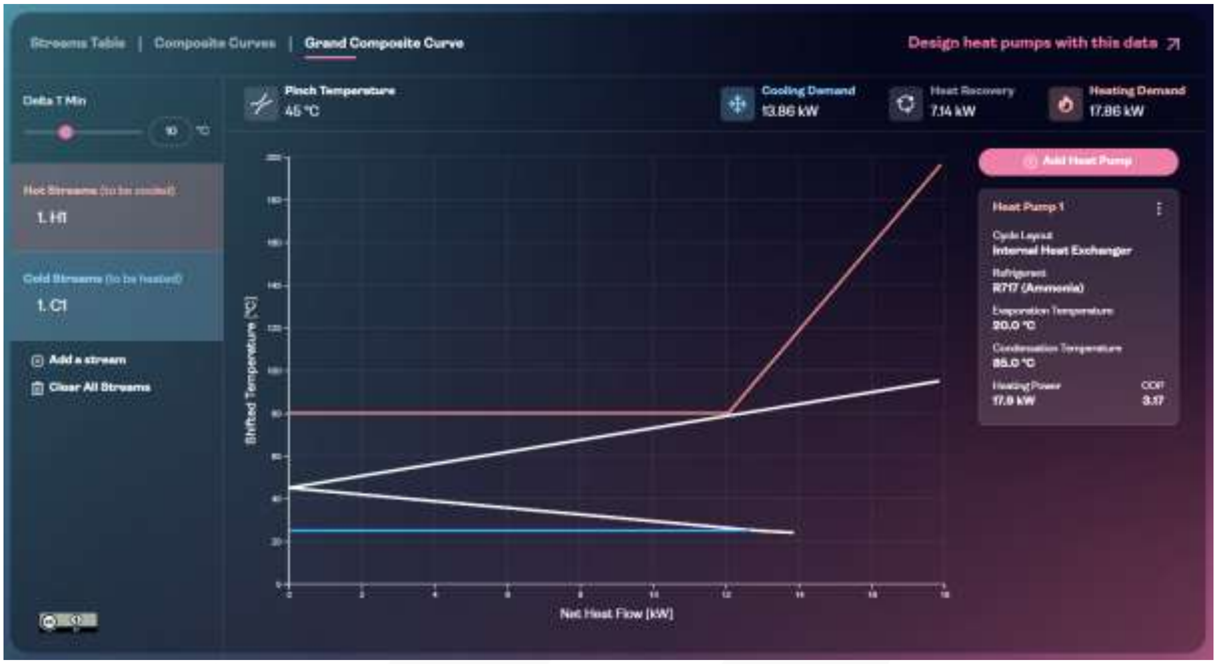


Figure 17 - Grand composite curve with heat pump included

# 4. ECONOMIC EVALUATION

The third and final part of the three-part web application is the Economic Evaluation Tool, which focuses on assessing the financial and environmental impact of heat pump integration. While the first tool (Pinch Analysis Online) identifies the technical potential for heat recovery and the second tool (Heat Pump Design Tool) enables the design and thermodynamic assessment of a heat pump system, this last step translates the technical design into economic and sustainability metrics.

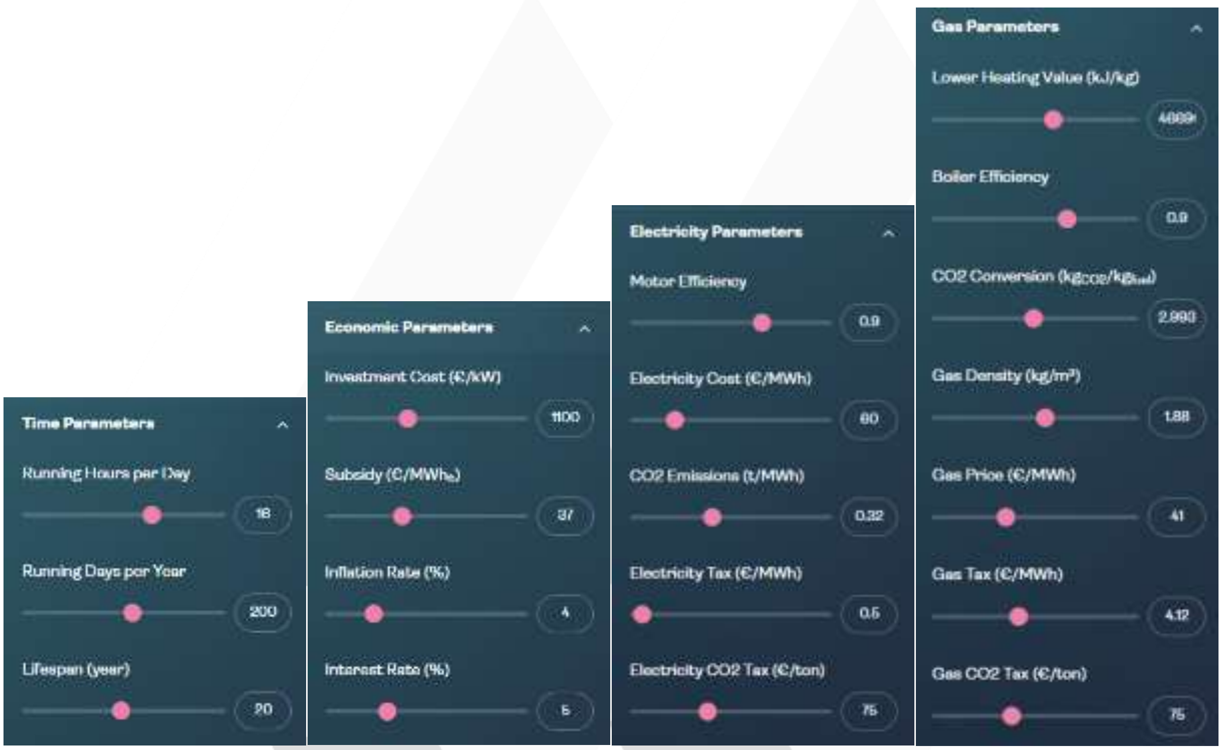


**Figure 18 – Input parameters of the business analysis.**

The tool starts from the defined heat pump configuration and combines it with standard values for electricity prices, gas boiler efficiency, and gas prices. These defaults make it possible to quickly obtain a first assessment. However, users can easily replace them with more precise or site-specific data to better reflect their own situation.

With these inputs, the tool calculates the performance of the heat pump and the associated electricity consumption, taking into account operating hours. It then derives the most relevant economic indicators, such as investment costs, operating expenses, and the expected return on investment. At the same time, the system is compared to a conventional gas boiler, allowing the user to see not only the cost differences but also the reduction in $CO_2$ emissions achieved by switching to a heat pump.


**Figure 19 - Overview of the business analysis tool output and input.**

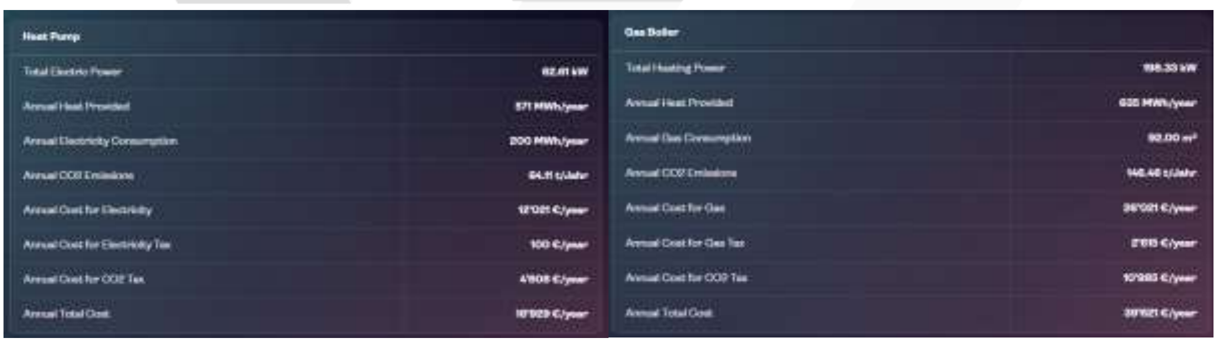


**Figure 20 – Advanced outputs of the business analysis.**

The results are clearly displayed in a table, where the user finds all relevant values at a glance — from efficiency and energy use to costs, payback period, and emission savings. This structured overview makes it straightforward to compare scenarios and supports transparent decision-making.

Funded by the European Union

Together, the three tools create a coherent workflow that guides the user from identifying energy-saving potential, through designing a suitable heat pump, to evaluating its economic and environmental benefits.

Funded by the European Union