SUPPORT DHC

Tool for the Techno-Economic Analysis of Integrating Data Centre Waste Heat into District Heating

- User Manual -

User Manual:

Tool for Techno-Economic Analysis (TEA) of Integrating Data Centre Waste Heat into District Heating

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Version 1.0

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This tool is intended for purposes such as research and support in estimating costs and benefits of integrating waste heat in district heating. Feedback is highly appreciated.

The authors accept no responsibility for the topicality, accuracy, completeness or quality of the tool in general, or the results in particular.

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List of Abbreviations

°C	Degree Celsius
CAPEX	Capital Expenditures
CHP	Combined Heat and Power
COP	Coefficient of Performance
CRF	Capital Recovery Factor
DC	Data Centre
DH	District Heating
DN	Diameter Nominal (standard nominal pipe diameter designation)
EoL	End-of-life
EU	European Union
EUR	Euro
HEx	Heat Exchanger
IRR	Internal Rate of Return
KPI	Key Performance Indicator
LCOH	Levelised Cost of Heat
m	Meter
MW	Megawatt
MWh	Megawatt-hour
NPV	Net Present Value
OPEX	Operational Expenditures
O&M	Operation & Maintenance
SCOP	Seasonal Coefficient of Performance
SRMC	Short-run Marginal Cost
WACC	Weighted Average Cost of Capital
WH	Waste Heat
Yr	Year

Executive Summary

The integration of waste heat from data centres and other industrial sources into district heating systems is increasingly recognised as an important opportunity to improve energy efficiency, reduce greenhouse gas emissions, and support the transition to sustainable heating systems. However, determining the economic value of waste heat and establishing economically viable contractual arrangements between waste heat providers and district heating operators can be complex, as both parties have fundamentally different economic perspectives.

From an economic point of view, district heating operators will only use waste heat if it is cheaper than existing alternatives. Depending on electricity prices and on the mix of other heat sources already in operation, such as gas boilers or combined heat and power plants, this may apply to only a fraction of the available hours. Data centre operators, in turn, justify their investment through avoided cooling costs and, where applicable, earnings from heat sales. Avoided cooling costs alone often cover a substantial share of the business case. Therefore, the central question in any such project is not whether waste heat integration is technically possible, but whether a price can be agreed that makes the project viable for both parties simultaneously.

This tool was developed to answer exactly this question. It evaluates the project explicitly from the perspective of both parties involved: the district heating operator (referred to throughout this manual and the tool as contractor 1) and the data centre operator (referred to as contractor 2). It calculates each contractor's internal rate of return (IRR) and break-even heat price separately, reflecting their different cost structures, risk profiles, and return expectations.

By comparing the negotiated heat price with the calculated break-even prices and the resulting IRRs, the tool identifies whether a mutually beneficial contractual solution exists. It can therefore be used jointly by both contracting parties to transparently evaluate different prices, contract types, and cost-sharing arrangements and to identify economically viable solutions.

In practice, the user enters technical and economic parameters for the project (such as heat pump, booster, and piping specifications, investment and operating costs) and defines a set of representative typical days that capture seasonal variation in heat demand, waste heat availability, and energy prices. These are combined into a typical year, from which the tool derives annual energy flows and the economic indicators described above. The user can then test different contract types, negotiated prices, and cost-sharing arrangements to see how they affect viability for each party.

The results are driven primarily by a small number of key parameters: the short-run marginal cost of alternative heat production, electricity prices, temperature levels affecting heat pump performance, and the availability of waste heat. The tool is designed as a screening and decision-support instrument, not a detailed engineering simulation. It runs entirely in Microsoft Excel and requires no specialised modelling software, allowing project stakeholders to explore different configurations and identify key economic drivers at an early stage of project development.

This user manual accompanies the tool and explains the structure of the workbook, the required input parameters, the calculation logic, and the interpretation of results, to help users apply the tool effectively from a first exploratory run through to a project-specific assessment.

1 Introduction and Motivation

Data centres generate large amounts of waste heat as a by-product of their cooling systems. In most cases, this heat is simply released into the environment, even though nearby district heating networks could use it as a competitive, low-emission heat source. Integrating data centre waste heat into district heating can benefit both parties: the **data centre operator** can generate earnings from waste heat sales while reducing active cooling costs, whereas the **district heating operator** gains access to a competitive, low-emission heat source that can replace more expensive conventional heat generation. Throughout this manual, the district heating operator is referred to as contractor 1 and the data centre operator as contractor 2.

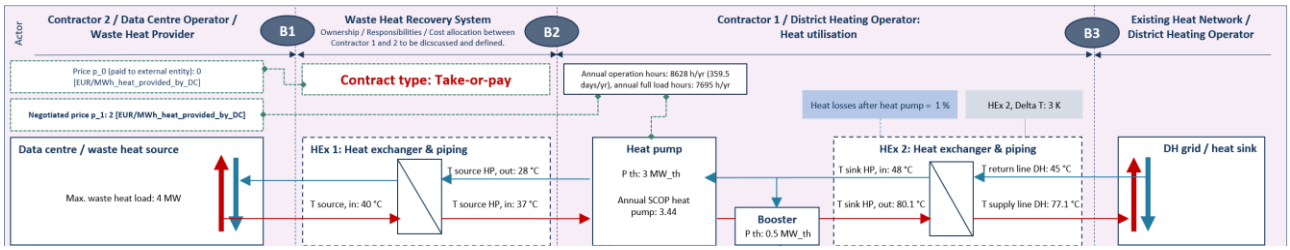


Figure 1. Overview of system borders and system components

Contractor 1 (Figure 1, B2 – B3) is responsible for integrating the waste heat into the existing district heating network. This includes the heat pump, booster system, heat exchanger 2, and the piping within its exclusive responsibility needed to raise the waste heat to district heating temperatures. Heat exchanger 1 and the connecting piping that extracts the waste heat from the data centre are shared infrastructure, with costs negotiable between both contractors (Figure 1, B1 – B2) . **Contractor 2** makes waste heat available to contractor 1 (Figure 1, left of B1). In addition to receiving p_1 for each MWh provided, contractor 2 also saves electricity that would otherwise be needed for active cooling, an important second revenue stream.

Despite these mutual benefits, making the project economically viable for both parties simultaneously requires careful analysis. Both contractors have different cost structures, different risk profiles, and different return expectations. The two contractors also follow different economic objectives: contractor 1 seeks to minimise system costs and will only utilise waste heat if it is competitive with alternative heat production, whereas contractor 2 seeks to maximise earnings from heat sales and avoided cooling costs. A central negotiation point is the waste heat price p_1 that contractor 1 pays contractor 2 for the waste heat, with the exact payment basis depending on the contract type (see chapter 2). Set too low, and the project is unattractive for contractor 2. Set too high, and it is uneconomical for contractor 1. A mutually beneficial business case exists only if both contractors can achieve their expected IRR at the same negotiated heat price.

To support this analysis, a calculation tool based on Excel has been developed — the **Tool for Techno-Economic Analysis (TEA) of Integrating Data Centre Waste Heat into District Heating**. The tool was designed as both an internal planning instrument and a means of providing direct support for negotiations between district heating and data centre operators. This requirement arose from practical experience: developers of waste heat recovery projects need a simple, transparent and flexible tool with which to test different prices, contract types

and cost-sharing arrangements in real time. This helps both parties to identify and agree on terms that work for them both.

Table 1 summarises the key differences between the two contractors and illustrates how the tool assesses and tracks project viability for each of them. The terms used here are introduced in detail in the subsequent chapters.

Table 1. Comparison of contractor 1 and contractor 2

	Contractor 1 (DH operator)	Contractor 2 (DC operator)
Area of responsibility	Heat utilisation: heat pump, booster, heat exchanger 2, connection to the DH network	Provision of waste heat at the contractual handover point to contractor 1
Main cost component	Typically, bears the larger investment (heat pump, booster, grid-connection)	Typically, a smaller investment, plus a possible share of the shared waste heat recovery infrastructure (heat exchanger 1 and the connecting piping from the data centre)
Main earnings source	Avoided cost of alternative heat production (SRMC)	Payment p_1 from contractor 1, plus avoided cooling costs
Risk exposure	Depends on the volatility of alternative heat production costs and, depending on the contract type, potential exposure to paying for waste heat that is not fully utilised	Avoided cooling costs provide a comparatively stable earnings base; earnings from p_1 depend on the negotiated contract type
Viability criterion	Calculated IRR ≥ expected IRR, and p_1 ≤ contractor 1's break-even price	Calculated IRR ≥ expected IRR, and p_1 ≥ contractor 2's break-even price
Condition for a viable business case	Contractor 2's break-even price is below contractor 1's, opening a negotiating range for p_1	Contractor 1's break-even price is above contractor 2's, opening a negotiating range for p_1
Relevant results sheets	'Calculation Break-Even' (section 6.4), 'Main Results Extended' (section 7.2)	'Main Results – IRR DC Operator' (section 7.1, primary focus), 'Main Results Extended' (section 7.2)

This user manual accompanies the tool and provides guidance for users on how to apply it effectively. It explains the structure of the workbook, the required input parameters, the underlying calculation logic, and the interpretation of results. It is structured to follow the logic of the tool itself. Chapter 2 explains the methodology and the typical-day approach in more detail. Chapter 3 covers the practical aspects of using the workbook, including software requirements and navigation. Chapter 4 describes the system boundaries and the roles of contractor 1 and contractor 2. Chapters 5 to 7 describe the input, calculation, and results sheets. Chapter 8 covers supporting reference sheets. Finally, chapter 9 provides practical guidance on applying the tool to real projects, including the use of the integrated default dataset, the compilation of project-specific input data, and a structured assessment workflow.

2 Approach

This tool supports the techno-economic analysis (TEA) of integrating data centre waste heat into district heating. It was developed within the **"Support DHC"** project, funded by the EU LIFE Programme, and can also be applied to other waste heat sources beyond data centres.

Implemented entirely in Microsoft Excel, the tool does not require specialised modelling software while remaining analytically robust. The underlying methodology captures the key technical and economic characteristics of waste heat integration while avoiding the complexity of detailed hourly simulation and extensive data requirements. Rather than simulating all 8,760 hours of the year individually, the tool represents system operation using a small set of representative typical days (e.g. winter day, summer weekend, maintenance day). Each typical day is defined by hourly profiles of heat availability, heat demand, temperatures, and energy prices (see section 9.2.2 for guidance on compiling typical-day data). The typical days are weighted according to their annual occurrence to form a representative year, from which annual energy flows, costs, and revenues are derived. This approach captures the interaction between heat availability, heat demand, electricity prices, and the existing heat generation portfolio, thereby determining the annual utilisation of waste heat and its economic value.

Two **contract types** are supported. Under a **take-or-pay** contract, contractor 1 pays contractor 2 the negotiated price p_1 for all waste heat made available, regardless of whether it is utilised in the heat pump. This gives contractor 2 greater cash-flow certainty but may result in a lower p_1 to compensate contractor 1 for the risk of paying for heat that may not always be usable. Under a **pay-as-you-go** contract, contractor 1 only pays when waste heat is utilised, which aligns payment with actual system performance and is less risky for contractor 1, but results in lower and less certain earnings for contractor 2 compared to a take-or-pay contract with the same negotiated price p_1. The contract type is selected on the **'Main Results – IRR DC Operator'** sheet (see section 7.1) and is applied consistently throughout all calculations. In addition, the tool allows users to investigate different cost-sharing arrangements for the shared waste heat recovery infrastructure, which is often a key parameter in contract negotiations.

The tool follows a structured workflow (see Figure 2) guiding the user from input definition to the evaluation of economic results. The overall process can be summarised in four main steps. Although presented as a sequential process, practical applications are typically iterative. Users are encouraged to begin with simplified assumptions and refine the inputs as more detailed information becomes available.

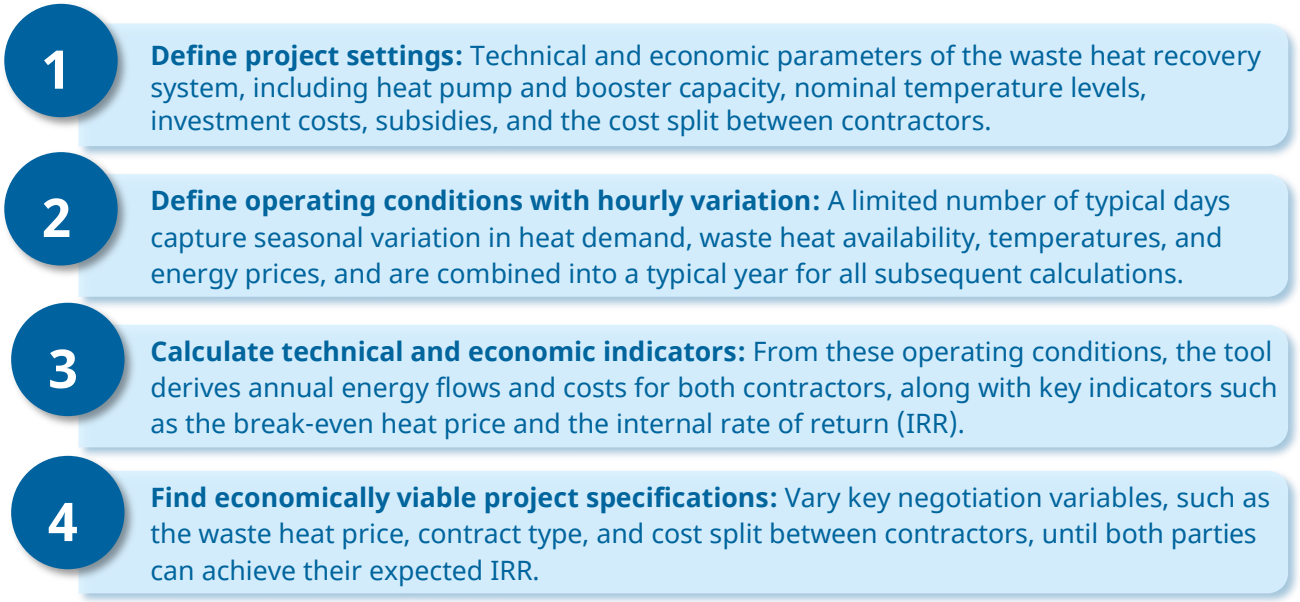


Figure 2. Workflow of the tool

The tool combines technical system parameters (such as temperatures, efficiencies, and capacities) with economic inputs (such as investment and operating costs, energy prices, and subsidies) to derive two primary economic indicators for each contractor: the break-even heat price and the internal rate of return (IRR). The **break-even heat price** is the price per MWh of waste heat at which a contractor exactly achieves its expected IRR: for contractor 2, the minimum price needed to cover all costs; for contractor 1, the maximum price that can still be paid while meeting the expected IRR. The **IRR** represents the effective return on a contractor's investment over the project lifetime and serves as the primary measure of financial viability.

Together, these two indicators define the feasible negotiating range for the **waste heat price p_1** (the underlying calculation variants are described in chapter 6, and the corresponding results sheets in chapter 7) and directly support contract negotiations. To aid their interpretation, the tool also provides the **levelised cost of heat (LCOH)** for contractor 1, useful for benchmarking waste heat against alternative heat sources, and **annual costs and earnings for each contractor**, the detailed economic picture underlying the IRR.

Together, these outputs provide a comprehensive economic basis for decision-making and contract negotiations. The results are particularly sensitive to a limited number of **key parameters**: the short-run marginal cost (SRMC) of alternative heat production, electricity prices, temperature levels affecting heat pump performance, and the availability of waste heat. These parameters should therefore be defined and interpreted with particular care.

3 Getting Started

3.1 Excel Compatibility and Software Requirements

This tool is a Microsoft Excel-based calculator built on standard formulas and structured worksheets. It requires Microsoft Excel 2016 or later (including Excel 2019, Excel 2021, and Microsoft 365 versions) on Windows 10 or later and is fully functional offline without macros or external add-ins. Mac users may use Excel for Mac (2016 or newer), but some formatting or functionality (e.g. charts, drop-downs, conditional formatting) may display differently.

The tool is not compatible with Excel Online or Google Sheets due to limitations in cross-sheet references and certain Excel functions, and functionality may be reduced in versions of Excel prior to 2016.

The tool uses data validation, conditional formatting, and linked sheets for intuitive navigation. To ensure optimal performance, enable editing and enable content if prompted when opening the file.

3.2 How to Navigate the Workbook

Each of the four steps described in chapter 2 corresponds to a group of worksheets in the workbook.

The worksheets supporting the assessment are described below in the order in which they are typically used. For clarity, the worksheet descriptions in this manual follow the logical workflow of using the tool, progressing from input definition and calculations to the interpretation of results. This sequence differs slightly from the workbook layout, where the main result sheets are positioned directly after the input sheets to facilitate interactive scenario analysis.

Each worksheet also includes a 'Go to Content' link to return to this overview.

Input definition

Input information is entered via four sheets, described in detail in chapter 5.

- **Project Setting** is the starting point, where all key techno-economic input data, including heat pump, booster system, and heat recovery setup are defined.
- **Grid Costs** covers the additional infrastructure costs required to connect the data centre to the existing DH network.
- **Definition of Typical Day** is used to define several ‘typical days’ representing different operating conditions throughout the year (such as heat demand & supply, temperature levels and energy prices).
- **Definition of Typical Year** combines these typical days to a ‘typical year’ used for annualised economic and energy performance evaluation.

Calculation

The main calculations are performed on the following sheets, described in chapter 6:

- **Calculation of Typical Day:** computes technical and financial parameters for each hour of each typical day.
- **Calculation of Typical Year:** aggregates the days into a full-year simulation.
- **Calculation IRR:** determines the internal rate of return (IRR) based on investment and operational cash flows over the project lifetime.
- **Calculation Break-Even:** calculates the break-even heat price: the price at which the project would have a net present value of zero using the contractor-specific expected IRR.

Results

The results of the calculations are summarised on four sheets (see chapter 7 for details):

- **Main Results – IRR DC Operator:** serves as the primary user interface for analysing project profitability, focused on contractor 2 (DC operator)**.** It displays and compares key results and performance indicators under different contract types and cost-sharing configurations.
- **Main Results Extended:** displays and compares key results and performance indicators under different contract types and cost-sharing configurations for both contractor 1 and contractor 2. Note that cost sharing cannot be changed on this sheet but must be set on the sheet **'Main Results – IRR DC Operator'**.
- **Calculation Break-Even:** in addition to the calculation, it also presents the break-even results in tabular form alongside annual costs and earnings for both contracting parties.
- **Operation at Typical Day:** is a support sheet that visualises system operation for the defined typical days.

Supporting information

In addition to the workflow sheets, the workbook contains two information sheets and two reference sheets that support the use of the tool, described in chapter 8. At the beginning of the workbook, the **'Info'** sheet provides background information, version details, and disclaimer notes, and the **'Content'** sheet serves as a clickable table of contents linking to every worksheet. At the end, the **'Additional Information'** sheet contains parameter explanations, assumptions, and translations, while **'TechKatalogGWPA'** provides reference data for the available technologies.

3.3 Conventions Used

The tool applies consistent formatting and structuring throughout the workbook to improve usability. 'Go to Content' links (light blue, underlined) allow quick navigation between major sections. Sheet names follow a step-by-step order to guide the workflow. If the user is unsure how to navigate, **'Main Results'** or **'Project Setting'** provide useful orientation points.

All numeric input and output fields are accompanied by **unit labels** (e.g. EUR/yr, MW_th, %). Users should ensure that input values are provided in the specified units to avoid calculation errors.

Both the worksheet tabs and the cells within the worksheets follow a consistent **colour-coding scheme** to improve navigation and distinguish between different functions. The worksheet tab colours indicate the purpose of each sheet (e.g. input, calculation, results, or supporting information), while the cell colours identify different cell types within each worksheet, as summarised in Table 2.

Table 2: Colour-coding conventions used throughout the workbook

Colour / style	Purpose
Header	Section headers and titles
Item / unit	Units and labels (item / unit columns)
User input	These cells are editable fields where the user provides data
Cell with formula	Formula cells – calculated automatically, not intended for editing
Go to Content	Navigation links – jump to other sections or sheets
Input - not used for calculation	Still visible for reference, but excluded from core calculations
Not used anymore: relevant for future works - do not change	Legacy input – not used anymore but kept for future reference; do not modify
Control cells	Highlight possible errors, data inconsistencies, or issues needing attention
Check settings / input data, there might be some error	Critical warning – a potential error has been detected

Some calculated fields and structural elements are **locked** to prevent accidental editing. If a cell cannot be edited, it is either a formula cell or a structural element that should not be changed. Calculation sheets are password-protected. The password can be found on the **'Content'** sheet.

Tooltips or comments are available on many input fields to explain their function or provide guidance. A consistent layout (e.g. same parameter colours, labels, and layout structure) is maintained across all sheets to support intuitive use.

4 System Boundaries

The system analysed in this tool (see Figure 1) is divided into **four sections** by **three boundary lines** (B1, B2 and B3). These boundaries are not arbitrary; each one marks a physical or contractual handover point that determines ownership, payment responsibilities, and the application of the heat price p_1. **B1** indicates where waste heat exits the data centre's standard cooling circuit. Everything to the left of B1 represents contractor 2's existing situation. **B2** represents the contractual handover point between contractor 1 and contractor 2. The heat price p_1 is applied here: under a take-or-pay contract, contractor 1 pays p_1 for all heat made available at B2. Under a pay-as-you-go contract, contractor 1 only pays for heat that is actually utilised (see chapter 2 for a description of both contract types). The contract type is selected on the **'Main Results – IRR DC Operator'** sheet (see section 7.1). **B3** marks the feed-in point to the existing district heating network. Everything to the right of B3 is the existing district heating system, which will not be modified by this project. The four sections defined by these boundaries are described in Table 3 and illustrated in Figure 1, Figure 23 and Figure 27.

Table 3: Overview of system sections defined by boundaries B1, B2, and B3

Section	Responsibility	Content	Economic significance
Left of B1 (data centre or other waste heat source)	Contractor 2 (DC operator)	The data centre and its existing active cooling system, as it would operate without waste heat recovery.	Contractor 2's baseline situation. The electricity saved by not running the active cooling system (avoided costs) becomes a key earnings stream for contractor 2 once the project is running.
B1 – B2 (waste heat recovery system)	Shared between contractor 1 and contractor 2 – cost split is negotiable	Heat exchanger 1 (HEx 1) and connecting piping to extract waste heat from the data centre cooling circuit and deliver it to the heat pump.	The most sensitive area for cost negotiations. The tool allows flexible cost-sharing between contractor 1 and 2 for investment, operational expenses, and variable costs. Changes here directly affect both contractors' IRR and break-even prices.
B2 – B3 (heat utilisation)	Contractor 1 (DH operator) – sole responsibility	Heat pump, booster system, HEx 2 and piping. These components raise the waste heat temperature to DH levels.	Contractor 1's main investment zone, Contractor 1 pays p_1 to contractor 2 at boundary B2 and benefits economically by displacing more expensive alternative heat production in the DH network.
Right of B3 (existing DH network)	Contractor 1 (DH operator)	The existing district heating grid, as it would operate without this project.	Reference point for calculating the value of waste heat to contractor 1: the SRMC of alternative heat production that the waste heat displaces.

The waste heat recovery system serves both contractors' interests. Without it, no waste heat can be transferred. But the costs of building and operating it reduce contractor 2's earnings and, if contractor 1 co-finances it, also increase contractor 1's investment. The tool enables users to evaluate alternative cost-sharing arrangements and immediately assess their impact on the economic performance of both contractors.

5 Input Definition

This chapter describes all input parameters required by the tool. It explains where each parameter is entered, its physical or economic meaning, and how it influences the subsequent calculations. The chapter follows the workflow of the Excel workbook, starting with the main project settings (section 5.1) and continuing with the definition of grid costs (section 5.2) and representative operating conditions (sections 5.3 and 5.4).

5.1 Excel Sheet 'Project Setting'

The '**Project Setting'** sheet is the main input sheet of the tool and serves as the central hub for all key techno-economic project parameters. As shown in Figure 3, it is divided into four sections. Figure 3 is provided for orientation only. The text shown in the figure is not intended to be legible but merely illustrates the overall structure of the worksheet, which is explained step by step in the following sections.

The first two sections contain the technical and economic input data for contractor 1 (DH operator), covering the heat utilisation system between B2 and B3 as well as the corresponding economic settings. The remaining two sections cover the shared waste heat recovery infrastructure (B1 – B2) and the technical and economic input data for contractor 2 (DC operator).

While the total costs of the waste heat recovery system (B1 – B2) are defined in **'Project Setting'**, the split of these costs between the two contractors is set separately on the **'Main Results – IRR DC Operator'** sheet.



Category	Sub-Category	Item	Unit			Description	
HEAT PUMP AND BOOSTER SYSTEM INCLUDING HEAT EXCHANGER AND PIPING TO THE DH GRID (B2 - B3)	Heat pump	All monetary values are expressed in constant prices (e.g. EUR 2025)					
	Technical data	Generating capacity	MW_th	3		Nominal capacity of heat pump (heat output); this value should be based on the available heat from the data Centre (in the sheet "Definition of Typical Day" - Available waste heat (DC heat source)	Link to additional information / German translation
		Technical lifetime	Years	20		The typical lifetime of a water-to-water heat pump is between 15 and 25 years, depending on many factors. Average lifetime can thus be estimated as 20 years.	Link to additional information / German translation
		COP - nominal	[MW / MW]	3		COP at 90°C supply temperature under nominal temperature levels as defined below	Link to additional information / German translation
		Capacity of waste heat stream (MWh) at nominal operation conditions	MW_th_in	2		This is the HP system capacity related to the waste heat stream (waste heat source). This capacity shall be in the order of magnitude of the waste heat energy source or the feed-in capacity of the district heating system.	Link to additional information / German translation
		Nominal temperature - heat pump source in	°C	25		Source-side inlet temperature: The temperature of the heat source fluid before it enters the evaporator. Nominal temperature for the selected heat pump (e.g. from specification sheets of the heat pump). The actual temperature of the waste heat source shall be provided in the sheet >Definition of Typical Day<.	Link to additional information / German translation
		Nominal temperature - heat pump source out	°C	21		Source-side outlet temperature: The temperature of the heat source fluid after it has passed through the evaporator and given up heat to the refrigerant. Nominal temperature for the selected heat pump (e.g. from specification sheets).	Link to additional information / German translation
		Nominal temperature - heat pump sink out	°C	90		Sink-side outlet Temperature: The temperature of the heat sink fluid after it has passed through the condenser and absorbed heat from the refrigerant. Nominal temperature for the selected heat pump (e.g. from specification sheets). The actual temperature of the heat sink (e.g. district heating network supply line temperature) shall be provided in the sheet >Definition of Typical Day<.	Link to additional information / German translation
		HEx 2: Heat exchanger (HP - district heating network) delta T	K	3		Temperature drop that occurs due to losses in the heat exchanger and heat pipe between the Heat Pump and the DH network.	Link to additional information / German translation
		HEx 1: Heat exchanger (HP - data centre cooling system) delta T	K	3		Temperature drop that occurs due to losses in the heat exchanger and heat pipe between the Heat Pump and the Data Centre Cooling System.	Link to additional information / German translation
		Nominal Temperature - Heat Pump Sink In	°C	60		Sink-side inlet Temperature: The temperature of the heat sink fluid before it enters the condenser. Nominal temperature for the selected heat pump (e.g. from specification sheets). The actual temperature of the heat sink (e.g. district heating network return line temperature) shall be provided in the sheet >Definition of Typical Day<.	Link to additional information / German translation
		Upper temperature limit - Heat pump Sink Out	°C	95		If the heat pump sink temperature (district heating supply line temperature + delta T of HEx 2) exceed this limit, then the remaining temperature needs to be provided by the booster.	Link to additional information / German translation
		Exponent for capacity drop if temperature spread of sink decreases		50%		Quantifies how sensitively the heat pump's heating capacity decreases when the temperature spread on the sink side (i.e. between sink outlet and inlet) becomes smaller. A higher exponent indicates a stronger reduction in capacity for small temperature spreads. If zero, than no impact on capacity, if 1 then a reduction of temperature spread of heat sink reduces the capacity by the same ratio. Set value between 0 and 1.	Link to additional information / German translation
		S - Source	-	0.0200	Check impact of settings on COP	Increase of COP per increasing degree of Heat Source in temperature as compared to 25°C. The impact of the settings on COP can be check at the bottom of this sheet.	Link to additional information / German translation
		S - Flow	-	0.0260	Check impact of settings on COP	Decrease of COP per increasing degree of Heat Sink Out temperature (e.g. grid supply line) as compared to 90°C. The impact of the settings on COP can be check at the bottom of this sheet.	Link to additional information / German translation
		S - Return	-	-	Check impact of settings on COP	Increase of COP per increasing degree of Heat Sink in temperature (e.g. grid return line) as compared to 60°C. PLEASE READ ADDITIONAL NOTES	Link to additional information / German translation
		Share of heat loss in heat exchangers & pipes from HP output	%	1		The percentage of thermal energy lost between the heat pump's output and the gridthat lead to reduced heat supplied to the grid as compared to the nominal capacity. This includes losses due to inefficiencies in heat exchangers, as well as thermal losses in piping.	Link to additional information / German translation
	Economic data	Specific investment costs (equipment, installation)	EUR/kW_th	1 500		The specific costs (i.e. expressed per unit of installed capacity) of acquiring and installing the heat pump system. Please be aware that the costs are defined in EUR/kW_th(out)	Link to additional information / German translation
		Investment costs	EUR	4 500 000		The total upfront investment needed for acquiring and installing the heat pump system.	Link to additional information / German translation
		Other one-time expenses	EUR	-		Non-recurring costs that arise during the project but are not directly related to equipment or installation (e.g. site preparation, permits and approvals, engineering or administrative fees) excluding planning as these costs are supposed to be provided below. Enter if applicable.	Link to additional information / German translation
		Total one-time expenses and costs excl. planning costs	EUR	4 500 000		The sum of all upfront costs for the heat pump system except planning-related expenses. It combines investment costs and other one-time expenses.	Link to additional information / German translation
		Regular annual expenses (heat pump specific)	EUR/yr	-		This parameter includes fixed annual expenses related to the operation of the heat pump system, such as personnel, rent, or service contracts—if applicable. It is considered equivalent to the corresponding value for the heat pump (as referenced in cell >O&M Costs - variable (excl. electricity)<), normalized to the pump's installed capacity (3 MW).	Link to additional information / German translation
		O&M Costs - fix	EUR/MW_th/yr	22 000		Operation & Maintenance costs that do not depend on system usage. These may include annual inspections, routine maintenance, and service contracts. Has the same impact as the >Regular annual expenses (heat pump specific)< defined above, but is specified per MW_th (nominal capacity) of the heat pump.	Link to additional information / German translation
		Total operation independent O&M costs related to heat pump: regular annual expenses (heat pump specific) + O&M Costs - fix * nominal capacity of heat pump	EUR/yr	66 000		Refers to the total fixed annual costs needed to keep the heat pump in good working condition, regardless of how much heat it delivers.	Link to additional information / German translation
		O&M Costs - variable (excl. electricity)	EUR/MWh_th	-		These are usage-dependent operational costs, excluding electricity. Examples include replacement of parts due to wear, maintenance that varies with operating hours or load, consumables (e.g., refrigerant top-up). Enter if relevant.	Link to additional information / German translation
		Electricity - grid fee and other electrical capacity-related costs	EUR/kW_electr_HP/yr	250		This are the consumption-independent electricity costs (e.g. grid charge, "LEISTUNGSPREIS" in German) in EUR/kW/yr that come on top of the electricity price (specified in the sheet >Definition of Typical Day<) that need to be paid per yr	Link to additional information / German translation
		Electricity - grid fee and other electrical capacity-related costs	EUR/yr	250 000		These are the annual consumption-independent electricity (grid) costs ("LEISTUNGSPREIS" in German), calculated by Electricity grid fee (cell above) in EUR/MWh times heat pump capacity (MW) / COP_nominal. This means that the grid fee costs are based on the nominal heat pump performance, not the actual worst case power demand (high temperature, low COP) or the actual rated nominal electricity load capacity of the grid connection.	Link to additional information / German translation
		Electricity - grid fee and other electricity consumption-related costs	EUR/MWh_electr_fuel	11		This are the consumption-dependent electricity costs (e.g. grid charge) that come on top of the electricity price (specified in the sheet >Definition of Typical Day<) that need to be paid when the heat pump system is running. To convert from EURCent/kWh, multiply by 10.	Link to additional information / German translation
	Subsidies	S1 (one-time, lump sum per MW)	EUR/kW_th			One-time investment grant per unit of installed capacity according to the 'BEG Zuschüsse', which provides up to 40% to help cover the capital costs of purchasing and installing the heat pump. Please be aware that the costs are defined in EUR/kW_th(out)	Link to additional information / German translation
		S1 total lump sum subsidies	EUR	0		Total one-time investment grant for the heat pump system	Link to additional information / German translation
		S2 (annually) for given number of yrs	EUR/MW_th/yr	-		This considers annual (operation-independent) subsidies for a defined number of year (10 years, as defined in the section: >S2 given for number of years<), for which the subsidies are given. If subsidies are given under a Take-or-Pay premise, then use this variable to specifiy the subsidies instead of S3 below.	Link to additional information / German translation
		S2 given for number of years	Years	10		Number of years, for which the annual (operation-independent) subsidies S2 (defined above) are given.	Link to additional information / German translation
		S2 (annually, discounted), average for calculatory project lifetime	EUR/MW_th/yr	0		This considers annual (operation-independent) subsidies for the entire lifetime of project (15 years, as defined in the section Economic settings below).	Link to additional information / German translation
		S3 (annually, based on supplied waste heat (WH) by DC). PLEASE BE AWARE THAT THIS KIND OF SUBSIDY IS ONLY PROVIDED BY SOME COUNTRIES, E.G. GERMANY	EUR/MWh_th (utilised waste heat, not HP output or electricity input)	-	Calculate approximate value according to German BEW (2026)	This subsidy applies to projects utilising waste heat, often in combination with heat pumps. It is a subsidy per utilized MWh of Waste heat (provided by DC under Take-as-you-go contract, NOT the MWh provided to the district heating network or the heat provided by the heat pump) for a defined lifetime of project (10 years, as defined in the section >S3 given for number of years<).	Link to additional information / German translation
		S3 given for number of years	Years	10		Number of years, for which the annual (operation-dependent) subsidies S3 (defined above) are given.	Link to additional information / German translation
		S3, average for calculatory project lifetime	EUR/MWh_th (utilised waste heat, not HP output or electricity input)	0.0		These subsidies are considered in the project evaluation, but not for the dispatch ("EINSATZPLANUNG" of the heat pump). Subsidy for waste heat utilization.	
		The following heat pump-related subsidies are currently considered: Lump-sum-subsidies: 0 EUR (one-time, lump sum) + capacity related subsidies: 0EUR/MW_th/yr + operation-related subsidies: 0EUR/MWh_th (utilised waste heat, not HP output or electricity input)					Link to additional information / German translation
HEAT PUMP AND BOOSTER SYSTEM INCLUDING HEAT EXCHANGER AND PIPING TO THE DH GRID (B2 - B3)	Booster						
	Technical data	Generating capacity	MW_th	0.5	Under current settings, a booster capacity of up to 0.19 MW is needed to fully utilise the heat.	Thermal output that defines the maximum amount of heat the booster can deliver. In this tool, the booster is used to raise the temperature of the heat pump's sink outlet flow when the required temperature level exceeds what the heat pump alone can provide.	Link to additional information / German translation
		Efficiency	%	99		The conversion efficiency of the booster technology that indicates how effectively it converts input energy (e.g., electricity or fuel) into usable heat. An additional 1% loss is assumed downstream of the booster, similar to the loss factor applied to the heat pump output.	Link to additional information / German translation
	Economic data	Specific investment costs	EUR/kW_th	150		The cost of purchasing and installing the booster system per kilowatt of thermal capacity. Please be aware the costs are defined in EUR/kW_th(out)	Link to additional information / German translation
		Investment costs	EUR	75 000		The total capital expenditure for the booster, including all equipment and installation costs for the full system (not per unit).	Link to additional information / German translation
		Other one-time expenses	EUR	-		Covers all non-recurring project-specific costs, such as site preparation, permitting, and documentation — excluding planning/design costs as they are supposed to be provided below.	Link to additional information / German translation
		Total one-time expenses and costs excl. Planning costs	EUR	75 000		The sum of all initial expenditures, including investment costs and other one-time expenses, but excluding planning costs.	Link to additional information / German translation
		Regular annual expenses (booster specific)	EUR/yr	2 000		General recurring costs such as rent, personnel, or administrative fees directly related to the booster system.	Link to additional information / German translation
		O&M Costs - fix	EUR/MW_th/yr	-		Fixed annual operation & maintenance costs per MW of installed thermal capacity. May include costs like preventive maintenance, inspections, and service contracts. Enter if applicable.	Link to additional information / German translation
		Total operation independent O&M costs related to booster	EUR/yr	2 000		The sum of all fixed annual costs associated with the booster system, independent of its usage.	Link to additional information / German translation
		O&M Costs - Variable	EUR/MWh_th	-		Variable costs per unit of thermal energy delivered. This includes usage-dependent expenses like consumables, wear-related replacements, and performance-based servicing.	Link to additional information / German translation
		Electricity / fuel - grid fee and other capacity-related costs	EUR/kW_electr_HP/yr	250		This are the consumption-independent fuel/electricity costs (e.g. grid charge) that come on top of the electricity/fuel price (specified in the sheet >Definition of Typical Day<) that need to be paid per year	Link to additional information / German translation
		Electricity - grid fee and other electrical capacity-related costs	EUR/yr	126 263		These are annual consumption-inndependent electricity (grid) costs ("LEISTUNGSPREIS" in German), calculated by electricity grid fee (cell above) in EUR/MWh for the Booster. This means that the grid fee costs are based on the booster capacity and performance, not the actual rated nominal electricity load capacity of the grid connection.	Link to additional information / German translation
		Electricity / fuel - grid fee and other consumption-related costs	EUR/MWh_electr_fuel	11		This are the consumption-dependent electricity/fuel costs (e.g. grid charge) that come on top of the electricity/fuel price (specified in the sheet >Definition of Typical Day<) that need to be paid when the booster system is running. To convert from EURCent/kWh, multiply by 10.	Link to additional information / German translation
	Subsidies for booster operation	S1 (one-time, lump sum per MW)	EUR/MW_th	-		If applicable. A one-time financial support granted per installed megawatt of thermal capacity (MW_th) of the heat pump system.	Link to additional information / German translation
	Piping (from DH grid to B2) and heat exchanger (HEx 2)						
		Investment costs in HEx2 (equipment, installation, heat exchangers, one-time, lump-s	EUR	500 000		Investment costs excluding planning cost and excluding subsidies (if applicable). Covers the full cost of installing piping and heat exchangers, including materials and labour, as a one-time payment.	Link to additional information / German translation
		Investment costs for heat network from DH grid to B2 (see >Grid Costs<)	EUR	1 050 000		Investment costs excluding planing cost and excluding subsidies (if applicable). Refers to the capital costs for the heat distribution network (e.g., main and branch pipelines, valves).	Link to additional information / German translation
	Planning costs						
		Planning costs [% total investment costs: Heat pump, booster, heat network, heat exchanger]	%	8.0		Share of the total investment allocated to project planning and engineering (e.g., design, permitting, studies).	Link to additional information / German translation
		Total investment costs (HP, booster, heat network, heat exchanger, etc.)	EUR	6 125 000		Sum of all relevant upfront investments used as the basis for calculating the planning cost share.	Link to additional information / German translation
		Planning costs [absolute]	EUR	490 000		Total planning cost calculated from the percentage share above.	Link to additional information / German translation
	Other OPEX						
		Auxiliary electricity consumption (share of heat gen.)	%	2.0		Proportion of total heat generation requiring auxiliary electricity (e.g., for circulation pumps, control systems).	Link to additional information / German translation
		Personnel	EUR/yr	20 000		Annual personnel costs associated with system operation (if applicable).	Link to additional information / German translation
		Rent	EUR/yr	-		Annual rental costs for land, buildings, or space used by the energy system (if applicable).	Link to additional information / German translation
	Other end-of-the-lifetime CAPEX						
		Demolishment	EUR	-		Specify the decomission costs, that occur at the end of the project lifetime (20 years, as specified in >Decommissioning after how many years<). Leave empty, if these costs shall not be considered.	Link to additional information / German translation
		Residual value of investment at the end of the lifetime	EUR	-		Specify the expected remaining value of the investment at the end of the project lifetime (20 years, as specified in >Decommissioning after how many years<), e.g., resale value or salvaged equipment, if it is to be considered.	Link to additional information / German translation
Contractor 1 / district heating operator	Economic settings						
		Decommissioning after how many years	Years	20		Defines the expected technical or economic end-of-life for the infrastructure (default: 20 years).	Link to additional information / German translation
		Depreciation time of project / calculatory lifetime	Years	15		Number of years over which the investment is financially depreciated in calculations (default: 15 years).	Link to additional information / German translation
		Annual general price increase (e.g. rate of inflation)	%	0		Annual increase in fuel or energy carrier prices in real terms, i.e., beyond inflation (default: 0%).	Link to additional information / German translation
	Project-specific interest rate						
	a) Based on weighted average costs of capital (WACC)					Alternative a) Calculate WACC	
		Average interest rate of loans in real terms (excluding inflation)	%	2.5		Effective borrowing cost after adjusting for inflation (default: 2.5%). While banks provide interest rates in nominal terms, economic calculations often require the real interest rate to accurately assess the true cost of capital over time. E.g. a loan is defined as 6M EURIBOR + 1%. If the 6M EURIBOR is at 4%, the inflation rate at 3%, then interest rate in real terms is defined as 4% + 1% - 3% = 2%	Link to additional information / German translation
		Expected interest rate on equity, again in real terms	%	7.0		Return required by equity investors, inflation-excluded (default: 7.0%). Inflation rate is subtracted like above.	Link to additional information / German translation
		Share of equity capital on total financing	%	20.0		Capital structure of the project (default: 20%).	Link to additional information / German translation
		Corporate tax rate	%	20.0		Tax rate used to calculate WACC after tax (default: 20%).	Link to additional information / German translation
		Weighted average costs of capital (WACC)	%	4.9		Weighted average cost of capital, combining debt and equity financing.	Link to additional information / German translation
	b) Set expected IRR manually					Alternative b) Use company-internal expected IRR for such project.	
		Required (company internal) Rate-of-Return for such project	%			If expected IRR defined, then this variable is used instead of WACC. Please be aware, that expected IRR excluding inflation shall be used.	Link to additional information / German translation
	Rate-of-Return used in the subsequent calculations						
		Rate-of-Return used in the subsequent calculations	%	4.9		expected IRR used for calculation	Link to additional information / German translation
		Capital recovery factor (annuity factor)	1/yr	0.096		Factor used to annualize capital costs based on interest rate and lifetime	Link to additional information / German translation
WASTE HEAT RECOVERY SYSTEM FROM DATA CENTRE (B1 - B2	Investments and running costs						
	Economic Data			Share paid by Contractor 1			
		Investment costs (equipment, installation, heat exchangers, one-time, lump sum)	EUR	500 000	0%	Investment costs excluding planning cost and excluding subsidies (if applicable). Covers the full cost of installing piping and heat exchangers, including materials and labour, as a one-time payment.	Link to additional information / German translation
		Investment costs for heat network (see >Grid Costs<)	EUR	126 000	0%	The investment costs for the necessary heat network, can be defined in the sheet Grid Costs	Link to additional information / German translation
		Total one-time expenses and costs excl. Planing costs	EUR	626 000		Total investment allocated to project planning and engineering (e.g., design, permitting, studies).	Link to additional information / German translation
		Planning costs [% investment costs]	%	8.0		Share of >Total one-time expenses and costs excl. Planing costs<	Link to additional information / German translation
		Planning costs [absolute]	EUR	40 000	0%	Total planning cost calculated from the percentage share above.	Link to additional information / German translation
		Regular annual expenses (WASTE HEAT RECOVERY specific)	EUR/yr	50 000	0%	General recurring costs such as rent, personnel, or administrative fees directly related to the heat recovery.	Link to additional information / German translation
		O&M Costs - Variable (incl. electricity)	EUR/MWh_th	2.0	100%	Variable costs per unit of thermal energy delivered by data centre. Has the same impact as the >Regular annual expenses (waste heat recovery specific)< defined above, but is specified per MWh_th	Link to additional information / German translation
		Heat price (Take-or-Pay) p_0	EUR/MWh_th	0.00	0%	Price p_0is the payment for waste heat from the data Centre to an external third party. This price and accociated costs are not considered as revenues for either Contractor 1 or Contractor 2 / DC operator but are revenues for a third party not within the scope of this tool. Note that these are to be considered costs that occur before considering the necessary investments by the Contractor 2 / DC operator. If a price is defined, then it is considered under Take-or-Pay conditions.	Link to additional information / German translation
	Subsidies			Share received by Contractor 1			
		S1 (one-time, lump sum)	EUR	-	0.0	One-time investment grant, if applicable	Link to additional information / German translation
Contractor 2 / data centre operator	Economic setting						
		Depreciation time of project / Calculatory lifetime	Years	15			Link to additional information / German translation
	Project-specific interest rate						
	a) Based on weighted average costs of capital (WACC)					Alternative a) Calculate WACC	
		Average interest rate of loans in real terms (excluding inflation)	%	2.5		Effective borrowing cost after adjusting for inflation (default: 2.5%). While banks provide interest rates in nominal terms, economic calculations often require the real interest rate to accurately assess the true cost of capital over time. E.g. a loan is defined as 6M EURIBOR + 1%. If the 6M EURIBOR is at 4%, the inflation rate at 3%, then interest rate in real terms is defined as 4% + 1% - 3% = 2%	Link to additional information / German translation
		Expected interest rate on equity, again in real terms	%	7.0		Return required by equity investors, inflation-excluded (default: 7.0%). Inflation rate is subtracted like above.	Link to additional information / German translation
		Share of equity capital on total financing	%	20.0		Capital structure of the project (default: 20%).	Link to additional information / German translation
		Corporate tax rate	%	20.0		Tax rate used to calculate WACC after tax (default: 20%).	Link to additional information / German translation
		Weighted average costs of capital (WACC)	%	4.9		Weighted average cost of capital, combining debt and equity financing.	Link to additional information / German translation
	b) Set expected IRR manually					Alternative b) Use company-internal expected IRR for such project.	
		Required (company internal) Rate-of-Return for such project	%	5.0		If expected IRR is defined, then this variable is used instead of WACC. If empty, than the WACC calculated above is used. Please be aware, that ROI excluding inflation shall be used.	Link to additional information / German translation
	Rate-of-Return used in the subsequent calculations						
		Rate-of-Return used in the subsequent calculations	%	5.0		ROI used for calculation	Link to additional information / German translation
		Capital recovery factor (annuity factor)	1/yr	0.096		Factor used to annualize capital costs based on interest rate and lifetime	Link to additional information / German translation
	Default active cooling system						
		Average weighted annual SCOP of active cooling unit		7.5		This is the average achieved ratio of removed thermal energy-to-electricity, weighted considering different operation conditions. Only for those hours, where active cooling is running and not considering the periods, where free cooling is applied. The ratio between active cooling and free cooling as well as the electricity price is defined in the sheet >Definition fo Typical Day<.	
		Electricity - grid fee	EUR/MWh_electr	11.0		This are the consumption-dependent electricity costs that come on top of the electricity price (specified in the sheet >Definition of Typical Day<) that need to be paid when the active cooling system is running. We do not consider additional capacity-related grid costs. To convert from EURCent/kWh, multiply by 10.	Link to additional information / German translation

CONTRACTOR 1 / DH OPERATOR

CONTRACTOR 2 / DC OPERATOR

Figure 3: Main sections of the 'Project Setting' sheet

5.1.1 Heat Pump and Booster System including Heat Exchanger and Piping to DH Grid for Contractor 1

This section defines the technical and economic input data for the heat utilisation system (between B2 and B3, Figure 1), which is owned by contractor 1. It covers the heat pump, the booster system, heat exchanger 2 (HEx 2), and the associated piping to the district heating network.

Heat pump – technical data:

The heat pump is the central component of contractor 1's system. It upgrades the waste heat received at boundary B2 to the temperature required by the district heating network. The following technical parameters must be specified (Figure 4):

- **Capacity** (MW_th): the installed thermal output of the heat pump
- **Temperature levels** (source / sink): Temperatures at which the heat pump receives heat from the waste heat recovery system (source) and delivers heat to the DH network (sink). These temperatures directly determine the coefficient of performance (COP) and therefore the electricity consumption and operating costs.
- **COP / performance sensitivity**: the COP at nominal conditions and how it varies with temperature. A higher COP reduces electricity consumption per MWh of useful heat produced and therefore improves the project's economic performance.
- **Efficiency losses**: heat losses between the heat pump and the DH feed-in point.

D PIPING TO THE DH GRID (B2 - B3)	Heat pump	All monetary values are expressed in constant prices (e.g. EUR 2025)		
	Technical data			
		Generating capacity	MW_th	3
		Technical lifetime	Years	20
		COP - nominal	[MW / MW]	3
		Capacity of waste heat stream (MWh) at nominal operation conditions	MW_th_in	2
		Nominal temperature - heat pump source in	°C	25
		Nominal temperature - heat pump source out	°C	28
		Nominal temperature - heat pump sink out	°C	90
		HEx 2: Heat exchanger (HP - district heating network) delta T	K	3
		HEx 1: Heat exchanger (HP - data centre cooling system) delta T	K	3
		Nominal Temperature - Heat Pump Sink In	°C	60
		Upper temperature limit - Heat pump Sink Out	°C	95
		Exponent for capacity drop if temperature spread of sink decreases		50%
		S - Source	-	0.0200
		S - Flow	-	0.0260
		S - Return	-	-
		Share of heat loss in heat exchangers & pipes from HP output	%	1

Figure 4: Technical data of the heat pump

At the bottom of the worksheet, users can evaluate how different assumptions regarding the heat pump performance affect the calculated COP under varying operating conditions (see Figure 5): **S - Source, S - Flow, and S - Return**. These describe how strongly the COP responds to a 1°C change in the source inlet temperature, the DH supply line temperature (sink outlet), and the DH return line temperature (sink inlet) respectively. They are empirical parameters derived from heat pump performance data. The default values provided are typical averages for large-scale heat pumps and can be left unchanged unless site-specific performance data from the heat pump manufacturer is available. Increasing S - Flow or reducing S - Source will make the calculated COP more sensitive to seasonal temperature variations, which affects the annual electricity consumption and therefore the break-even price.

Check COP at alternative temperature levels based on settings for S - Source, S - Flow and S - Return			
Alternative heat source in temperature (e.g. DC waste heat temperature)	30	Alternative temperature COP (30°C instead of 25°C)	3.10
Alternative heat sink out temperature (e.g. district heat supply line temperature)	80	Alternative temperature COP (80°C instead of 90°C)	3.26
Alternative heat sink in temperature (e.g. district heat return line temperature)	45	Alternative temperature COP (45°C instead of 60°C)	3.00
Combined effect: Alternative temperature COP (30°C instead of 25°C), (80°C instead of 90°C), (45°C instead of 60°C)			**3.36**

S - Source, S - Flow and S - Return values as defined above		
S - Source	0.020	Go to settings above
S - Flow	0.026	Go to settings above
S - Return	0.000	Go to settings above

Figure 5: Cells to test the assumed COP-sensitivity of the heat pump

Heat pump - economic data:

Only component-specific investment costs are entered here. The tool automatically calculates the total investment based on the installed capacity (see Figure 6). General planning costs and project-wide operating expenses are specified separately in the sections "Planning costs" and "Other OPEX".

Economic data			
	Specific investment costs (equipment, installation)	EUR/kW_th	1 500
	Investment costs	EUR	4 500 000
	Other one-time expenses	EUR	-
	Total one-time expenses and costs excl. planning costs	EUR	4 500 000
	Regular annual expenses (heat pump specific)	EUR/yr	-
	O&M Costs - fix	EUR/MW_th/yr	22 000
	Total operation independent O&M costs related to heat pump: regular annual expenses (heat pump specific) + O&M Costs - fix * nominal capacity of heat pump	EUR/yr	66 000
	O&M Costs - variable (excl. electricity)	EUR/MWh_th	-
	Electricty - grid fee and other electrical capacity-related costs	EUR/kW_electr_HP/yr	250
	Electricty - grid fee and other electrical capacity-related costs	EUR/yr	250 000
	Electricty - grid fee and other electricity consumption-related costs	EUR/MWh_electr_fuel	11

Figure 6: Economic data of the heat pump

Heat pump - subsidies:

Subsidies can significantly change the economics of a project. Three types can be defined for the heat pump (see Figure 7):

- **S1**: One-time lump-sum subsidy, defined in EUR/MW_th and paid independently of the project's operation or lifetime.
- **S2**: Annual capacity-based subsidy in EUR/MW_th/yr, paid over a defined number of years, independent of actual operation. As the tool uses real monetary values, nominal subsidies must be converted to real terms before entry if they are not indexed to inflation.
- **S3:** Operational subsidy per MWh_th paid for utilised waste heat (excluding electricity input to the heat pump and booster energy, and heat losses). The payment period can be specified by the user. As for S2, subsidies must be entered in real monetary terms. Furthermore, the use can specify whether to consider the S3 subsidies in the dispatch as short-run marginal costs or not. In the second case, the decision whether or not the marginal costs of running the heat pump are below the alternative heat production costs, does not consider that this kind of subsidies might lower SMRC of the project and thus might increase the number of hours, for which it is economically viable to run the heat pump.

Subsidies			
S1 (one-time, lump sum per MW)	EUR/kW_th		
S1 total lump sum subsidies	EUR	0	
S2 (annually) for given number of yrs	EUR/MW_th/yr	-	
S2 given for number of years	Years	10	
S2 (annually, discounted), average for calculatory project lifetime	EUR/MW_th/yr	0	
S3 (annually, based on supplied waste heat (WH) by DC). PLEASE BE AWARE THAT THIS KIND OF SUBSIDY IS ONLY PROVIDED BY SOME COUNTRIES, E.G. GERMANY	EUR/MWh_th (utilised waste heat, not HP output or electricity input)	20.0	
S3 given for number of years	Years	10	
S3, average for calculatory project lifetime	EUR/MWh_th (utilised waste heat, not HP output or electricity input)	16.0	
Consider (average) subsidies (S3) in dispatch	1/0	1	

Figure 7: Data on subsidies for the heat pump

For projects in Germany, the tool includes a calculator for the S3 subsidy level according to German law ('Bundesförderung für effiziente Wärmenetze (BEW)', 2026[1]), this can be done using the calculator at the bottom of the sheet (Figure 8). The user enters the relevant Seasonal Coefficient of Performance (SCOP) and receives the corresponding subsidy level to be used. The tool also displays the annual SCOP calculated from the project data as an orientation value. Note that there is no automatic link between this calculated SCOP and the S3 input field; the user must set both the SCOP and the S3 level manually.

1 https://www.bafa.de/DE/Energie/Energieeffizienz/Waermenetze/Effiziente_Waermenetze/effiziente_waermenetze_node.html

Calculated subsidies based on "Bundesförderung für effiziente Wärmenetze (BEW)", Merkblatt Antragstellung, technische Anforderungen und Verwendungsnachweis, v3, 01.01.2026			
This is relevant under German law (BEW) only and thus partly in German			
SCOP, as currently calculated for the project based on this tool (HP_heat_output_per_year /HP_electricity_input_per_year)	-	3.44	
SCOP	**-**	**3.47**	**Dieser Wert muss manuell eingegeben werden**
Wärmepumpen mit allgemeiner Versorgung (§3 Nr. 17EnWG)			
Förderbetrag	Cent/kWh	5.72	
Fördersumme je 1 kWh Strominput	Cent/kWh_Strom	14.14	
Fördersumme je 1 kWh Abwärme	Cent/kWh_Abwärme	5.72	
Fördersumme je 1 MWh Abwärme	**EUR/MWh_Abwärme**	**57.24**	**Dies ist der Wert, der oben manuell (S3) einzusetzen ist; es gibt keine automatische Verknüpfung!**
Wärmepumpen mit Strom aus EE-Erzeugern ohne Durchleitung öffentliches Netz			
Förderbetrag	Cent/kWh	2.33	
Fördersumme je 1 kWh Strominput	Cent/kWh_Strom	8.08	
Fördersumme je 1 kWh Abwärme	Cent/kWh_Abwärme	3.27	
Fördersumme je 1 MWh Abwärme	**EUR/MWh_Abwärme**	**32.72**	**Dies ist der Wert, der oben manuell (S3) einzusetzen ist; es gibt keine automatische Verknüpfung!**

Figure 8: BEW subsidy calculator for S3 based on SCOP

Booster:

The booster is an auxiliary heat source that supplements the heat pump whenever the required district heating supply temperature cannot be achieved by the heat pump alone. This is most common in winter, when DH supply temperatures are highest and the heat pump's temperature lift is at its maximum. As shown in Figure 9, the booster parameters are:

Technical data: The generating capacity (MW_th) and thermal efficiency (%) of the booster are defined here. The user sets the installed capacity; the tool displays the minimum capacity needed under the current settings as an orientation value.

Economic data: Investment costs are entered as a specific cost in EUR/kW_th, from which the absolute value is calculated automatically. Additional one-time expenses, fixed and variable annual O&M costs, and grid fees or other charges for the booster's energy source (electricity or fuel) can also be specified.

Subsidies: Only one-time lump-sum subsidies (S1, in EUR/MW_th) can be defined for the booster.

Booster			
Technical data			
	Generating capacity	MW_th	0.5
	Efficiency	%	99
Economic data			
	Specific investment costs	EUR/kW_th	150
	Investment costs	EUR	75 000
	Other one-time expenses	EUR	-
	Total one-time expenses and costs excl. Planning costs	EUR	75 000
	Regular annual expenses (booster specific)	EUR/yr	2 000
	O&M Costs - fix	EUR/MW_th/yr	-
	Total operation independent O&M costs related to booster	EUR/yr	2 000
	O&M Costs - Variable	EUR/MWh_th	-
	Electricty / fuel - grid fee and other capacity-related costs	EUR/kW_electr_HP/yr	250
	Electricty - grid fee and other electrical capacity-related costs	EUR/yr	126 263
	Electricty / fuel - grid fee and other consumption-related costs	EUR/MWh_electr_fuel	11
Subsidies for booster operation			
	S1 (one-time, lump sum per MW)	EUR/MW_th	-

Figure 9: Techno-economic data for the booster system

Piping and heat exchanger:

To avoid double counting, the investment costs for piping and heat exchangers are distributed across two worksheets according to the system boundaries defined in chapter 4. The investment for the heat exchanger 2 (HEx 2, between the heat pump and the DH network) is defined here (see Figure 10), while piping costs for the network connecting the waste heat source to the existing district heating network are defined on the **'Grid Costs'** sheet, where pipe lengths and unit costs per diameter are specified.

Note that all heat losses and temperature drops in the piping are specified in the heat pump section above, not here. The costs here cover only the physical investment in the components.

Piping (from DH grid to B2) and heat exchanger (HEx 2)			
	Investment costs in HEx2 (equipment, installation, heat exchangers, one-time, lump-s	EUR	500 000
	Investment costs for heat network from DH grid to B2 (see >Grid Costs<)	EUR	1 050 000

Figure 10: Section for the input data on piping and heat exchanger

Planning costs, other OPEX, and end-of-life CAPEX

This section contains project-wide cost items that cannot be assigned to a single component. These include planning costs, general operating expenses and end-of-life costs (see Figure 11). Planning costs are specified as share of the total investment costs, covering the heat pump,

the booster, the heat network and the heat exchangers. Other OPEX includes auxiliary electricity consumption, personnel costs, and site rental. End-of-life CAPEX covers decommissioning costs and/or the residual value of equipment at the end of the project lifetime.

Planning costs			
	Planning costs [% total investment costs: Heat pump, booster, heat network, heat exchanger]	%	8.0
	Total Investment costs (HP, booster, heat network, heat exchanger, etc.)	EUR	6 125 000
	Planning costs [absolute]	EUR	490 000
Other OPEX			
	Auxiliary electricity consumption (share of heat gen.)	%	2.0
	Personnel	EUR/yr	20 000
	Rent	EUR/yr	-
Other end-of-the-lifetime CAPEX			
	Demolishment	EUR	-
	Residual value of investment at the end of the lifetime	EUR	-

Figure 11: Section for the input data on the planning costs, other OPEX and other end-of life time CAPEX

5.1.2 Economic Settings for Contractor 1 (DH Operator)

This section defines the financial assumptions used to evaluate the investment from contractor 1's perspective. These parameters determine the expected IRR against which the project's profitability is assessed.

- **Depreciation time:** The user can define the technical (relevant for decommissioning planning) and economic lifetime (depreciation period used for calculating annualised costs).
- **Project specific interest rate / expected IRR:** The user can either calculate the project-specific interest rate based on weighted average costs of capital (WACC) or enter an expected IRR manually. This value defines the minimum acceptable return for the investment and is subsequently used to assess the project's economic viability.

Note: All economic parameters in the tool are expressed in constant prices (e.g. EUR 2025). It is therefore assumed that all costs and prices increase at the same inflation rate over time, so inflation does not need to be modelled explicitly. Interest rates for loans, however, are typically quoted in nominal terms and must be converted to real terms before entry. Guidance on this conversion is available on the **'Additional Information'** sheet.

Figure 12 shows this input section.

Contractor 1 / district heating operator				
Economic settings				
		Decommissioning after how many years	Years	20
		Depreciation time of project / calculatory lifetime	Years	15
		Energy carrier price increase on top of inflation	%	0
	Project-specific interest rate			
	a) Based on weighted average costs of capital (WACC)			
		Average interest rate of loans in real terms (excluding inflation)	%	2.5
		Expected interest rate on equity, again in real terms	%	7.0
		Share of equity capital on total financing	%	20.0
		Corporate tax rate	%	20.0
		Weighted average costs of capital (WACC)	%	4.9
	b) Set expected IRR manually			
		Required (company internal) Rate-of-Return for such project	%	
	Rate-of-Return used in the subsequent calculations			
		Rate-of-Return used in the subsequent calculations	%	4.9
		Capital recovery factor (annuity factor)	1/yr	0.096

Figure 12: Section for defining the economic settings of contractor 1

5.1.3 Waste Heat Recovery System

This section defines the investment and operating costs of the shared waste heat recovery infrastructure located between B1 and B2 (see Figure 13). These costs will later be split between contractor 1 and contractor 2 on the **'Main Results – IRR DC Operator'** sheet. The inputs are:

- **Infrastructure costs**: Investment costs for the heat exchanger and piping within the heat recovery system at the data centre.
- **Planning costs**: Specified as a percentage of investment or as an absolute value.
- **OPEX**: Personnel, electricity, rent, and any other regular expenses that are directly linked to the waste heat recovery system; defined per year and per MWh_th waste heat delivered.
- **End-of-life parameters** (optional): Decommissioning costs and residual investment value.
- **Subsidies:** Only one-time lump-sum subsidies can be defined for the waste heat recovery system.

WASTE HEAT RECOVERY SYSTEM FROM DATA CENTRE: B1 - B2					
Investments and running costs					
	Economic Data				**Share paid by Contractor 1**
		Investment costs (equipment, installation, heat exchangers, one-time, lump sum)	EUR	500 000	50%
		Investment costs for heat network (see >Grid Costs<)	EUR	126 000	0%
		Total one-time expenses and costs excl. Planing costs	EUR	626 000	
		Planning costs [% Investment costs]	%	8.0	
		Planning costs [absolute]	EUR	40 000	0%
		Regular annual expenses (WASTE HEAT RECOVERY specific)	EUR/yr	50 000	0%
		O&M Costs - Variable (incl. electricity)	EUR/MWh_th	2.0	100%
		Heat price (Take-or-Pay) p_0	EUR/MWh_th	0.00	0%
	Subsidies				**Share received by Contractor 1**
		S1 (one-time, lump sum)	EUR	-	0.0

Figure 13: Section for defining investment and running costs of the waste heat recovery system

5.1.4 Economic Settings for Contractor 2 (DC Operator / WH Provider)

This section defines the financial assumptions used to evaluate the project from the perspective of the data centre operator (contractor 2). The same note on real vs. nominal interest rates applies. Figure 14 shows these input sections.

Contractor 2 / data centre operator	**Economic setting**			
	Depreciation time of project / Calculatory lifetime		Years	15
	Project-specific interest rate			
	a) Based on weighted average costs of capital (WACC)			
		Average interest rate of loans in real terms (excluding inflation)	%	2.5
		Expected interest rate on equity, again in real terms	%	7.0
		Share of equity capital on total financing	%	20.0
		Corporate tax rate	%	20.0
		Weighted average costs of capital (WACC)	%	4.9
	b) Set expected IRR manually			
		Required (company internal) Rate-of-Return for such project	%	5.0
	Rate-of-Return used in the subsequent calculations			
		Rate-of-Return used in the subsequent calculations	%	5.0
		Capital recovery factor (annuity factor)	1/yr	0.096

Figure 14: Section for defining the economic settings of contractor 2

In addition, the user can specify the SCOP of the data centre's default active cooling system (see Figure 15). This value is used to calculate how much electricity contractor 2 saves when its active cooling does not need to operate, because the waste heat is now being delivered to the district heating system instead of being dissipated via the default cooling system. The resulting avoided cooling costs represent an additional economic benefit for contractor 2 and can significantly improve the project's profitability.

	Default active cooling system			
		Average weighted annual SCOP of active cooling unit		7.5
		Electricty - grid fee	EUR/MWh_electr	11.0

Figure 15: Section to define the SCOP of the active cooling system of the data centre

All values entered on this sheet feed into **'Calculation of Typical Day'** and are subsequently used across all calculation and results sheets.

5.2 Excel Sheet 'Grid Costs'

The **'Grid Costs'** worksheet determines the investment costs of the piping infrastructure required to connect the waste heat source to the existing district heating network. It distinguishes between infrastructure owned by contractor 1 and contractor 2 and calculates total investment costs based on user-defined pipe lengths and standard unit costs for different

pipe diameters. These investment costs are subsequently used throughout the economic evaluation.

The user defines the following inputs (see Figure 16):

- **Specific costs per DN size [EUR/m]**: Unit costs for pipe installation, including trenching, works, joints, and materials, depending on the **pipe diameter (DN)**. Larger diameters usually have higher specific costs. The same cost curve applies to both contractor 1 and contractor 2.
- **Pipe segments**: The infrastructure is divided into specific segments based on their function and ownership:
  - From the existing DH network to heat exchanger 2 (i.e. the heat exchanger between DH network and heat pump).
  - Between heat exchanger 2 and heat pump (including piping needed to connect booster).
  - From heat pump to system boundary B2 (i.e. the connection point to the shared waste heat recovery infrastructure).

  This split into three sections is intended to make it easier to estimate the total cost of the piping. It is not necessary to distinguish between these sections, since the total cost of the piping for each contractor is used later on (one number per contractor).

Contractor 1 (district heating operator)								
Dimension (DN)	mm	20	25	32	40	50	65	80
Specific cost (including pipe works and joints)	EUR/m	760	800	856	920	1000	1120	1240
Trench / pipe length per DN (Ensure that consistent use of either trench or pipe length is used)								
Pipe length existing DH network (B3) to heat exchanger 2 (HEx 2), if applicable	m							
Pipe length heat exchanger 2 to heat pump including piping needed to connect booster (if applicable)	m							
Pipe length from heat pump to system boundary B2	m							
Total pipe length within system boundary: Contractor 1	m	-	-	-	-	-	-	-
Investment costs for network invested by Contractor 1	EUR	-	-	-	-	-	-	-
Contractor 2 (data centre operator)								
Dimension (DN)	mm	20	25	32	40	50	65	80
Specific cost (including pipe works and joints)	EUR/m	760	800	856	920	1000	1120	1240
Trench / pipe length per DN (Ensure consistent use of either trench or pipe length)								
Total pipe length from within system boundary B2 to system boundary B1 (existing waste heat source): Contrator 2 / data centre operator	m							
Investment costs for network invested by Contrator 2 / Datacenter operator	EUR	-	-	-	-	-	-	-

Figure 16: Section for defining costs of pipes used in the waste heat recovery system as well as to connect the waste heat facility with the existing district heating system

Total investment costs for the piping are automatically calculated based on the entered specific cost and length for each pipe segment. The results are visualised in the charts (see Figure 17). For both contractor 1 and contractor 2, the specific cost curve by pipe diameter and total investment costs per DN size are displayed. For contractor 1, an additional chart shows the investment breakdown across the three connection segments; this chart is not shown for contractor 2, as the recovery system on that side comprises only a single connection segment.

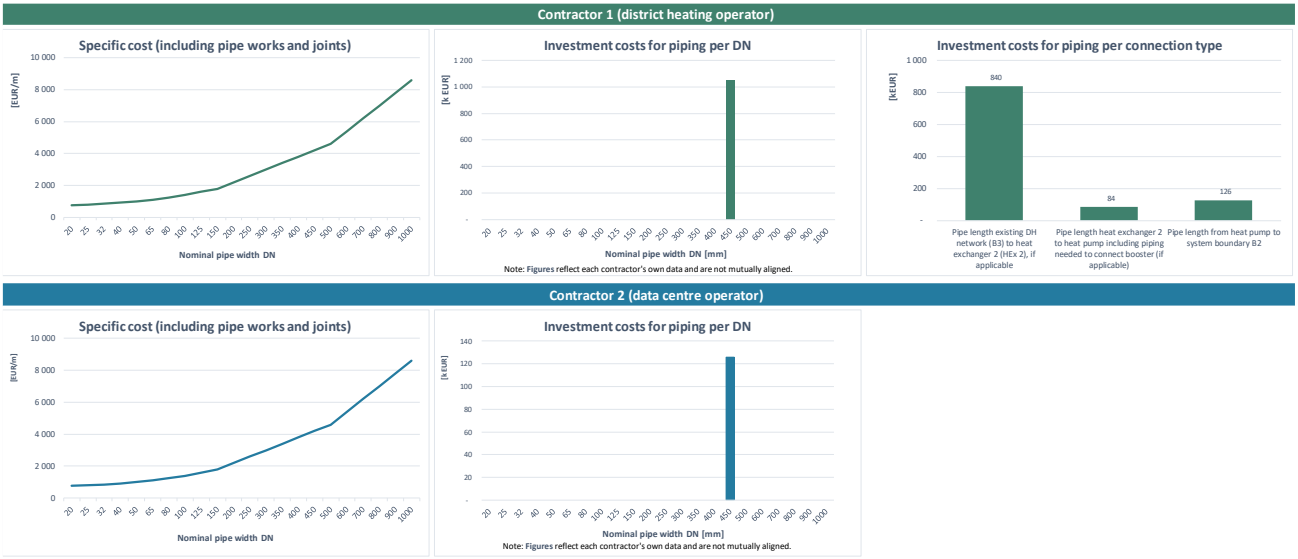


Figure 17: Figures to visualise the data inserted and used to specify the grid costs of the project

The values entered on this sheet feed into the cost-related sections of **'Project Setting'** and are subsequently used in **'Calculation of Typical Year'**, **'Calculation Break-Even'**, and the other calculation and results sheets.

5.3 Excel Sheet 'Definition of Typical Day'

To efficiently simulate annual system operation, the tool represents the year by a limited number of representative typical days instead of modelling every day individually. Each typical day represents a group of days with similar heat demand, waste heat availability, district heating temperatures, energy prices and active cooling operation. The weighted combination of these typical days forms the typical year used for all subsequent technical and economic calculations (see section 5.4).

The workbook provides predefined data for six typical day categories (see

Table 4) and supports up to 20 typical days in total. Users can modify the predefined days to serve their needs as well as define further (up to additional 14) typical days in columns K to X by entering a name and the corresponding hourly profiles for all ten input parameters. These additional typical days are automatically available on the **'Definition of Typical Year'** sheet, where only their annual weighting has to be specified.

Table 4: Predefined typical days in the tool

No.	Name	Season	Description
1	Winter day	Winter	High demand, low waste heat, heat pump requires backup from booster
2	Spring / fall weekday	Spring / fall	Moderate demand, moderate waste heat availability
3	Spring / fall weekend	Spring / fall	Similar to weekday but with reduced demand
4	Summer weekday	Summer	Low district heating demand, waste heat available
5	Summer weekend	Summer	Similar to weekday but with even lower demand
6	Maintenance	Any	No heat pump operation (planned maintenance or zero demand scenario)

Each typical day includes a **qualitative description** and a season label to guide the user (see Figure 18).

Typical day	1	2	3	4
Name of typical day	**Winter day**	**Spring / fall weekday**	**Spring / fall weekend**	**Summer**
Season of typical day	Winter	Spring / Fall	Spring / Fall	Summer
	The amount of waste heat is significantly lower than the heat demand. The grid supply temperature is higher than the maximum heat pump temperature, so additional heating via direct electric heating is required.	On a typical fall weekday, the amount of waste heat is clearly lower than the demand in the existing network. Supply temperatures are not very high yet.	Similar to the weekday scenario – on a fall weekend, the amount of waste heat remains lower than demand, and supply temperatures are still not very high.	On a summer weekd temperature is lowe available waste hea
Outside Temperature				
Available waste heat	High	Moderate	Moderate	
Waste heat higher than demand	No	No	No	
Waste heat temperature	Constant	Constant	Constant	Cons
Grid temperature	High	Medium	Medium	Lo
HP outage / maintenance	No	No	No	N

Figure 18: Qualitative description of the typical days to ease the use of the sheet

For each of the defined 'typical days', the user needs to specify an **hourly profile** for the following parameters:

- **Available waste heat** (DC heat source): The maximum thermal output that the data centre's cooling system can deliver to the heat exchanger in a given hour. The actual amount utilised may be lower if heat demand or heat pump capacity is the limiting factor.
- **Max heat demand - grid** (heat pump heat sink): The upper limit of the amount of heat that can be fed into the DH grid in each hour, representing the network's absorption capacity. If the available waste heat always falls below the demand, this parameter will rarely be binding. However, if the network is sometimes saturated, it will limit utilisation.
- **Heat source temperature (DC)** / temperature of the cooling system before HEx 1: The temperature of the data centre's cooling water at the inlet of HEx 1. After the temperature drop across HEx 1, the heat enters the heat pump at a lower temperature on the source

side. The higher this temperature, the smaller the temperature lift the heat pump must achieve, and therefore the higher the COP and the lower the electricity consumption per MWh delivered.

- **DH supply line temperature**: Temperature at the DH feed-in point, equal to the heat pump sink out minus the temperature drop between the heat pump sink out temperature and the feed-in point DH network (delta T heat exchanger).
- **DH return line temperature**: Temperature of the water returning from the DH network to the heat pump, equal to the heat pump sink in temperature minus the temperature drop between the heat pump sink in and the return point of the DH network (delta T heat exchanger).
- **Short-run marginal cost** (SRMC) of alternative heat production: The variable cost of producing an additional MWh from the existing DH system, which is primarily made up of fuel, variable O&M and CO_2 costs. This is the economic threshold for dispatch: waste heat is only utilised when its marginal cost falls below the SRMC, regardless of the selected contract type. It also determines the economic value of the project: the difference between the SRMC and the full annualised cost of waste heat utilisation, including investment costs, represents the potential gain that can be shared between contractor 1 and contractor 2 through the negotiated price p_1. Using a seasonal profile rather than a single annual average is particularly important for the SRMC, as illustrated in section 9.2.3.
- **Data centre operator's share of active cooling** (if heat is not taken up by contractor 1): The fraction of the DC's active cooling that operates when waste heat is not utilised. A value of 1.0 means that active cooling runs fully whenever waste heat is not utilised. This determines the avoided cooling costs, which represent an earnings component for contractor 2.
- **Electricity price heat pump**: The marginal procurement cost of electricity for the heat pump. In markets with time-variable pricing, using hourly values significantly improves accuracy.
- **Energy price for energy used by the booster system**: The cost per MWh of energy input to the booster, matching the booster's fuel type. If the booster is not activated on an average day, this parameter has no effect.
- **Data centre operator's electricity price for the active cooling system**: The cost of procuring electricity for the DC's active cooling system, which is used to calculate the avoided cooling cost for contractor 2. This may differ from the heat pump electricity price if the DC and DH operator procure electricity under different contracts.

For the electricity and energy price parameters above (heat pump, booster, and active cooling), grid fees can alternatively be entered separately on 'Project Setting'. Ensure that fees are not double-counted by including them in only one of the two locations. For the booster and active cooling prices, also ensure that the corresponding efficiency values defined on 'Project Setting' (booster efficiency, active cooling SCOP) are set consistently.



Figure 19: Examples of hourly input visualisation charts in the 'Definition of Typical Day' sheet

It is important to note that the tool calculates a steady-state solution for every hour of each representative day. It does not consider interdependencies between different hours or dynamic effects, such as ramp-up and ramp-down constraints, or limits on permitted daily start-ups and shut-downs. Therefore, the hours do not need to be in chronological order and can be sampled using alternative methods. However, the input data would be easier to read if they represented typical days in chronological order.

5.4 Excel Sheet 'Definition of Typical Year'

The **'Definition of Typical Year'** worksheet scales the results of the representative typical days up to an annual operating year. By assigning a weighting factor to each typical day, the tool derives annual technical and economic results while maintaining a computationally efficient modelling approach (see Figure 20).

Typical days	Name of typical day	Weight of typical day	Days of Typical Day in Typical Year
-		%	days
	Labels each characteristic day (e.g. Winter day, Summer weekend)	Relative share of typical day in analysed typical year. Shares will be scaled automatically to 100% (365 days per year), if total sum of shares don't sum up to 100%	Number of days that each typical day represents across the entire year
1	Winter day	**25.0**	95
2	Spring / fall weekday	**33.5**	127
3	Spring / fall weekend	**13.4**	51
4	Summer weekday	**17.0**	64
5	Summer weekend	**6.8**	26
6	Maintenance of HP	**0.8**	3
7	7	**0**	0
8	8	**0**	0
9	9	**0**	0
10	10	**0**	0
11	11	**0**	0
12	12	**0**	0
13	13	**0**	0
14	14	**0**	0
15	15	**0**	0
16	16	**0**	0
17	17	**0**	0
18	18	**0**	0
19	19	**0**	0
20	TEST Settings	**0**	0
		96.5	**365**

Figure 20: Weighting of typical days to create a typical year

For each typical day, the tool multiplies the daily technical and economic results (drawn from **'Definition of Typical Day'**) by the number of occurrences per year, and sums these across all typical days to produce annual totals. The weighting can be adjusted to reflect site-specific conditions, climate patterns, or energy price profiles. The resulting annual values feed into **'Calculation IRR', 'Calculation Break-Even'**, and the **'Main Results'** sheets. If the entered weighting factors do not sum to 100 %, the tool automatically normalises them.

6 Calculation

The calculation worksheets process the user-defined technical and economic inputs and convert them into hourly, annual, and financial results. The calculations are carried out sequentially, beginning with the simulation of representative typical days, followed by the aggregation to annual values and the subsequent economic evaluation. The worksheets presented in this chapter are calculation sheets only and therefore do not require any user input.

6.1 Excel Sheet 'Calculation of Typical Day'

The **'Calculation of Typical Day'** sheet combines the technical and economic input parameters from the **'Project Setting'** sheet with the hourly operating profiles defined in **'Definition of Typical Day'**. Based on these inputs, the tool simulates the operation of the waste heat recovery system for every hour of each typical day.

The hourly simulation for each typical day accounts for four technical and economic aspects:

- **Temperature levels:** The effective source and sink temperatures are determined from the heat source and DH network temperatures, adjusted for the temperature drops across the heat exchangers (HEx 1 and HEx 2, delta T).
- **COP adjustment:** The heat pump COP is adjusted for the actual source and sink temperatures at each hour, reflecting that efficiency decreases as the required temperature lift increases (e.g. in winter when DH supply temperatures are high).
- **Booster activation:** The booster activates automatically when the heat pump alone cannot reach the required DH supply temperature. Fuel or electricity consumption for the booster is calculated accordingly.
- **Distribution losses** occurring between the heat pump/booster output and the DH feed-in point are subtracted, based on the efficiency values entered in 'Project Setting'.

Waste heat is then dispatched whenever its resulting short-run marginal cost (electricity for heat pump and fuel/electricity for the booster, plus variable O&M for both as well as negotiated price p_1 for the waste if a pay-as-you-go contract is being chosen) is below the SRMC of alternative heat production. If the take-or-pay contract type is chosen, contractor 1 is charged p_1 for all waste heat that is made available in a given hour, whether or not it is utilised. In this case, the waste heat price represents fixed costs that are independent of operation and do not contribute to short-run marginal costs.

In practice operation-dependent subsidies for waste heat utilization (S3) are also part of short-run marginal cost. In this tool, the user can defined in the sheet 'Project Setting' whether or not to include these subsidies in the dispatch decision. Even if they are excluded from the dispatch decision, they will still be calculated correctly for the economic assessment of the project.

These calculations, together with the dispatch decision, produce the following outputs for each simulated hour:

- **Energy flows:** Waste heat utilised, electricity and fuel consumption, and heat delivered to the district heating network after accounting for distribution losses.

- **Operating costs and avoided costs:** The operating costs of the heat pump and booster are compared with the avoided costs of conventional heat generation. The difference represents the economic benefit of waste heat utilisation for contractor 1.
- **Avoided cooling costs for contractor 2:** The electricity savings from not running the active cooling system in hours when waste heat is utilised. This is contractor 2's second earnings stream alongside the heat sale payment p_1.
- **Subsidies received:** Any usage-linked subsidies (S3) applicable to the heat utilised in that hour.

These hourly values are the building blocks from which all annual results are derived in the **'Calculation of Typical Year'** sheet.

6.2 Excel Sheet 'Calculation of Typical Year'

The **'Calculation of Typical Year'** sheet converts the results of the representative typical days into annual values. For each typical day, the calculated hourly results are multiplied by the corresponding annual weighting factor defined in the **'Definition of Typical Year'** sheet. The weighted results are then summed to obtain annual technical and economic indicators.

The annual totals include:

- **Energy flows:** waste heat utilised, heat fed into the DH grid, and electricity and fuel consumed by the heat pump and booster.
- **Costs and earnings:** fixed and variable O&M costs, waste heat payments, subsidies, and avoided alternative heat production costs.
- **SRMC-based values:** the short-run marginal cost of alternative heat production, aggregated across all typical days weighted by their frequency.

These annual values provide the basis for all subsequent financial calculations and result dashboards.

6.3 Excel Sheet 'Calculation IRR'

The **'Calculation IRR'** sheet calculates the **internal rate of return (IRR),** a key financial performance indicator for assessing whether the investment in the waste heat recovery and the integration into the existing district heating system is economically viable over the project lifetime. It is calculated separately for both contractors, bringing together all annual cash inflows and outflows to determine whether the project achieves a return above the required rate (e.g., WACC or expected IRR).

The **IRR** is the discount rate at which the **net present value (NPV)** of all cash flows (inflows and outflows) equals zero:

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{\mathrm{CF}_t}{(1+\mathrm{IRR})^t} = 0$$

Where:

- NPV: Net present value of the project

- T: Total number of years in the project lifetime
- CF_t: Net cash flow in year t (i.e., revenues – costs)

An **IRR above the expected IRR** indicates a **financially attractive** investment. If the IRR falls below it, the project may not be viable under current assumptions.

The IRR is computed using Excel's IRR() or XIRR() function, applied to annual net cash flows calculated from:

- Investment costs (CAPEX): heat pump, booster, piping, heat exchangers, planning costs, net of subsidies (S1)
- Annual earnings: heat sales to contractor 1 (at price p_1), avoided cooling costs for contractor 2, avoided alternative heat production costs for contractor 1
- Annual costs: fixed and variable O&M, electricity and fuel costs, share of waste heat recovery system costs, net of operational subsidies (S2, S3)
- End-of-life cash flows: decommissioning costs and/or residual equipment value.

The resulting IRR for each contractor is one of the headline KPIs shown on the **'Main Results'** sheets.

6.4 Excel Sheet 'Calculation Break-Even'

Note that the **'Calculation Break-Even'** sheet is described under section 6 (Calculation) because it performs the break-even calculation, but its results are discussed in section 7.3.

The sheet determines various break-even prices for the heat transferred between contractor 2 (DC operator / WH provider) and contractor 1 (DH operator). For both contractors, break-even prices are calculated for different heat streams (e.g. heat provided by DC operator, heat utilised in the heat pump, or heat supplied to the district heating system).

The break-even heat price p_{BE} [EUR/MWh] is defined as the price at which total revenues equal total costs. Because the two contractors occupy opposite roles in the negotiation, this general condition results in two different formulas.

For contractor 1, it represents the maximum price that can be paid while still meeting the expected IRR:

$$p_{BE}(\text{contractor 1}) = \frac{\text{avoided costs} - \text{annual costs, net of subsidies}}{\text{heat stream}}$$

Avoided costs are the SRMC-based costs of the alternative heat production that waste heat displaces. Annual costs comprise contractor 1's own investment and operating costs, net of any subsidies received.

For contractor 2, it represents the minimum price that must be received to meet the expected IRR:

$$p_{BE}(\text{contractor 2}) = \frac{\text{annual costs, net of subsidies} - \text{avoided cooling costs}}{\text{heat stream}}$$

where annual costs comprise contractor 2's own investment and operating costs, net of any subsidies received, and avoided cooling costs are the electricity savings from reduced active cooling.

In both formulas, annual costs include the annualised investment cost, calculated using the **Capital Recovery Factor (CRF).** The CRF converts a one-time investment into an equivalent annual payment over the project lifetime, based on the real interest rate and the depreciation period:

$$\mathrm{CRF} = \frac{\mathrm{i}(1+\mathrm{i})^{\mathrm{n}}}{(1+\mathrm{i})^{\mathrm{n}} - 1}$$

where i is the real interest rate and n is the depreciation period in years. Multiplying the net investment (after subsidies) by the CRF gives the annual capital cost that must be covered by revenues. A higher interest rate or shorter depreciation period increases the CRF and therefore raises the break-even price.

The calculated break-even prices are compared with the negotiated heat price p_1 on the **'Main Results – IRR DC Operator'** sheet. Together, these values indicate whether a mutually beneficial contractual agreement is possible. A comparison of the negotiated price with the break-even price also provides guidance for selecting an appropriate value for p_1. For contractor 2, the relationship can be interpreted as follows:

- **p_1 > pBE** → the project is potentially profitable.
- **p_1 ≈ pBE** → the project is approximately at break-even.
- **p_1 < pBE** → the project is not economically viable unless additional earnings or subsidies compensate for the shortfall or the contractor accepts a lower expected rate of return.

For contractor 1, the interpretation is reversed: the negotiated price p_1 should remain **below** contractor 1's break-even price to satisfy the expected IRR.

A detailed explanation of the break-even prices, their calculation, and the corresponding result sections is provided in section 7.3.

The inputs for the calculations on this sheet are listed in Table 5.

Table 5: Inputs for the calculation of the break-even heat price

Required input	Source sheet	Description
CAPEX	'Project Setting'	Total investment costs
CRF	'Project Setting'	Based on lifetime and discount rate
Energy costs	'Calculation of Typical Year'	Cost of electricity, auxiliary energy
Subsidies	'Project Setting'	Lump sum and per-MWh subsidies
Avoided costs	'Calculation of Typical Year'	Savings from displaced conventional production
Heat delivered	'Calculation of Typical Year'	Total heat fed into DH system

The outputs are used in:

- **'Main Results':** visual comparison of actual vs. break-even price
- Scenario evaluations (e.g., 'take-or-pay' vs. 'pay-as-you-go' contract setting, different settings for the negotiated price p1, different split of investment and running costs for the heat recovery system)

Note: when a **pay-as-you-go contract** assessment is performed, the dispatch and, consequently, the economic outcomes used to derive the break-even heat price **depend on the negotiated heat price p1 used in the calculation**. Therefore, if the negotiated heat price differs significantly from the break-even heat price, the resulting break-even heat price may be inaccurate. In this case, **the calculation should be repeated using a negotiated price p1 that is closer to the break-even heat price obtained**.

7 Results

This chapter explains how to interpret the results generated by the tool. The presented indicators support the assessment of technical performance, economic viability and contractual feasibility from the perspectives of both contractors. As the tool is intended for preliminary project assessment, the results should be interpreted as a techno-economic screening rather than a detailed investment evaluation.

7.1 Excel Sheet 'Main Results - IRR DC Operator'

The **'Main Results – IRR DC Operator'** sheet is the primary dashboard of the tool. It combines the most relevant technical, contractual and economic information required to evaluate the project from contractor 2's perspective and to analyse different contractual scenarios.

The sheet consists of three main sections. At the top, a user-adjustable analysis section (see Figure 21) allows interactive modification of contractual parameters. This is followed by an overview of the technical, contractual and economic input data (Figure 23) and a summary of the calculated economic results (Figure 24).

User-adjustable analysis settings

This section contains parameters that can be modified interactively (light-green cells) to evaluate different contractual scenarios without changing the underlying technical assumptions (see Figure 21):

- **Contract type** (take-or-pay or pay-as-you-go): affects dispatch logic and contractor 2's revenue certainty. See chapter 2 for explanation.
- **Negotiated price p_1** [EUR/MWh_heat_provided_by_DC]: the price contractor 1 pays contractor 2 for waste heat. The central negotiation variable. Increasing p_1 improves contractor 2's IRR but worsens contractor 1's economics, and vice versa.
- **Cost shares for the waste heat recovery system**: the fraction of investment costs, operational expenses, and variable costs borne by contractor 1 and contractor 2 respectively. Shifting costs from contractor 1 to contractor 2 reduces contractor 2's required break-even price, potentially making a lower p_1 viable for both parties.

The **yellow cells** are calculated automatically based on the selected input parameters and the technical results from the previous worksheets. They cannot be edited directly and include:

- investment costs and subsidies;
- annual operation and maintenance (O&M) costs;
- the allocation of costs between contractor 1 and contractor 2;
- total annual expenses, earnings, and electricity cost savings;
- the internal rate of return (IRR) for contractor 2; and
- the break-even prices for waste heat supplied by the data centre and utilised by the heat pump.

Whenever any user-adjustable parameter is modified, all calculated values are updated automatically. This enables rapid sensitivity analyses and allows users to evaluate how contractual conditions, investment allocations, and negotiated prices influence the economic performance of the waste heat recovery project.

To quickly assess the current scenario, the summary boxes at the bottom of the section highlight three key performance indicators (see Figure 21 and Figure 22):

- Contractor 2's **gross annual earnings** from waste heat sales, calculated using the negotiated waste heat price (p_1);
- Contractor 2's **annual savings in electricity costs** resulting from reduced demand for active cooling at the data centre;
- Contractor 2's **internal rate of return (IRR)**, which provides an overall measure of the project's financial attractiveness from the data centre operator's perspective.

Economics of waste heat recovery system (B1 - B2)

Contract type between Contractor 1 and Contractor 2	Take-or-pay	1	Select contract type: waste heat sold by DC based on (1) Take-or-pay contract or (2) Pay-as-you-go (utilisied heat)
Negotiated energy price p_1	[EUR/MWh_heat_provided_by_DC]	-1.00	Price p_1 for waste heat from DC between Contractor 1 / DH operator and Contractor 2 / DC operator. These are costs for Contractor 1 / DH operator and revenues for Contractor 2 / DC operator.
Energy price p_0 paid to external entity	Take-or-pay [EUR/MWh_waste_heat_provided]	0.00	Price p_0 represents the payment for waste heat from the data centre to an external third party. This cost is not considered as revenue for either Contractor 1 or Contractor 2 / DH operator price

Total investment			Share paid by Contractor 1
Investment costs: equipment, installation, heat exchang	EUR	500 000	50%
Heat network	EUR	126 000	0%
Planning	EUR	40 000	0%
Total	EUR	666 000	

Annual operation independent O&M expenses			Share paid by Contractor 1
Regular annual expenses	EUR/yr	50 000	0%
Cost for waste heat p_0 (Take-or-pay contract)	EUR/yr	0	0%
Total annual operation independent expenses	EUR/yr	50 000	

CAPEX investment subsidies			Share received by Contractor 1
Total subsidies	EUR	0	0%
Total	EUR	0	

Annual variable costs			Share paid by Contractor 1
Variable O&M costs per year	EUR/yr	32 762	100%
Total annual operation dependent expenses	EUR/yr	32 762	

Costs paid by Contractor 2 / DC operator			Share	Total costs
Investments	EUR	416 000	62%	666 000
Annual operation independent O&M expenses	EUR/yr	50 000	100%	50 000
Annual variable costs	EUR/yr	0	0%	32 762

Costs paid by Contractor 1 / DH operator			Share
	EUR	250 000	38%
	EUR/yr	0	0%
	EUR/yr	32 762	100%

Total annual expenses (excluding annualised investments)	**EUR/yr**	**50 000**
Annual earnings (under negotiated price p_1)	**EUR/yr**	**-17 384**
Annual reduced electricty costs for active cooling	**EUR/yr**	**121 446**

IRR of Contractor 2 / DC Operator	**9.8 %**
Considering a underlying lifetime of 15 year for Contractor 2 / DC Operator	
Break-even price for Contractor 2 / DC Operator	Break-even price for waste heat supplied by DC: -1.82 EUR/MWh_provided_by_DC Break-even price for waste heat utlilised by HP: -1.93 EUR/MWh_utilized_by_HP

Contractor 2's gross earnings due to heat sold to contractor 1: -17.4 kEUR/yr

Contractor 2's avoided electricity costs for active cooling due to heat sold to contractor 1: 121.4 kEUR/yr

Contractor 2's Internal rate of return: 9.8 % per year (considering calculatory life time of 15 years)

Figure 21: Economic parameters of the waste heat recovery system

This sheet does not show contractor 1's full economic results. For a side-by-side view of both contractors, use the **'Main Results Extended'** sheet. However, if the expected IRR of contractor 1 (as defined in the **'Project Setting'**) is not met, a red flag appears in two positions that notifies the user (see Figure 22).

Economics of waste heat recovery system (B1 - B2)

Contract type between Contractor 1 and Contractor 2	Take-or-pay	1	Select contract type: waste heat sold by DC based on (1) Take-or-pay contract or (2) Pay-as-you-go (utilisied heat)
Negotiated energy price p_1	[EUR/MWh_heat_provided_by_DC]	2.00	Price p_1 for waste heat from DC between Contractor 1 / DH operator and Contractor 2 / DC operator. These are costs for Contractor 1 / DH operator and revenues for Contractor 2 / DC operator.
Energy price p_0 paid to external entity	Take-or-pay [EUR/MWh_waste_heat_provided]	0.00	Price p_0 represents the payment for waste heat from the data centre to an external third party. This cost is not considered as revenue for either Contractor 1 or Contractor 2 / DH operator price

Expected IRR of Contractor 1 / DH operator cannot be met

Total investment			Share paid by Contractor 1
Investment costs: equipment, installation, heat exchangers	EUR	500 000	0%
Heat network	EUR	126 000	0%
Planning	EUR	40 000	0%
Total	EUR	666 000	

Annual operation independent O&M expenses			Share paid by Contractor 1
Regular annual expenses	EUR/yr	50 000	0%
Cost for waste heat p_0 (Take-or-pay contract)	EUR/yr	0	0%
Total annual operation independent expenses	EUR/yr	50 000	

CAPEX investment subsidies			Share received by Contractor 1
Total subsidies	EUR	0	0%
Total	EUR	0	

Annual variable costs			Share paid by Contractor 1
Variable O&M costs per year	EUR/yr	32 762	100%
Total annual operation dependent expenses	EUR/yr	32 762	

Costs paid by Contractor 2 / DC operator			Share	Total costs
Investments	EUR	666 000	100%	666 000
Annual operation independent O&M expenses	EUR/yr	50 000	100%	50 000
Annual variable costs	EUR/yr	0	0%	32 762

Costs paid by Contractor 1 / DH operator			Share
	EUR	0	0%
	EUR/yr	0	0%
	EUR/yr	32 762	100%

Total annual expenses (excluding annualised investments)	**EUR/yr**	**50 000**
Annual earnings (under negotiated price p_1)	**EUR/yr**	**34 768**
Annual reduced electricty costs for active cooling	**EUR/yr**	**121 446**

Expected IRR of Contractor 1 / DH operator is not met.

IRR of Contractor 2 / DC Operator	13.59 %
Considering a underlying lifetime of 15 year for Contractor 2 / DC Operator	
Break-even price for Contractor 2 / DC Operator	Break-even price for waste heat supplied by DC: -0.45 EUR/MWh_provided_by_DC Break-even price for waste heat utlilised by HP: -0.48 EUR/MWh_utilized_by_HP

Contractor 2's gross earnings due to heat sold to contractor 1: 34.8 kEUR/yr

Contractor 2's avoided electricity costs for active cooling due to heat sold to contractor 1: 121.4 kEUR/yr

Contractor 2's Internal rate of return: 13.59 % per year (considering calculatory life time of 15 years)

Figure 22: Economics of the waste heat recovery system flagging that the expected IRR of contractor 1 (DH operator) cannot be met

Users can adjust the negotiated heat price p_1 and the allocation of shared costs to identify a contractual configuration that satisfies the expected IRR of both contractors. If no feasible price range exists, changes in the cost allocation or project assumptions may be required.

Input overview section

Figure 23 provides a comprehensive overview of the waste heat recovery system, from the data centre to the district heating grid. Organised into the same four sections introduced in chapter 4, the figure combines the most important technical, contractual and economic input parameters in a single view. This allows users to verify their assumptions before interpreting the calculated results presented later in the worksheet.

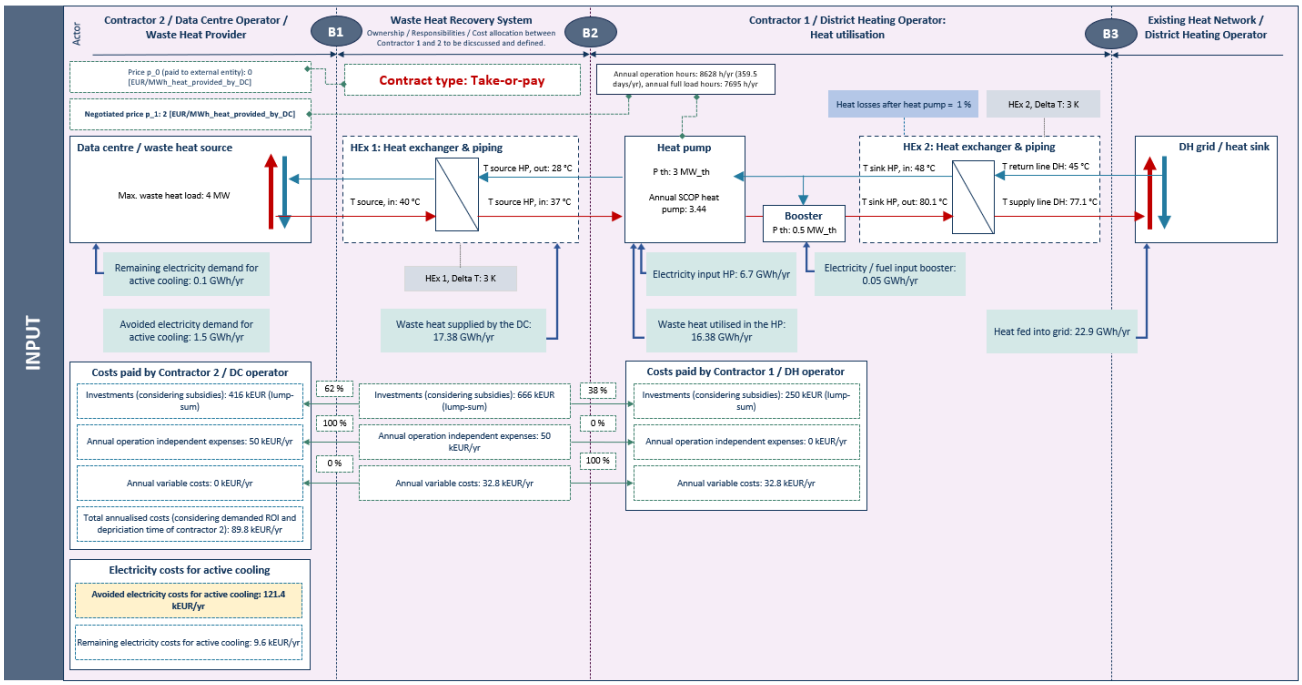


Figure 23: Overview of the system with the defined system boundaries, technical and economic input data

- **Contractor 2 / data centre operator** (first column): This contains the input parameters related to the data centre, including available waste heat, contractual settings (e.g. contract type and negotiated waste heat price), investment and operating cost allocation, and electricity costs associated with active cooling.
- **Waste heat recovery system** (B1 – B2) (second column): Summarises the technical design of the waste heat recovery system, including heat exchangers, temperature levels, heat flows and total investment and operating costs allocated to this system section, including the cost split between both contractors.
- **Heat utilisation** (B2 – B3) / **contractor 1** (third column): Presents the technical and economic parameters of the district heating operator, including the heat pump, booster and operating conditions, as well as contractor 1's share of the investment and operating costs. This section also contains indicators showing whether the selected contractual arrangement satisfies contractor 1's required return on investment.
- **District heating grid** (fourth column): It displays the operating conditions at the district heating interface, including the supply and return temperatures, the annual amount of heat delivered to the network and the reference values used to determine the economic benefits of replacing conventional heat generation methods. This is the reference point for contractor 1's avoided alternative heat production costs.

Economic output section

The outputs are presented in Figure 24 and are organised into five groups:

- **Investment:** Contractor 2's total investment needs, including the share of the waste heat recovery system costs and any subsidies received. This is the upfront capital commitment contractor 2 must make.
- **Costs:** Contractor 2's total annual expenses broken down into two sub-figures, including and excluding annualised investment costs. The distinction is important: the annualised investment cost depends on the assumed lifetime and expected IRR, so separating it from pure O&M costs makes the cost structure more transparent and easier to compare across scenarios.
- **Earnings:** Contractor 2's gross earnings from heat sold to contractor 1 (= annual waste heat volume × p_1), net earnings after all costs (including annualised investment), net earnings per MWh supplied, and avoided electricity costs from reduced cooling operation.
- Contractor 2's **internal rate of return (IRR):** The calculated IRR is compared with the expected IRR defined in the **'Project Setting'** worksheet. A project is considered economically attractive if the IRR is equal to or greater than the expected IRR. If this condition is not met, the contract type, negotiated price p_1, cost-sharing arrangement, or subsidy assumptions should be adjusted.
- **Break-even prices:** Two break-even prices are reported for contractor 2, each referring to a different heat quantity (waste heat provided by the data centre and heat delivered by the heat pump). They represent the minimum negotiated heat price (p_1) required for contractor 2 to achieve the expected IRR under the selected project assumptions. A negative break-even price indicates that contractor 2 can achieve the expected IRR solely through avoided cooling costs, even without any payment from contractor 1, representing a particularly favourable business case. Comparing the break-even prices with the negotiated price p_1 immediately shows whether the negotiated price is above or below the viability threshold.



Figure 24: Overview of economic output data of the analysis related to contractor 2

An overview chart at the end of the sheet (Figure 25) displays the main operation parameters per hour and typical day. The figure shows when the system is running and how key conditions (such as heat demand, waste heat availability, and economic feasibility) interact with the activation of the heat pump and booster.

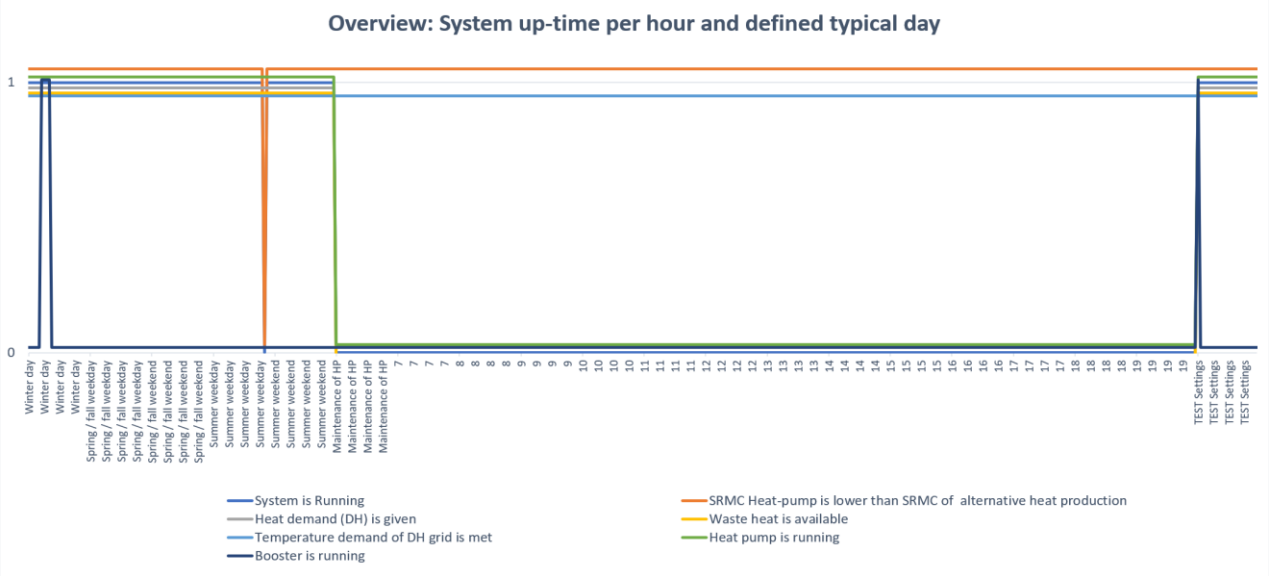


Figure 25: Overview graph showing operation data hourly per typical day

7.2 Excel Sheet 'Main Results Extended'

The **'Main Results Extended'** sheet complements the **'Main Results – IRR DC Operator'** sheet by presenting the technical and economic results for contractors 1 and 2 side by side. In contrast to the contractor-specific dashboard, this worksheet provides a comprehensive overview of the technical and economic performance of the entire project, allowing direct comparison of both contractors.

The sheet enables users to:

- Compare the negotiated heat price (p_1) with the calculated break-even prices of both contractors.
- Assess the economic performance of both contractors, using key indicators shown in Figure 26.
- Evaluate the overall feasibility of the project across the entire system.

Economic overview of both contractors

Figure 26 illustrates the **'Economics of Heat Recovery' section** at the top of the worksheet. The figure provides an overview of the project's economic input parameters and the resulting financial indicators. The top section contains the contractual settings, including the selected contract type (e.g. Take-or-Pay), the negotiated waste heat price and payments to external parties. These values are linked to the **'Main Results – IRR DC Operator'** sheet and are displayed here for reference only; they cannot be modified on this sheet.

The remainder of the figure summarises the economic inputs and calculated results for both contractors. These include the allocation of investment costs, subsidies, annual operation and maintenance (O&M) costs, variable operating costs, and the annual costs borne by each contractor. For the data centre operator, annual earnings from waste heat sales and savings in cooling electricity costs are also displayed. At the bottom of the section, the **calculated internal rate of return (IRR)** for both contractors is shown. The calculated IRR is compared with the expected IRR defined in the **'Project Setting'** worksheet to assess the project's financial attractiveness under the current assumptions.

Economics of heat recovery

DO NOT CHANGE VALUES IN THIS SHEET BUT IN SHEET >Main Results - IRR DC Operator<

Contract type between Contractor 1 and Contractor 2	Take-or-pay	1	Select contract type: Waste heat sold by DC based on (1) take-or-pay contract or (2) pay-as-you-go (utilisied heat)
Negotiated energy price p_1	[EUR/MWh_heat_provided_by_DC]	2.0	Price p_1 for waste heat from DC between Contractor 1 / DH operator and Contractor 2 / data centre operator. These are costs for Contractor 1 / DH operator and earnings for Contractor 2 / DC operator.
Energy price p_0 paid to external entity	Take-or-pay	0.0	Price p_0 for waste heat from DC paid to external party. These are neither earnings for Contractor 1 nor Contractor 2 / DH operator

Total investment			**Share paid for by Contractor 1**
Investment costs: equipment, installation, heat exchange	EUR	500 000	50%
Heat network	EUR	126 000	0%
Planning	EUR	40 000	0%
Total	EUR	666 000	

CAPEX Investment subsidies			**Share received by Contractor 1**
Total subsidies	EUR	0	0%
Total	EUR	0	

Annual operation independent O&M expenses			**Share paid for by Contractor 1**
Regular annual expenses	EUR/yr	50 000	0%
Cost for waste heat p_0 (Take-or-pay contract)	EUR/yr	0	0%
Total annual operation independent expenses	EUR/yr	50 000	

Annual variable costs			**Share paid for by Contractor 1**
Variable O&M costs per year	EUR/yr	32 762	100%
Total annual operation dependent expenses	EUR/yr	32 762	

Costs paid for by Contractor 2 / DC operator			**Total costs**	**Costs paid for by Contractor 1 / DH operator**		
Investments	EUR	416 000	666 000	Investments	EUR	250 000
Annual operation independent O&M expenses	EUR/yr	50 000	50 000	Annual operation independent O&M expenses	EUR/yr	0
Annual variable costs	EUR/yr	0	32 762	Annual variable costs	EUR/yr	32 762

Total annual expenses (excluding annualized investments)	EUR/yr	50 000
Annual earnings (under negotiated price p_1)	EUR/yr	34 768
Annual reduced electricty costs for active cooling	EUR/yr	121 446

24.59 %	**Internal Rate of Return**	**3.86 %**
Considering a underlying lifetime of 15 year for Contractor 2		Considering a underlying lifetime of 15 year for Contractor 1

Figure 26: Economics of heat recovery: overview of contractual settings, cost allocation, earnings and profitability indicators for both contractors

Overview of inputs and outputs for both contractors

The results shown in the **'Main Results – IRR DC Operator'** sheet (Figure 27) is divided into two parts. The upper section shows the input overview for both contractors side by side, using the same four-column structure as Figure 21, but now displaying the technical and economic parameters of both contractors together. This allows users to verify that all inputs are consistent and complete before interpreting the calculated results.

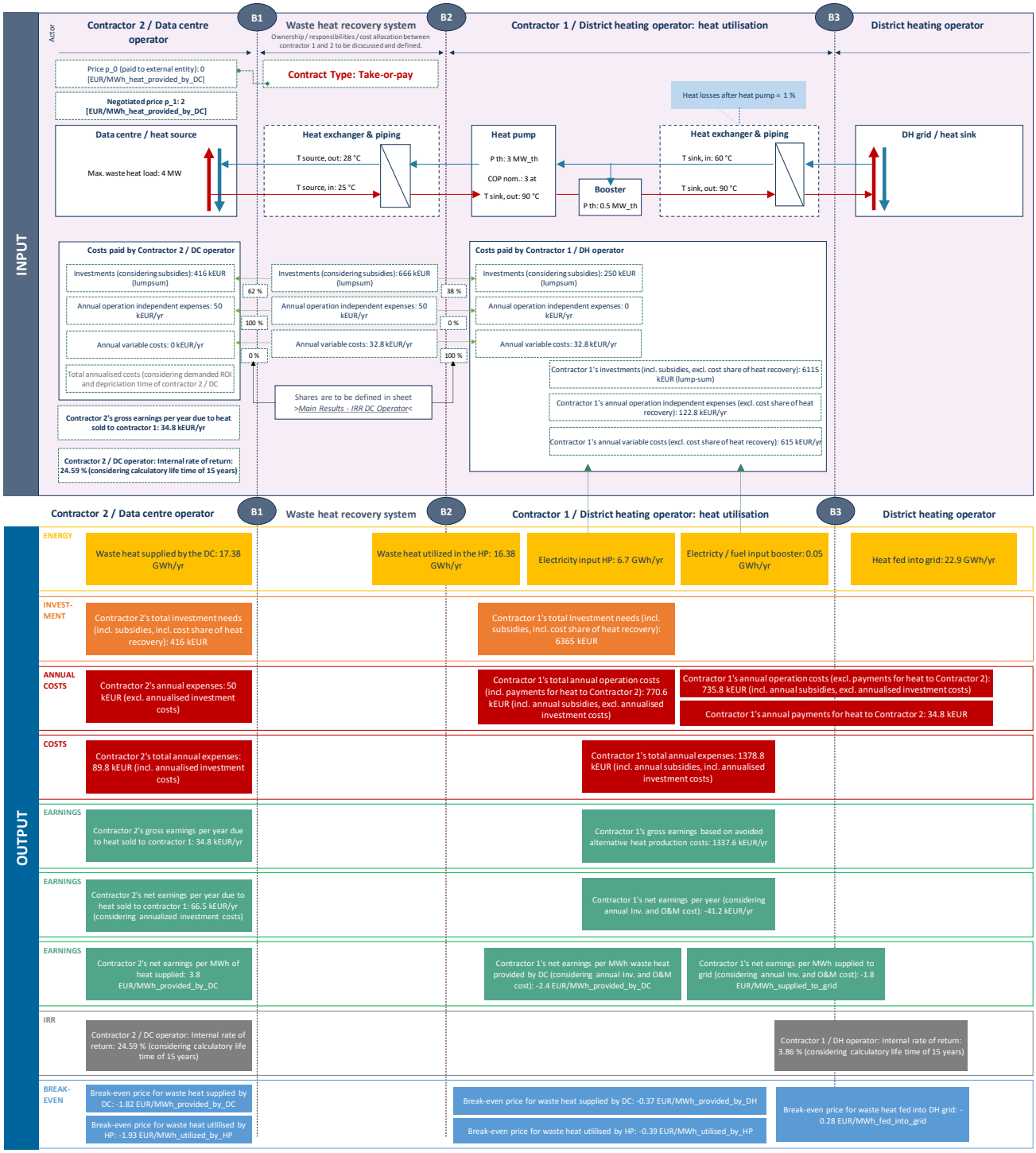


Figure 27: Integrated overview of project inputs and economic outputs (contractor 2 on the left side, contractor 1 on the right side)

To facilitate the interpretation of the calculated results shown in Figure 27, Table 6 summarises the main output categories and provides guidance on how these results should be interpreted when assessing the project's technical and economic performance.

Table 6: Output categories shown in the 'Main Results Extended' sheet and their interpretation

Category	Content	Purpose / interpretation
Energy	Annual energy flows: waste heat provided, utilised, and fed into the DH grid	Check whether the utilisation rate is plausible given the typical day profiles; a low utilisation rate may indicate that SRMC or p_1 is too high under pay-as-you-go
Investment	Total investment allocated to each contractor, net of subsidies	Compare with contractor's available capital and benchmark against comparable projects
Annual costs	Annualised investment, O&M, and waste heat payments, per contractor	Identify which cost component dominates; investment-heavy projects are more sensitive to the interest rate; operation-heavy projects are more sensitive to energy prices
Earnings	Gross and net annual earnings per contractor	Net earnings should be positive for both contractors; if negative, the current p_1 or cost-sharing split is not viable
Specific earnings	Net earnings per MWh of waste heat supplied or delivered	Useful for benchmarking: a positive value confirms the project generates a surplus above the break-even threshold
IRR	Internal rate of return achieved by each contractor	Must meet or exceed the expected internal rate of return for the project to be financially viable.
Break-even price	Minimum p_1 for contractor 2 and maximum p_1 for contractor 1	A viable business case exists when the negotiated price p_1 lies between contractor 2's minimum break-even price and contractor 1's maximum break-even price.

Table 7 summarises the interpretation of the two key economic indicators used to assess the financial viability of the project from the perspective of both contractors.

Table 7: Interpretation of the main economic KPIs

KPI	Contractor 1 (DH operator)	Contractor 2 (DC operator)
IRR	If the calculated IRR is equal to or greater than the expected IRR, the project is financially viable.	If the calculated IRR is equal to or greater than the expected IRR, the project is financially viable.
Break-even price	Maximum negotiated price p_1 at which contractor 1 still achieves the expected IRR; the negotiated price must remain below this value.	Minimum negotiated price p_1 required for contractor 2 to achieve the expected IRR; the negotiated price must be above this value.

7.3 Excel Sheet 'Calculation Break-Even'

The sheet **'Calculation Break-Even'** summarises the annual cost and earning components of both contractors and presents the resulting break-even prices, as shown in Figure 28 and Figure 29 respectively. While section 6.4 describes the underlying calculation methodology, this section focuses on interpreting the displayed results.

	Summary of Results						
Contractor 1 / DH operator	CAPEX: Investment & planning & one-time costs (HP and Booster)	5 065 000	EUR	484 024	EUR/yr	21.1	EUR/MWh_fed_into_grid
	CAPEX: Piping and grid connection costs	1 050 000	EUR	100 341	EUR/yr	4.4	EUR/MWh_fed_into_grid
	CAPEX: Decomission costs (HP and Booster, etc.)	0	EUR	0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	CAPEX: Residual value (HP and Booster)	0	EUR	0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	CAPEX: One-time subsidies (HP and Booster) (Earnings)	0	EUR	0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	CAPEX: Waste Heat Recovery System paid for by Contractor 1 / DH operator	250 000	EUR	23 891	EUR/yr	1.0	EUR/MWh_fed_into_grid
	CAPEX (total, incl. lump-sum subsidies)	**6 365 000**	**EUR**	**608 255**	**EUR/yr**	**26.6**	**EUR/MWh_fed_into_grid**
	CAPEX (total, incl. lump-sum subsidies excl. heat extraction system investment costs share paid by contractor 1)	**6 115 000**	**EUR**	**584 364**	**EUR/yr**	**25.5**	**EUR/MWh_fed_into_grid**
	OPEX - fix: Waste heat payment to Contractor 2 / DC operator under a take-or-pay contract (based on the negotiated price p_0)			34 768	EUR/yr	1.5	EUR/MWh_fed_into_grid
	OPEX - fix: Regular annual costs (HP and Booster)			68 000	EUR/yr	3.0	EUR/MWh_fed_into_grid
	OPEX - fix: Personnel			20 000	EUR/yr	0.9	EUR/MWh_fed_into_grid
	OPEX - fix: Rent			0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	OPEX - fix: Capacity dependent annual subsidies (HP and Booster) (Earnings)			0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	OPEX - fix: Waste Heat Recovery System paid for by Contractor 1 / DH operator			0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	OPEX - fix (total) excl. waste heat payment to Contractor 2 / DC operator			**88 000**	**EUR/yr**	**3.8**	**EUR/MWh_fed_into_grid**
	OPEX - fix (total) incl. waste heat payment to Contractor 2 / DC operator (take-or-pay) excluding heat extraction system investment costs share paid by contractor			**122 768**	**EUR/yr**	**5.4**	**EUR/MWh_fed_into_grid**
	OPEX - fix (total) excl. waste heat payment to Contractor 2 / DC operator			**88 000**	**EUR/yr**	**3.8**	**EUR/MWh_fed_into_grid**
	OPEX - fix (total) incl. waste heat payment to Contractor 2 / DC Operator (take-or-pay) excluding heat extraction system investment costs share paid by contracto			**122 768**	**EUR/yr**	**5.4**	**EUR/MWh_fed_into_grid**
	OPEX - var: Waste heat payment to Contractor 2 / DC Operator under a Pay-as-you-go contract (based on the negotiated price p_1)			0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	OPEX - var: Electricity costs (HP)			571 161	EUR/yr	24.9	EUR/MWh_fed_into_grid
	OPEX - var: Fuel costs (Booster)			3 674	EUR/yr	0.2	EUR/MWh_fed_into_grid
	OPEX - var: Electricity costs (Auxilary)			40 207	EUR/yr	1.8	EUR/MWh_fed_into_grid
	OPEX - var: O&M Var (w.o. electricity for heat pump and electricty / fuel for booster)			0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	OPEX - var: Waste heat dependent annual subsidies (HP and Booster) (Earnings)			0	EUR/yr	0.0	EUR/MWh_fed_into_grid
	OPEX - var: Waste Heat Recovery System paid for by Contractor 1 / DH Operator			32 762	EUR/yr	1.4	EUR/MWh_fed_into_grid
	OPEX - var (total) excl. waste heat payment to Contractor 2 / DC operator			**647 805**	**EUR/yr**	**28.3**	**EUR/MWh_fed_into_grid**
	OPEX - var (total) incl. waste heat payment to Contractor 2 / DC operator (pay-as-you-go)			**647 805**	**EUR/yr**	**28.3**	**EUR/MWh_fed_into_grid**
	OPEX - var (total) excl. waste heat payment to Contractor 2 / DC operator (pay-as-you-go) excluding heat extraction system investment costs share paid by contra			**615 043**	**EUR/yr**	**26.9**	**EUR/MWh_fed_into_grid**
	OPEX - var (total) incl. waste heat payment to Contractor 2 / DC operator (pay-as-you-go) excluding heat extraction system investment costs share paid by contrac			**615 043**	**EUR/yr**	**26.9**	**EUR/MWh_fed_into_grid**
	Earnings - Avoided variable costs (SRMC) of alternative production (i.e. refrence marginal heat costs)			1 337 631	EUR/yr	58.4	EUR/MWh_fed_into_grid
	Expenses / LCOH without payment to Contractor 2 / DC operator			1 344 060	EUR/yr	58.7	EUR/MWh_fed_into_grid
	Expenses - Payment to Contractor 2 / DC operator			34 768	EUR/yr	1.5	EUR/MWh_fed_into_grid
	Expenses / LCOH without payment to Contractor 2 / DC operator excluding heat extraction system investment costs share paid by contractor 1			1 287 407	EUR/yr	56.2	EUR/MWh_fed_into_grid
	Total net earnings of Contractor 1 / DH operator					**-2.4**	**EUR/MWh_supplied_by_DC**
	Total net earnings of Contractor 1 / DH operator					**-2.5**	**EUR/MWh_waste_heat_utilized_by_HP**
	Total net earnings of Contractor 1 / DH operator			**-41 196**	**EUR/yr**	**-1.8**	**EUR/MWh_fed_into_grid**
	Net earnings of contractor 1 / DH operator excluding heat extraction system investment costs share paid by contractor 1			**15 456**	**EUR/yr**	**0.7**	**EUR/MWh_fed_into_grid**

Figure 28: Annualised costs and earnings for contractor 1 (DH operator)

Contractor 2 / DC Operator	CAPEX: Investments heat recovery & planning & heat exchanger, etc., paid for by DC operator	290 000	EUR	27 939	EUR/yr	1.6	EUR/MWh_provided_by_DC
	CAPEX: Piping, paid for by DC operator	126 000	EUR	12 139	EUR/yr	0.7	EUR/MWh_provided_by_DC
	CAPEX: One-time subsidies (Earnings), recieved by DC Operator	0	EUR	0	EUR/yr	0.0	EUR/MWh_provided_by_DC
	CAPEX (total, incl. lump-sum subsidies)	**416 000**	**EUR**	**39 754**	**EUR/yr**	**2.3**	**EUR/MWh_provided_by_DC**
	OPEX - fix: Other operation indepentend O&M costs, paid for by DC operator			50 000	EUR/yr	2.9	EUR/MWh_provided_by_DC
	OPEX - fix: Energy costs under p_0 paid to external entity			0	EUR/yr	0.0	EUR/MWh_provided_by_DC
	OPEX - (total) fixed costs			**50 000**	**EUR/yr**	**2.9**	**EUR/MWh_provided_by_DC**
	OPEX - var: O&M costs paid by DC operator			0	EUR/yr	0.0	EUR/MWh_provided_by_DC
	OPEX - (total) variable costs			**0**	**EUR/yr**	**0.0**	**EUR/MWh_provided_by_DC**
	Earnings: Payment from Contractor 1 / DH operator (take-or-pay OR pay-as-you-go)			34 768	EUR/yr	2.0	EUR/MWh_provided_by_DC
	Earnings: Avoided electricity costs for cooling			121 446	EUR/yr	7.0	EUR/MWh_provided_by_DC
	Total expenses			89 754	EUR/yr	5.2	EUR/MWh_provided_by_DC
	Total net earnings of Contractor 2 / DC operator			**66 459**	**EUR/yr**	**3.8**	**EUR/MWh_provided_by_DC**

Figure 29: Annualised costs and earnings for contractor 2 (DC operator / WH provider)

The sheet also presents **three reference points for heat streams** (heat provided to the district heating network over the year, heat utilised in the heat pump, and heat provided by contractor 2, and calculates **four levelised costs of heat (LCOH) variants** for each, as shown in Figure 30. The four variants result from two dimensions: whether the negotiated payment p_1 to contractor 2 is included or excluded in the cost base, and whether contractor 1's share of the waste heat recovery system investment is included or excluded. Excluding p_1 shows the cost to contractor 1 before the inter-contractor payment; including it reflects the full cost including the waste heat purchase. The LCOH excluding p_1 is particularly useful for comparing

waste heat with alternative heat sources because it represents the production cost independently of the negotiated transfer price.

Produced heat - fed into grid	458 005	MWh for entire project lifetime	22 900	MWh/yr	
Waste heat utilisied in heat pump	327 618	MWh for entire project lifetime	16 381	MWh/yr	
Waste heat provided by DC	347 675	MWh for entire project lifetime	17 384	MWh/yr	
Reference avoided marginal heat costs			1 337 631	EUR/yr	58.4 EUR/MWh_fed_into_grid
LCOH - excl. payment to DC operator based on negotiated price p_1 between Contractor 1 and Contractor 2					57.6 EUR/MWh_fed_into_grid
LCOH - incl. payment to DC operator based on negotiated price p_1 between Contractor 1 and Contractor 2					59.7 EUR/MWh_fed_into_grid
LCOH - excl. payment to DC operator based on negotiated price p_1 between Contractor 1 and Contractor 2 excluding heat extraction system investment costs share paid by contractor 1					56.2 EUR/MWh_fed_into_grid
LCOH - incl. payment to DC operator based on negotiated price p_1 between Contractor 1 and Contractor 2 excluding heat extraction system investment costs share paid by contractor 1					58.3 EUR/MWh_fed_into_grid

Figure 30: Reference heat streams and the related LCOH for the waste heat

Figure 31 shows **five different break-even prices** for contractor 1 (DH operator) and two for contractor 2 (DC operator / WH provider), together with main contract negotiation settings from the **'Main Results – IRR DC Operator'** sheet.

The calculated break-even price for waste heat is the upper limit the DH operator can afford to pay for the waste heat to reach the break-even point under the pre-defined economic parameters (Required ROI and calculatory life time as defined in the Project Sheet)		
Contractor 1: Break-even waste heat price per MWh fed into the grid	-0.28	EUR/MWh_fed_into_grid
Contractor 1: Break-even waste heat price per MWh waste heat utilisied in heat pump	-0.39	EUR/MWh_utilized_by_HP
Contractor 1: Break-even waste heat price per MWh waste heat provided by DC operator	-0.37	EUR/MWh_provided_by_DC
Contractor 1: Break-even waste heat price per MWh waste heat utilisied in heat pump excluding heat extraction system investment costs share paid by contractor 1	3.07	EUR/MWh_utilized_by_HP
Contractor 1: Break-even waste heat price per MWh waste heat provided by DC operator excluding heat extraction system investment costs share paid by contractor 1	2.89	EUR/MWh_provided_by_DC
The calculated break-even price for waste heat is the lower limit for the DC operator to recieve to reach the break-even point under the predefined economic parameters. (Required ROI and calculatory life time as defined in the Project Sheet)		
Contractor 2 / DC operator: Break-even waste heat price per MWh waste heat utilisied in heat pump	-1.93	EUR/MWh_utilized_by_HP
Contractor 2 / DC operator: Break-even waste heat price per MWh waste heat provided by DC operator	-1.82	EUR/MWh_provided_by_DC
Underlying assumptions on waste heat contract (used to determine SRMC)		
Share Take-or-pay (ToP) Contract: In case of ToP contract, the waste heat price is not part of the SRMC, but constitutes annual fix costs	100%	
Share Pay-as-you-go (Payg) Contract: In case of PayG contract, the waste heat price is part of the SRMC, and has an impact on SRMC	0%	
Average waste heat price (p_1 as negotiated between Contractor 1 and Contractor 2) per heat fed into grid	1.5	EUR/MWh_fed_into_grid
Average waste heat price (p_1 as negotiated between Contractor 1 and Contractor 2) per waste heat utilized by Contractor 1	2.1	EUR/MWh_utilized_by_HP
Average waste heat price (p_1 as negotiated between Contractor 1 and Contractor 2) per waste heat provided by DC operator	2.0	EUR/MWh_provided_by_DC

In the selected example, the project can only be economically viable for contractor 1 if the share of costs currently assigned to contractor 1 is reduced, or if contractor 2 pays contractor 1 at least about 0.39 €/MWh for the waste heat utilised. For contractor 2, the project is economically viable under the current settings even if they pay contractor 1 up to €1.8-1.9/MWh for the waste heat. This result for contractor 2 is triggered by the avoided electricity costs of dissipating the waste heat in the data centre's default cooling system.

Figure 31: Presentation of different break-even prices for contractor 1 and contractor 2 together with assumption and settings from the contract negotiation

The **break-even prices** are interpreted as follows. For contractor 1, p_1 must remain below the break-even price for the project to meet contractor 1's expected IRR. For contractor 2, p_1 must remain above the break-even price for the project to meet contractor 2's expected IRR. A viable business case exists only when these two conditions can be satisfied simultaneously, that is, when contractor 2's break-even price is lower than contractor 1's, leaving a negotiating range for p_1.

For contractor 1, three break-even variants cover all project costs and differ only by heat stream denominator. Two further variants exclude contractor 1's share of the waste heat recovery system investment, isolating the break-even price for the heat utilisation section alone. These are useful for assessing how sensitive contractor 1's economics are to the cost-

sharing arrangement. The two break-even prices for contractor 2 differ only by heat stream denominator.

A **mutually beneficial business case** exists if contractor 2's break-even price is lower than contractor 1's. In this case, there is a negotiating range for p_1 in which both parties can meet or exceed their return expectations. How the resulting surplus is shared (for example based on each party's risk exposure) is a matter for negotiation and is outside the scope of the tool.

If contractor 2's break-even price exceeds contractor 1's, no viable business case can be established under the current settings. In this situation, the contractors could consider lowering IRR expectations, seeking higher subsidies where available, reducing project-related costs, or reassessing assumptions on future electricity prices.

Under a **pay-as-you-go contract,** the break-even heat prices depend on the negotiated price p_1 used in the calculation. **If p_1 differs significantly from the resulting break-even price, the calculation should be repeated** (see note in section 6.4).

7.4 Excel Sheet 'Operation at Typical Day'

The **'Operation at Typical Day'** sheet visualises the hourly operation of the system for a selected typical day. It combines technical and economic results in three diagrams showing energy flows, energy costs and temperatures, thereby illustrating not only how the system operates but also why specific operating decisions are taken (see Figure 32).

The **energy flows** section shows how much waste heat is available and how much is actually utilised, alongside heat pump electricity consumption, booster energy input, and heat fed into the grid. Comparing available waste heat against utilised waste heat immediately reveals hours where capacity, demand, or economics limit dispatch.

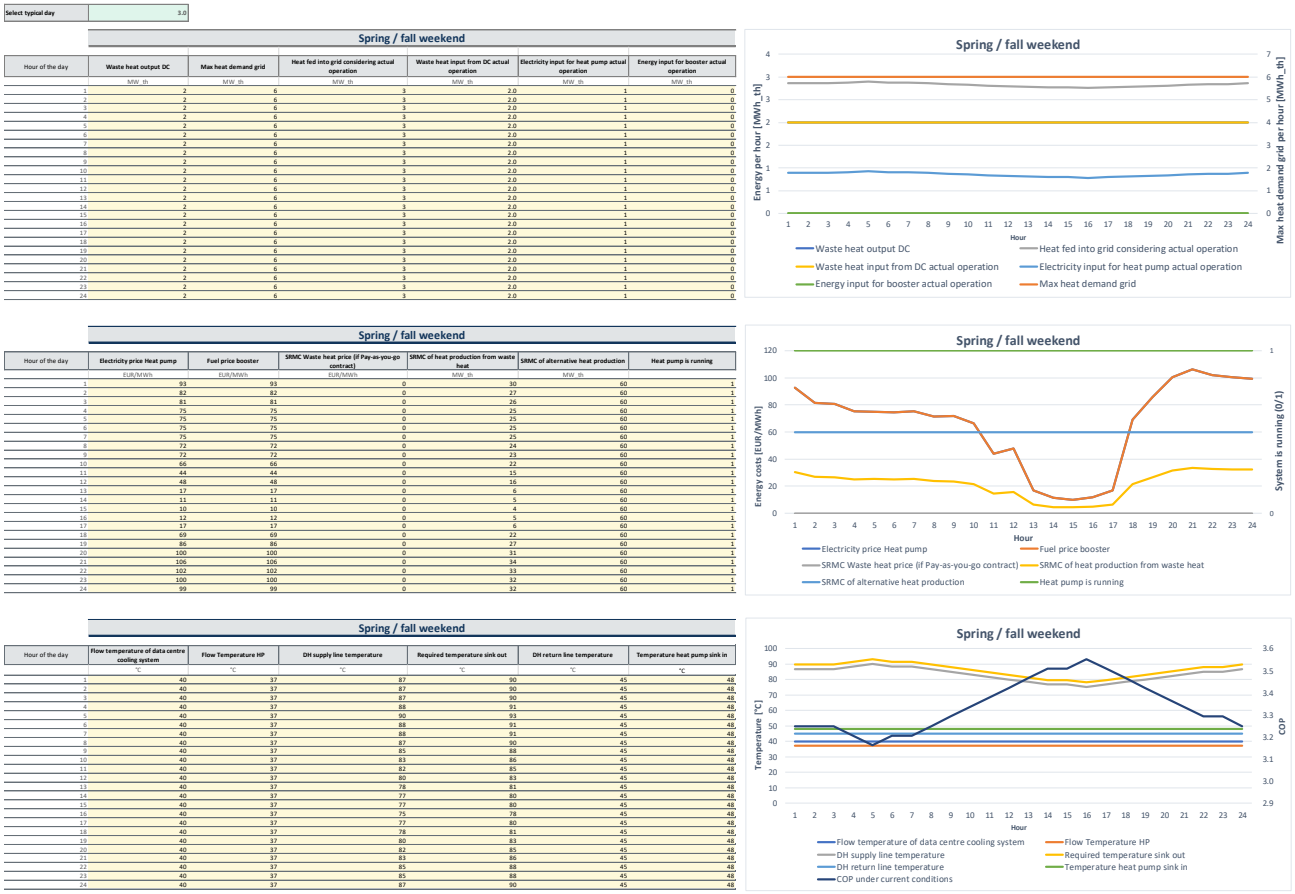
The **energy costs** section displays the SRMC of alternative heat production alongside the marginal cost of waste heat utilisation (electricity and fuel costs), making it possible to assess, hour by hour, whether waste heat is economically competitive. An indicator explicitly shows whether waste heat is dispatched in each hour or whether conventional heat production is more economical based on the SRMC comparison. This provides a clear explanation of the resulting annual waste heat utilisation rate.

The **temperature** section shows the heat pump source and sink temperatures, the DH supply and return line temperatures, and the resulting COP in each hour. This helps verify that the temperature profiles entered in **'Definition of Typical Day'** produce a plausible and physically consistent operating pattern.

The charts are also well-suited for communicating system operation to stakeholders who are not directly working with the tool, since the visual format makes hourly behaviour immediately accessible without requiring familiarity with the underlying spreadsheet structure.

The user selects a typical day from the dropdown menu at the top of the sheet (e.g., winter day, summer weekend, maintenance day). All charts and tables update automatically.

The sheet should be consulted after entering typical day profiles and before interpreting annual results, to verify that the simulated operation is physically plausible.



Select typical day: 3.0

Spring / fall weekend

Hour of the day	Waste heat output DC	Max heat demand grid	Heat fed into grid considering actual operation	Waste heat input from DC actual operation	Electricity input for heat pump actual operation	Energy input for booster actual operation
	MW_th	MW_th	MW_th	MW_th	MW_th	MW_th
1	2	6	3	2.0	1	0
2	2	6	3	2.0	1	0
3	2	6	3	2.0	1	0
4	2	6	3	2.0	1	0
5	2	6	3	2.0	1	0
6	2	6	3	2.0	1	0
7	2	6	3	2.0	1	0
8	2	6	3	2.0	1	0
9	2	6	3	2.0	1	0
10	2	6	3	2.0	1	0
11	2	6	3	2.0	1	0
12	2	6	3	2.0	1	0
13	2	6	3	2.0	1	0
14	2	6	3	2.0	1	0
15	2	6	3	2.0	1	0
16	2	6	3	2.0	1	0
17	2	6	3	2.0	1	0
18	2	6	3	2.0	1	0
19	2	6	3	2.0	1	0
20	2	6	3	2.0	1	0
21	2	6	3	2.0	1	0
22	2	6	3	2.0	1	0
23	2	6	3	2.0	1	0
24	2	6	3	2.0	1	0

Spring / fall weekend

Hour of the day	Electricity price Heat pump	Fuel price booster	SRMC Waste heat price (if Pay-as-you-go contract)	SRMC of heat production from waste heat	SRMC of alternative heat production	Heat pump is running
	EUR/MWh	EUR/MWh	EUR/MWh	MW_th	MW_th	
1	93	93	0	30	60	1
2	82	82	0	27	60	1
3	81	81	0	26	60	1
4	75	75	0	25	60	1
5	75	75	0	25	60	1
6	75	75	0	25	60	1
7	75	75	0	25	60	1
8	72	72	0	24	60	1
9	72	72	0	23	60	1
10	66	66	0	22	60	1
11	44	44	0	15	60	1
12	48	48	0	16	60	1
13	17	17	0	6	60	1
14	11	11	0	5	60	1
15	10	10	0	4	60	1
16	12	12	0	5	60	1
17	17	17	0	6	60	1
18	69	69	0	22	60	1
19	86	86	0	27	60	1
20	100	100	0	31	60	1
21	106	106	0	34	60	1
22	102	102	0	33	60	1
23	100	100	0	32	60	1
24	99	99	0	32	60	1

Spring / fall weekend

Hour of the day	Flow temperature of data centre cooling system	Flow Temperature HP	DH supply line temperature	Required temperature sink out	DH return line temperature	Temperature heat pump sink in
	°C	°C	°C	°C	°C	°C
1	40	37	87	90	45	48
2	40	37	87	90	45	48
3	40	37	87	90	45	48
4	40	37	88	91	45	48
5	40	37	90	93	45	48
6	40	37	88	91	45	48
7	40	37	88	91	45	48
8	40	37	87	90	45	48
9	40	37	85	88	45	48
10	40	37	83	86	45	48
11	40	37	82	85	45	48
12	40	37	80	83	45	48
13	40	37	78	81	45	48
14	40	37	77	80	45	48
15	40	37	77	80	45	48
16	40	37	75	78	45	48
17	40	37	77	80	45	48
18	40	37	78	81	45	48
19	40	37	80	83	45	48
20	40	37	82	85	45	48
21	40	37	83	86	45	48
22	40	37	85	88	45	48
23	40	37	85	88	45	48
24	40	37	87	90	45	48

Figure 32: Representation of energy flows (top), energy costs (middle) and temperatures (bottom) on hourly basis for a selected typical day

8 Supporting Information

This chapter describes the supporting worksheets that provide background information, navigation aids, and reference data used throughout the tool. These worksheets support data entry, improve the understanding of the underlying methodology, and facilitate the interpretation of results.

8.1 Excel Sheet 'Info'

The **'Info'** sheet provides general information about the tool, including its purpose, version history, authorship, funding acknowledgement, and disclaimer notes. Users should consult this sheet to verify the tool version and review important information regarding its intended use and limitations.

8.2 Excel Sheet 'Content'

The **'Content'** sheet serves as the central navigation page of the workbook. It provides a clickable table of contents with hyperlinks to all worksheets and allows users to quickly access any part of the tool. Each worksheet also contains a **'Go to Content'** hyperlink, enabling users to return to this overview page at any time. The password for the protected calculation sheets is also provided on this sheet.

8.3 Excel Sheet ‘Additional Information’

The **'Additional Information'** sheet serves as a reference guide for the parameters used throughout the workbook. It provides definitions, methodological explanations and background information for technical and economic inputs, including financial parameters, heat pump characteristics, subsidy schemes and calculation methods.

The sheet clarifies model logic and the role of individual parameters, shows how derived values such as the capital recovery factor are calculated, and helps users adapt the tool to specific national or project contexts.

Each input parameter row on the main input sheets includes a link in the first column that navigates directly to the corresponding explanation in this sheet.

Note that the German translations currently included in this sheet are based on automated translation and are still being reviewed. They should not be relied upon as authoritative German-language definitions until they have been verified.

8.4 Excel Sheet 'TechKatalogGWPA'

The **'TechKatalogGWPA'** sheet contains reference data from the German technology catalogue[2] for large-scale waste heat heat pumps ("Technologiekatalog Großwärmepumpen Abwärme"). The data include benchmark values for heat pump performance, investment costs, operating costs and technical lifetimes and can be used whenever project-specific information is not yet available.

These reference values are useful when site-specific data from a manufacturer or project engineer are not yet available and help align tool inputs with German national guidelines for heat planning (Wärmeplanung).

Users are encouraged to consult this sheet when setting cost and technical assumptions in **'Project Setting'**, particularly for heat pump capacity, specific investment costs, and O&M rates.

[2] See https://www.kww-halle.de/service/infothek/detail/kww-technikkatalog-waermeplanung-begleitdokument

9 Application of the Tool

This chapter provides practical guidance for applying the tool to concrete projects. Section 9.1 describes the default dataset integrated into the tool, which allows users to explore its functionality without entering data of their own. Section 9.2 outlines methods for compiling the input data required for assessing concrete projects. Section 0 presents an exemplary workflow showing how a structured assessment might proceed from first estimates to a grounded understanding of the project's economic characteristics. Section 9.4 concludes with important aspects to consider in practice.

9.1 Default Dataset

The tool includes a default dataset that allows users to become familiar with the workflow and methodology without first compiling project-specific data. It serves as a learning and demonstration case, not as a benchmark or reference project. It enables users to perform a first assessment immediately after opening the workbook.

The default dataset represents a plausible but simplified project integrating data centre waste heat into an existing district heating system. The data centre is a comparatively small facility with relatively high waste heat temperatures, as is typical for water-cooled data centres. It is located within 300 m of the district heating network. The network operates with seasonal supply temperatures between approximately 60 °C and 90 °C. Alternative heat production is represented by a portfolio of conventional technologies with different short-run marginal costs (SRMC). A heat pump with a nominal thermal capacity of 3 MW upgrades the waste heat to a nominal outlet temperature of 90 °C (maximum 95 °C). A 0.5 MW booster provides the additional temperature lift when higher supply temperatures are required.

The dataset combines technology data, economic assumptions and representative operating conditions from publicly available sources and project experience. Electricity prices represent the spot market component only. Grid fees can be entered either as part of the electricity price or separately on **'Project Setting'.** The default dataset keeps them separate to avoid double-counting. For contractor 1's heat pump and booster, grid fees comprise a capacity-related charge of 250 EUR/kW_el/yr (German "Leistungspreis") and a consumption-related charge of 11 EUR/MWh ("Arbeitspreis"). For contractor 2's active cooling, only the consumption-related charge applies. The district heating operator is assumed to pay a spot market price 10 EUR/MWh lower than the data centre operator.

No investment or operating subsidies are considered. The project is assumed to be located in central Europe with cold winters and hot summers. This is reflected in the share of active cooling, which varies across the typical days.

Several economic parameters, such as planning costs, depreciation periods and operation and maintenance costs, represent average assumptions for orientation. The default dataset should therefore be critically reviewed and adapted before assessing a real project. Guidance on replacing the default assumptions with project-specific data is provided in sections 9.2 and 0.

Table 8 summarises the principal assumptions of the integrated dataset and indicates where the corresponding parameters are defined within the workbook. Only the most influential technical and economic assumptions are listed. Additional input parameters are pre-filled throughout the workbook and can be reviewed or modified as required.

Table 8. Key parameters of the default dataset

Parameter	Default value	Description	Worksheet
REFERENCE SYSTEM			
Available waste heat	2 MW_th	Hourly thermal output from the data centre that is available for heat recovery.	Definition of Typical Day
Heat source temperature	~40 °C	Temperature of the cooling system before HEx 1.	Definition of Typical Day
DH supply temperature	65–95 °C (seasonal variation)	The required supply temperature that must be delivered to the DH network.	Definition of Typical Day
HEAT RECOVERY SYSTEM			
Generating capacity (heat pump)	3 MW_th	Nominal capacity of heat pump (heat output).	Project Setting
Nominal temperature – heat pump sink out	90 °C (max. 95 °C)	Sink-side outlet temperature: the temperature of the heat sink fluid after it has passed through the condenser.	Project Setting
Generating capacity (booster)	0.5 MW_th	Thermal output that defines the maximum amount of heat the booster can deliver.	Project Setting
Average weighted annual SCOP of active cooling unit	7.5	Average achieved ratio of removed thermal energy to electricity, weighted considering different operation conditions.	Project Setting
OPERATIONAL ASSUMPTIONS			
Typical year weighting	Predefined for six typical days	Relative share of typical day in the analysed typical year.	Definition of Typical Year
SRMC of alternative heat production	40 EUR/MWh (summer); 65 EUR/MWh (winter)	The cost of producing 1 MWh of heat using alternative sources that the recovered data centre heat replaces.	Definition of Typical Day
Electricity price heat pump	~75 EUR/MWh (range: -2.2 to 190.5 EUR/MWh)	Hourly electricity price paid for operating the heat pump.	Definition of Typical Day
Electricity price active cooling	~85 EUR/MWh (range: 7.8 to 200.5 EUR/MWh)	Electricity price for active cooling system that has to be paid by the data centre operator (Contractor 2).	Definition of Typical Day
ECONOMIC ASSUMPTIONS			
Specific investment costs (heat pump)	Based on TechKatalogGWPA	The specific costs of acquiring and installing the heat pump system.	Project Setting
Subsidies	None	No investment or operational subsidies are assumed in the default dataset.	Project Setting
Depreciation time of project	15 years	Number of years over which the investment is financially depreciated in calculations.	Project Setting
Discount rate (in real terms)	5 %	Expected IRR used for the investment assessment.	Project Setting
Initial negotiated waste heat price (p_1)	~2 EUR/MWh (predefined reference value)	Price p_1 for waste heat from DC between contractor 1 and contractor 2.	Main Results – IRR DC Operator

9.2 Methods for Data Compilation

The quality of the assessment depends primarily on the quality of the input data. While the default dataset provides a suitable starting point for exploring the tool and understanding its logic, a meaningful project assessment requires project-specific data. This section outlines approaches for compiling the required technical and economic inputs, with a particular focus on two aspects that typically require the most effort: deriving representative typical day profiles and determining appropriate short-run marginal costs of alternative heat production.

9.2.1 General Approach

Data compilation should be regarded as an iterative process rather than a one-time task. During the early stages of a project, only limited information is typically available. As the project progresses and additional technical and economic data become available, the input parameters can gradually be refined to improve the reliability of the assessment.

The objective is not to determine every parameter with high accuracy from the outset, but to establish a technically consistent and economically plausible representation of the project. Parameters with the greatest influence on the results, such as investment costs, electricity prices, heat demand and the short-run marginal costs of alternative heat production, should therefore receive particular attention.

For a first screening, annual averages and catalogue-based cost estimates are sufficient. More detailed hourly time series and site-specific cost data are needed once the first results indicate that a viable business case may exist and a more accurate analysis is warranted.

Most cost and economic parameters (e.g., investment costs, O&M rates, electricity tariffs, expected IRR, and subsidy levels) can be obtained from equipment suppliers, network operators, and publicly available references such as the German technology catalogue (sheet **'TechKatalogGWPA'**). The most challenging inputs to compile are the hourly profiles required for the typical days, which are discussed in detail below.

9.2.2 Compiling Typical Day Data

The annual operation of the waste heat integration into the district heating system is represented by a limited number of typical days, each characterised by a representative 24-hour operating profile. These profiles are among the most data-intensive inputs in the tool and must be defined for ten variables: available waste heat, heat demand, heat source temperature, district heating supply and return temperatures, SRMC of alternative heat production, heat pump electricity price, booster energy price, DC cooling electricity price, and the share of active cooling (see section 5.3 for definitions). Additionally, the definition of the hourly values for the typical days has a strong influence on the results of the assessment. Therefore, it is important to carefully define and compile these data for obtaining reliable results. In the following two different methods to derive these profiles from raw time-series data are presented.

Method A: Manual grouping and use of median values

Method A groups the hourly values for all parameters into periods with expected similar characteristics, e.g. a winter day or a summer weekend. Typical 24-hour profiles are then derived from calculating median values for all values considered in the period. This method is simple and easy to implement. However, potentially decisive differences in the characteristics of profiles might get lost due to the use of median values in the generated profiles. The following description shows potential grouping options for this method that might be used.

Method A derives representative typical days by grouping the year according to seasonal and operational characteristics and assigning representative hourly profiles to each group. The grouping should reflect the main drivers of system operation, such as seasonal heat demand, district heating supply and return temperatures, waste heat availability, electricity prices, maintenance periods, and differences between weekdays and weekends.

The six typical day categories already provided in the workbook (see section 5.3, Table 4) can be used as a starting point by users. This structure reflects the most relevant seasonal and weekday/weekend variations for typical district heating operation, while keeping the number of profiles manageable. Users can adapt this structure by splitting the winter category into weekday and weekend, for example, using the additional typical day columns provided in the workbook.

For each group, collect the available hourly time series for all required input variables. Representative 24-hour profiles are then derived by calculating median values for each hour using all values for this specific hour of the day within each group (e.g. winter day). Usually, electricity prices are the dominant operating variables deciding on the economic performance of the system. Therefore, all hourly values in a group (e.g. winter day) may first be sorted from lowest to highest electricity prices, then split into 24 slices and for each of these 24 slices the median value for each parameter is used in the typical day profile.

The annual weighting of each typical day corresponds to the number of days represented by the respective group. These weighting factors are entered on the **'Definition of Typical Year'** sheet and are automatically normalised to 100 % by the tool.

Method B: Automated compilation using statistical clustering

Method B derives representative typical days from hourly data by applying statistical clustering techniques. Instead of defining groups manually, the algorithm identifies days with similar operating characteristics and determines a representative day together with its annual weighting. Consequently, the typical days emerge from the data itself rather than from predefined seasonal categories.

Compared with Method A, this approach captures the interactions between all relevant variables simultaneously. For example, a cold day with unusually high electricity prices is treated differently from a cold day with normal electricity prices, although both would belong to the same seasonal group in Method A. As a result, Method B generally provides a more realistic representation of annual system operation and is less sensitive to extreme outliers, such as short-term electricity price spikes.

A suitable clustering method is the K-Medoids algorithm, which groups days according to the similarity of their 24-hour profiles and selects an actual observed day, the medoid, to represent each cluster. Using real operating days rather than synthetic average profiles preserves the

physical consistency between all variables, including temperatures, heat demand, waste heat availability and electricity prices.

K-Medoids can be implemented using standard data analysis software such as Python or R and requires complete hourly data for all relevant variables over an entire year.

e-think has developed a tool using the k-medoids method for deriving typical day profiles for the tool. In case you wish to receive assistance in setting up representative profiles applying this method, please get in contact: hummel@e-think.ac.at.

9.2.3 Determining the SRMC of Alternative Heat Production

In addition to the technical operating conditions, representative values for the short-run marginal costs (SRMC) of the alternative heat production must be defined for each typical day. The SRMC represents the avoided heat generation costs resulting from waste heat utilisation and is therefore one of the most influential economic input parameters of the tool. Because the marginal heat generation technology varies throughout the year, the SRMC also changes with operating conditions and should therefore be determined separately for each typical day rather than as a single annual average.

Understanding the SRMC using the Merit Order

The concept of the SRMC can be illustrated using the merit-order curves shown in the following figures, taken from a study of the Linz Mitte district heating system (Moser et al., 2020[3]). In a merit-order diagram, heat generation units are arranged in ascending order of their variable heat generation costs. For a given heat demand, the last generation unit required to satisfy the demand is referred to as the **marginal unit**. Its variable heat generation costs determine the SRMC and therefore the avoided costs of the heat replaced by waste heat utilisation.

The marginal unit is not fixed but changes with heat demand, electricity prices, fuel prices and the availability of generation units. Consequently, different operating conditions lead to different SRMC values.

Figure 33 shows a typical winter operating condition with high heat demand. Since demand extends into the gas boiler range, gas boilers become the marginal technology and determine the SRMC.

[3] Moser, S., Puschnigg, S., & Rodin, V. (2020). Designing the heat merit order to determine the value of industrial waste heat for district heating systems. *Energy, 200*, 117579. https://doi.org/10.1016/j.energy.2020.117579

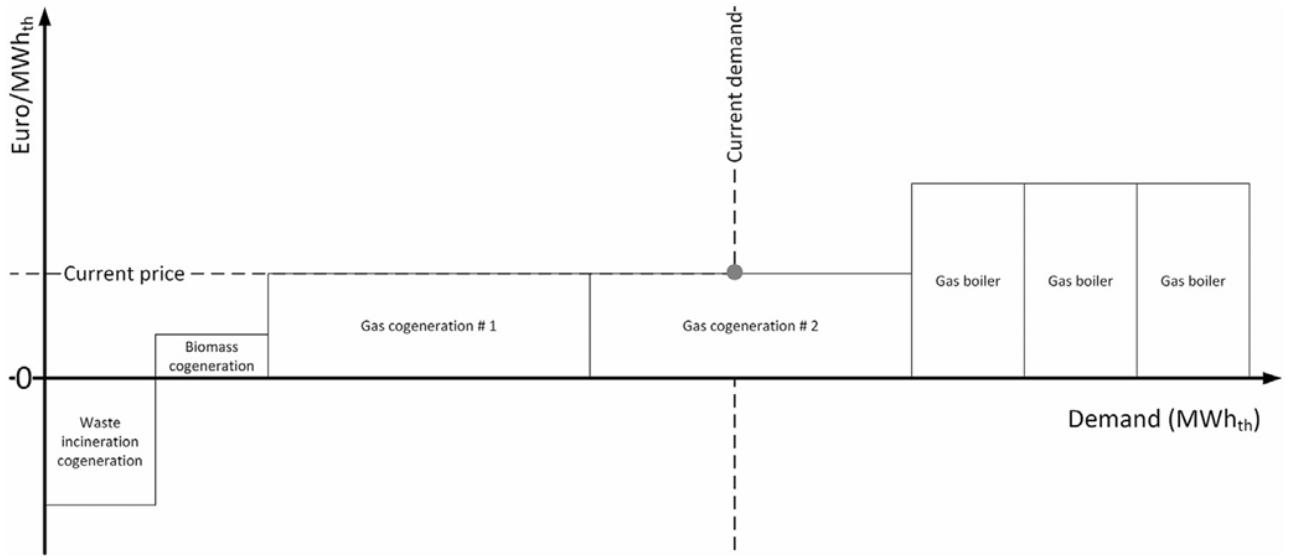


Figure 33. The predominant 15-min "Linz Mitte" Heat Merit Order in winter months (Source: Moser et al., 2020)

Figure 34 illustrates the effect of high electricity prices. As electricity prices increase, gas-fired combined heat and power (CHP) plants become less competitive and move to the right in the merit order. Consequently, more expensive technologies become marginal at lower heat demand levels, increasing the SRMC even though the heat demand itself remains unchanged.

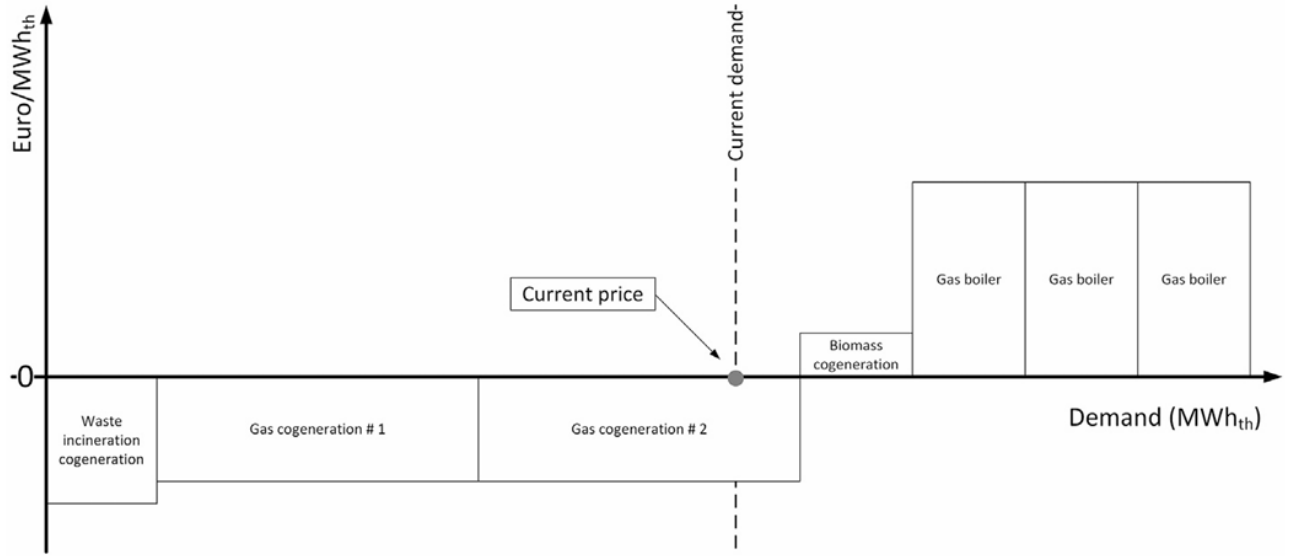


Figure 34. The 15-min "Linz Mitte" Heat Merit Order curve when electricity prices shift gas-fired CHP to the second rank (Source: Moser et al., 2020)

Figure 35 presents a typical mid-summer operating condition with substantially lower heat demand. Under these conditions, demand is met by lower-cost base-load units, resulting in a lower SRMC than during winter operation.

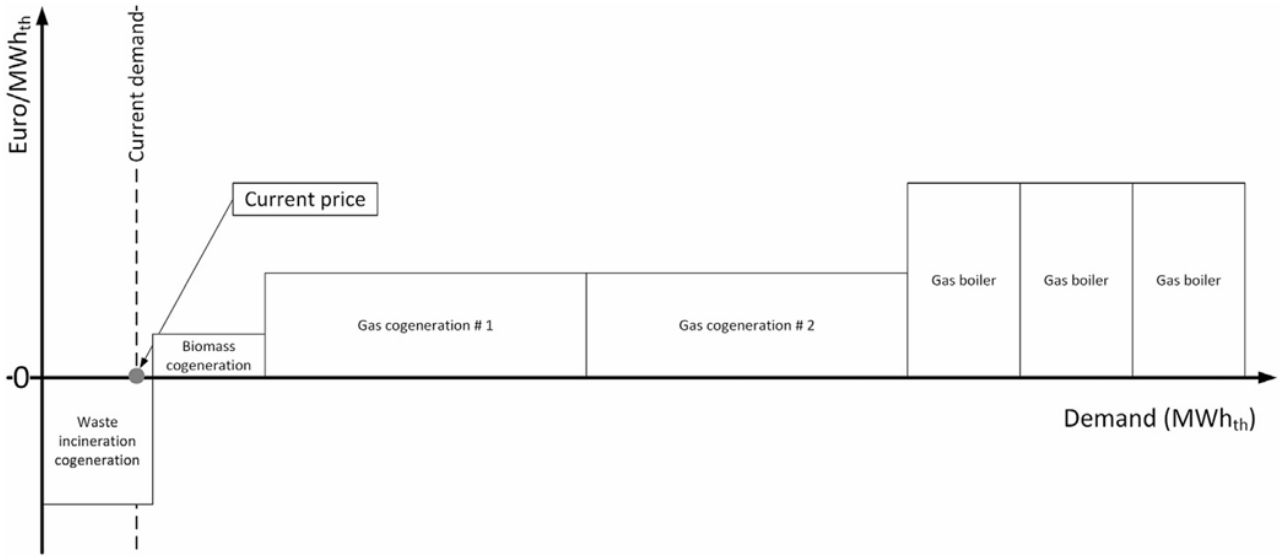


Figure 35. The 15-min "Linz Mitte" Heat Merit Order curve in mid-summer (Source: Moser et al., 2020)

Figure 36 demonstrates the effect of planned maintenance. When low-cost CHP plants are unavailable, more expensive technologies become marginal, increasing the SRMC despite unchanged heat demand. Maintenance periods should therefore be represented by a separate typical day whenever they have a significant influence on system operation.

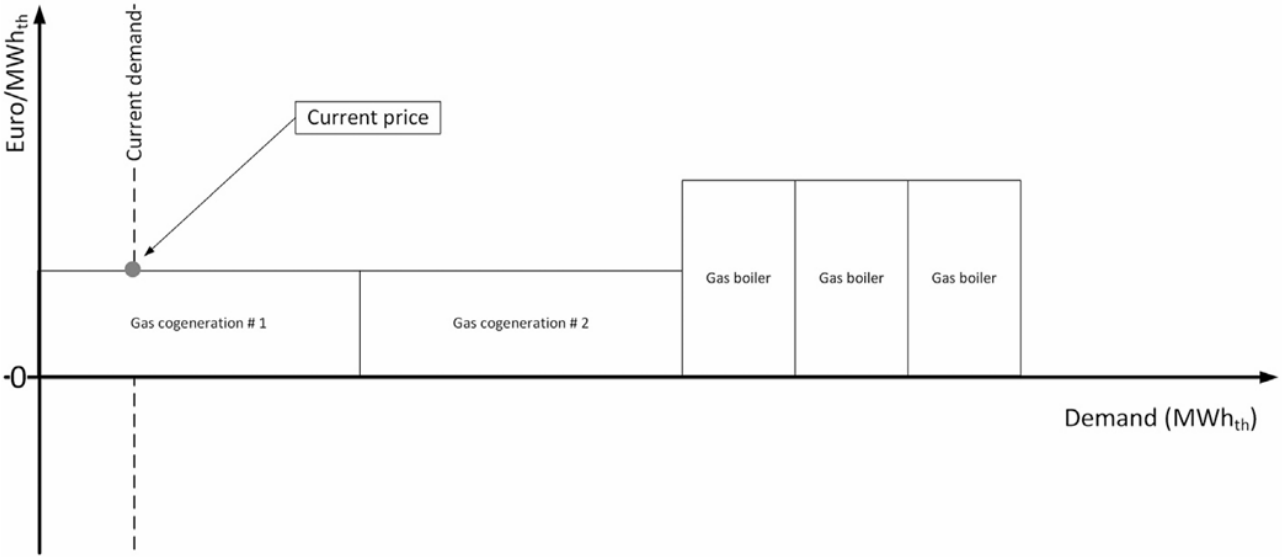


Figure 36. The 15-min "Linz Mitte" Heat Merit Order curve in mid-summer when the low-cost CHP plants undergo maintenance (Source: Moser et al., 2020)

These examples illustrate why a single annual average SRMC is generally insufficient. The marginal heat generation technology and its associated variable costs change considerably throughout the year depending on heat demand, electricity prices and plant availability. Assigning representative SRMC values to each typical day is therefore essential for obtaining meaningful economic results.

The following two methods show how representative SRMC values reflecting this merit-order logic can be determined in practice, depending on the available data and the required level of detail.

Method A: Engineering Estimation

For preliminary feasibility studies, representative SRMC values can be estimated using engineering judgement and available operational information. The objective is not to determine exact hourly marginal costs but to assign plausible SRMC values to the selected typical days.

The following aspects should be considered:

- the expected heat demand during the typical day,
- the position of the marginal generation unit in the merit order,
- seasonal variations in electricity and fuel prices,
- maintenance or outage periods of individual generation units, and
- operational experience of the district heating operator.

This approach requires comparatively little input data and is therefore well suited for early-stage project assessments.

Method B: Derivation from Dispatch Simulations

If detailed operational data or dispatch simulations are available, representative SRMC values can be derived directly from the simulated operation of the district heating system. Suitable dispatch models for this purpose include energyPRO[4] or the Hotmaps DH supply dispatch module[5], which identify the least-cost combination of the available generation portfolio for each hour of the year via an optimisation approach.

For each simulated hour, the heat generation unit that would have supplied the marginal heat demand in the absence of waste heat utilisation is identified. The variable heat generation costs of this marginal unit correspond to the hourly SRMC. Representative SRMC values for each typical day can then be obtained by averaging or otherwise aggregating these hourly values.

This approach provides a more accurate representation of system operation but requires considerably more detailed data and modelling effort. It is therefore recommended for advanced project studies or whenever dispatch models of the district heating system are available.

[4] See https://www.emd-international.com/software/energypro
[5] See https://wiki.hotmaps.eu/en/CM-District-heating-supply-dispatch

9.3 Recommended Workflow

The following workflow illustrates a structured approach for carrying out an initial assessment with the tool. It guides the user from a first familiarisation with the model to a progressively more refined economic evaluation based on project-specific data.

Step 1: Familiarise yourself with the tool

Open the tool and review the results produced by the default dataset without changing any inputs. On the **'Calculation Break-Even'** sheet**,** verify whether a negotiating range exists under the default assumptions by checking whether contractor 2's minimum break-even price is below contractor 1's maximum break-even price. On the **'Main Results – IRR DC Operator'** sheet, review the IRR values for both contractors and observe how the results respond to changes in the negotiated waste heat price (p_1) and the selected cost-sharing arrangement. This provides an initial understanding of the economic relationships within the model before project-specific data are entered. The purpose of this step is not to assess the default case itself, but to understand the interaction between the input parameters and the resulting economic indicators.

Step 2: Replace the most influential parameters

Replace the default values gradually, beginning with the parameters that are expected to have the greatest influence on the project economics. Enter these on the sheets indicated:

- On **'Project Setting'**: Heat pump capacity and investment costs, booster capacity, project lifetime, and expected IRR.
- On **'Definition of Typical Day'**: Electricity prices for the heat pump and active cooling system, district heating supply and return temperatures, available waste heat, heat source temperatures, and the SRMC of alternative heat production. These parameters typically have the strongest influence on the results. Use representative profiles derived as described in section 9.2.2.
- On **'Definition of Typical Year'**: Weighting factors to each typical day to reflect their frequency throughout the year.
- On **'Grid Costs'**: Pipeline lengths and unit costs reflecting the actual distance and routing between the waste heat source and the district heating network.

Before proceeding to Step 3, use the **'Operation at Typical Day'** sheet to verify that the hourly operation profile is physically plausible.

Step 3: Run a first assessment

Once the most important parameters have been updated, review the key results.

- On **'Calculation Break-Even'**: Verify whether contractor 2's minimum break-even price is below contractor 1's maximum break-even price. If this condition is fulfilled, a potentially viable business case may exist. Assess the width of the negotiating range for p_1 and compare the resulting LCOH with the SRMC of alternative heat production.

- On **'Main Results – IRR DC Operator'**: Assess whether contractor 2 achieves its expected IRR at a plausible value of p_1. Check whether the warning indicator for contractor 1 appears and evaluate how changes in p_1 affect the economics of both parties.
- On **'Main Results Extended'**: Compare IRRs, investment requirements, and break-even prices for both contractors to confirm whether a mutually beneficial agreement appears feasible.

Step 4: Perform a sensitivity analysis

After the first assessment, test the robustness of the results by varying the most influential assumptions.

- Vary electricity prices to assess the sensitivity of IRRs and break-even prices to energy costs.
- Reduce the assumed waste heat availability by 10 – 20 % to simulate seasonal fluctuations or lower-than-expected performance.
- Compare scenarios with and without subsidies to quantify the project's dependence on public support.
- Vary the cost-sharing arrangement for the waste heat recovery system to evaluate whether alternative allocations improve the business case for either contractor.
- Document the resulting changes in the key performance indicators rather than focusing solely on individual scenarios.

Step 5: Refine and adapt

If the initial assessment indicates that a viable business case may exist, refine the inputs progressively. Where greater accuracy is required, replace seasonal averages with representative profiles derived from detailed time-series data using the clustering method described in section 9.2.2. Obtain investment cost quotes from suppliers to replace catalogue-based estimates. Align SRMC assumptions with the actual generation portfolio or dispatch model of the district heating operator.

For projects outside Germany, adapt investment costs, energy prices, and subsidy schemes to the relevant national context. For waste heat sources other than data centres, such as supermarkets or industrial facilities, adjust the typical-day profiles to reflect the specific availability patterns and temperature levels of the respective heat source.

The refinement process should continue until the remaining uncertainties no longer materially influence the investment decision.

9.4 Important Considerations

The tool is intended for preliminary techno-economic assessments of waste heat integration projects. While it provides a transparent and robust basis for comparing different project configurations and contractual arrangements, the results should always be interpreted in the context of the underlying assumptions and the quality of the input data. The following aspects should therefore be considered when applying and interpreting the results.

Interpretation of the results

The calculated IRRs, break-even prices and levelised heat costs are only as reliable as the input data. Uncertainty in electricity prices, waste heat availability, investment costs and the SRMC of alternative heat production can significantly influence the results. It is therefore recommended to test the robustness of the results by performing sensitivity analyses and, where appropriate, evaluating alternative scenarios.

Time-dependent project conditions

The tool represents a typical operating year and assumes that the defined technical and economic conditions remain constant over the project lifetime. If major changes are expected, such as increasing electricity prices, changing district heating temperatures or future extensions of the district heating network, users should analyse several scenarios representing different stages of the project lifetime rather than relying on a single dataset. The tool should therefore be regarded as a decision-support model rather than a forecasting model.

Importance of the SRMC of alternative heat production

The SRMC of the alternative heat production is one of the most influential parameters in the tool because it determines the avoided heat generation costs for the district heating operator. As discussed in section 9.2.3, representative SRMC values should be derived separately for each typical day. Particular care is warranted for district heating systems with several competing heat generation technologies. Together with the full load hours of the heat pump, the SRMC defines the spread between the costs incurred for operating the heat recovery system and the costs avoided by not operating the alternative heat generation unit, which is the primary source of value creation for the district heating operator.

Electricity prices and grid charges

Electricity costs strongly influence both the operating costs of the heat pump and the avoided cooling costs of the data centre. In many countries, electricity grid charges represent a considerable share of the total operating costs and should therefore be included whenever applicable. Users should also ensure that the selected electricity prices and grid charges are consistent with the contractual arrangements of the respective contractors. For Germany, for example, grid charges may account for around 10 – 15 % of the total operating costs of the heat pump and booster system.

Heat pump performance

The performance of the heat pump depends strongly on the temperature levels of both the heat source and the district heating system. Lower source temperatures or higher district heating supply temperatures reduce the COP and may also reduce the available heating capacity. Consequently, realistic operating temperatures are essential for obtaining meaningful economic results. Whenever possible, performance assumptions should be

verified using manufacturer data or project-specific performance curves rather than nominal catalogue values alone. A reduced temperature spread between the district heating flow and return lines, compared with nominal design conditions, also reduces the thermal capacity delivered by the heat pump at a given electrical input, since the achievable increase in volume flow is limited. This effect should be considered when assessing the available heating capacity under real operating conditions.

Interpretation of the break-even price

The calculated break-even prices represent the minimum (contractor 2) and maximum (contractor 1) economically acceptable waste heat prices under the specified assumptions. They should therefore be interpreted as a negotiation range rather than as a recommended market price. The final contractual heat price will additionally depend on risk allocation, investment responsibilities, contract duration and the bargaining position of both parties.

Role of subsidies

Break-even prices are calculated using the complete set of project assumptions. Consequently, any investment or operational subsidies specified in the **'Project Setting'** worksheet are automatically reflected in the calculated break-even prices. It is therefore important to consider which types of subsidies are relevant and meaningful for a given project. Investment subsidies for the heat pump or connecting infrastructure reduce the capital costs to be recovered and therefore widen the negotiating range, while operational subsidies for the waste heat delivered directly increase the value attributed to waste heat utilisation. Users should verify which subsidy schemes are applicable in the relevant jurisdiction and clearly document their assumptions, since the calculated business case can depend strongly on the availability and design of such support.

Differences between the two contractors

The two contractors are affected differently by the project, as summarised in Table 1 (chapter 1). These different investment and revenue structures should always be considered when interpreting the calculated IRRs and negotiating the cost allocation. A business case should therefore always be evaluated from the perspective of both contractors, as a project that appears attractive for one party may not be economically viable for the other.

Typically, the investment required by the data centre operator is comparatively low, often below EUR 1 million, with earnings arising from avoided electricity costs for active cooling, generally in the range of 10 – 20 % of the investment per year, and potentially from a negotiated price for the waste heat delivered. The district heating operator, by contrast, usually faces substantially higher investment requirements, often well above EUR 1 million, with earnings arising from the spread between the avoided costs of alternative heat production and the costs of operating the heat recovery system.

Tool limitations

The tool is intended to support feasibility studies and the comparison of alternative project configurations. It simplifies certain aspects of real project development and does not replace detailed engineering design, hydraulic network calculations or dispatch optimisation models. As project planning progresses, the input data should therefore be refined using project-specific measurements, supplier quotations and operational data to improve the reliability of the assessment.

10 Troubleshooting & FAQ

10.1 Common User Errors

Most calculation errors can be traced back to incomplete inputs, inconsistent parameter values, or unintended modifications of worksheet formulas. The following list summarises the most common issues encountered when using the tool and provides guidance on how to resolve them.

- **Circular reference warning:** This warning can occur if formulas are accidentally modified or if a formula references its own calculation chain. Check the **'Calculation IRR'** and **'Calculation Break-Even'** worksheets and verify that only designated input cells have been edited.
- **#DIV/0! errors:** These errors are typically caused by missing, incomplete, or zero input values used in the calculations, particularly for heat delivered or CAPEX. Ensure that all mandatory input fields in **'Project Setting'** and **'Definition of Typical Day'** are completed before reviewing the results.
- **Incomplete or inconsistent results:** Check that all inputs in **'Project Setting'** are complete and internally consistent before interpreting the results. Compare key assumptions with the default dataset where appropriate and use the **'Operation at Typical Day'** worksheet to verify that hourly operation profiles are physically plausible.
- **Unexpected economic results:** Review the input assumptions for electricity prices, heat demand, investment costs, expected IRR, and operating hours, as these parameters have a significant influence on the calculated economic indicators.

10.2 Excel-Specific Issues

Some issues are related to Microsoft Excel rather than to the calculation methodology itself. The following recommendations address common workbook and calculation problems that may occur during use.

- If formulas do not update automatically, press Ctrl + Alt + F9 to force recalculation of all worksheets. If the problem persists, verify that Excel is set to Automatic Calculation under the calculation options.
- If charts appear blank, check that all numerical inputs are complete and that values have not been entered as text. Blank charts may also indicate that required input data are missing or that no valid operating results have been calculated.
- Only cells designated as user input fields (identified by the user input colour) should be edited. Overwriting formulas or protected cells may result in calculation errors or incomplete outputs.

10.3 Resetting Calculations or Clearing Inputs

When analysing multiple projects or scenarios, it is important to preserve the integrity of the workbook. The same rule on editing only designated input cells (see above) applies when resetting or clearing a project.

To start a new project, clear the inputs in the **'Project Setting', 'Definition of Typical Day',** and **'Grid Costs'** worksheets, without deleting or modifying any formulas.

For repeated use, it is recommended to save a clean template copy of the workbook and work on separate copies for each project. This ensures that the original workbook remains unchanged and allows different project scenarios to be documented and compared without affecting previous analyses.

If none of the above steps resolve the issue, please contact e-think at office@e-think.ac.at for further support.