KNOW HOW HP

D3.2

Training material for installers

Public Report

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Project information

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About the project

The objective of the three-year project KnowHowHP is to upskill installers and professionals with an integral planning process to increase the use of heat pumps (HP) in existing multistorey buildings. HP is increasingly used in single-family homes rather than in existing apartment buildings.

Increased use of HP in this field helps to fulfil the EU's climate and energy goals and the European Green Deal. The training and qualification of planners and installers are crucial to ensure that HP and refurbishment concepts are optimally aligned; otherwise, these refurbishments and the transition to HP are just not realised with the argument that it is not -feasible.

The special KnowHowHP training and upskilling consists of a knowledge-based software-supported process. That means planners, energy consultants, and installers get upskilled with an integral planning and implementation process for climate-friendly and socially acceptable refurbishments of multi-family houses with HP.

Such planning offers the following advantages: better quality, simpler, faster, more robust planning, better planning documents, more planning reliability (lower risk, error prevention) and better scalability (higher renovation rate). The basis for these planning instruments is the latest research results deducted from various projects and through in-depth investigation. The project consortium consists of three scientific and four knowledge dissemination partners, all with many years of experience in training courses.

In this composition, the existing training offers and planning processes are first analysed (WP2), and then the new KnowHowHP training and digital toolbox are developed (WP3+4). The dissemination partners will then pass this knowledge to the target groups of installers and professionals (WP5). At the same time, strong communication with all stakeholders involved, including the owners of the buildings, will be ensured to disseminate the content beyond the project area and duration.

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1. Project background and WP3 scope

The project has been conceived to meet the pressing need for high-quality training and holistic planning strategies that enable professionals to integrate heat pumps (HP) effectively into multi-storey building renovations. While the benefits of heat pumps — reduced energy consumption, lower greenhouse gas emissions, and improved occupant comfort — are well documented, their adoption in large residential complexes has proceeded more slowly than in single-family homes. Several causes contribute to this discrepancy, ranging from the heightened complexity of multi-apartment hydraulic systems to the logistical challenges of coordinating work in buildings with diverse ownership and occupancy patterns. Recognizing these realities, the project leverages both established knowledge and cutting-edge methodologies, aiming to equip planners, energy consultants, and installers with the necessary competences and collaboration frameworks to design and execute robust HP retrofits in large-scale dwellings.

The broader project context underscores the importance of an "integral planning process," in which interdisciplinary teams — spanning architecture, HVAC engineering, building physics, and property management — work in tandem from the early conceptual phase. Previous initiatives have demonstrated that failing to involve key stakeholders at the design stage can result in misaligned technical solutions, occupant dissatisfaction, or missed opportunities for energy savings. The approach promoted by the project draws upon lessons learned from related LIFE CET and Horizon 2020 efforts, as well as from national research projects, which consistently emphasize that training and capacity-building must be embedded in actual project workflows to spur meaningful changes in professional practice.

Within this project, Work Package 3 (WP3) occupies an important role. A key group are the installers of heat pumps. In their training, the focus is usually on the HVAC-specific features of the installers. To achieve optimum results, especially in the renovation sector, further knowledge is required beyond the pure installation and planning of heat pump systems.

An adaptation of training and further education is essential to supply the existing building stock with heat pumps and to achieve the required number of installed heat pumps, higher efficiency, flawless execution, and an integral planning approach are necessary.

An integral planning approach is crucial for efficiently operating heat pumps in existing buildings. This integral planning does not currently play a role for installers. Therefore, the training and further education of installers must cover topics such as the building envelope. Improving the building envelope leads to a reduction in the flow temperature and, thus, to greater efficiency of the heat pump. The training material developed here is specially designed for installers. To check the quality of the training material, it will be evaluated in a pilot phase with trained installers, and improvements will be made as necessary.

The overarching framework for this work is the integrated refurbishment approach defined in Deliverable D2.4 (Integrated Refurbishment Approach Document). D2.4 considers heat-pump

integration in existing multi-family buildings as part of a wider refurbishment concept in which the building envelope, heat demand, heat-emission and hydraulic systems, domestic hot water, the heat-pump system and source, acoustics, space, costs and implementation are addressed together. It explicitly recommends that WP3 develop installer-oriented material on the practical implications of this approach. The training material described in this report translates the approach into the perspective of installers. In line with D2.4, the term integral planning process refers to the iterative pre-design activity in which technically and economically viable refurbishment and heat-pump-system options are developed and compared.

2. Knowledge gap of installers

The “Knowledge Transfer” in Work Package 3 reveals target group-specific (installers) gaps in the area of the integral planning approach on training material.

It is based, among other things, on the results of WP2. In particular, the summarized results of T2.2, which are described in Deliverable 2.1. For WP3, the findings on teaching materials for installers are particularly relevant. In a survey and interview (see WP2, D2.1), target groups (installers) were also asked about relevant gaps in training and courses.

Existing training and planning materials for installers were reviewed with regard to integral planning approaches.

The existing courses and course materials showed that the planning and project documentation for heat pumps and integral planning for newly constructed buildings are particularly well prepared.

However, major gaps were identified in the area of integrated planning for renovations with heat pumps.

In particular with regard to:

- Radiators (capacity) - general
- Radiators with various supply temperature
- Radiators in combination with floor/wall heating systems
- Interactions between heat demand and heating systems
- Interactions between renovations and required supply temperatures
- Supply temperature (room by room)
- Lowering supply temperature (specific rooms) (iterative approach)
- Hydraulics in renovation
- Heat load calculation in refurbishments (measured, simulated)

D2.1 shows the knowledge gap. Chapter 3.2.2 shows the technical skills and professional training deficits. The most immediate and widely reported gaps concern the technical design and operational understanding of heat pump systems, especially in the context of large, diverse, and structurally complex residential buildings. Installers and planners alike indicated insufficient exposure to the principles of system dimensioning under partial-load conditions, thermal zoning, and variable-speed control integration. This is particularly critical for retrofits, where legacy heating distribution systems – often radiators designed for high-temperature supply – require careful recalibration or replacement to function efficiently with low-temperature heat pumps.

Installers reported a lack of structured training on commissioning protocols and hydronic balancing in multi-apartment settings, where the combination of high-performance expectations and low tolerance for service interruptions creates additional pressure. While some training offers exist, they are often perceived as generic or tailored to single-family contexts. Several interviewees noted that they learned critical skills "on the job" and that structured pathways for formalizing this knowledge remain absent.

In D2.1. chapter 4 shows the recommendations for training development in general.

Chapter 4.3 especially for installers:

“Installers in the context of multi-storey refurbishment are typically highly experienced, often with more than a decade of practice. Their work involves adapting system designs to actual site conditions, managing installation sequencing, and resolving unforeseen issues during implementation. Most rely on manufacturer-specific tools for sizing and configuration, and early involvement in the design phase is rare.

The typical environment they encounter is characterised by confined technical rooms, difficult access to distribution lines, restrictive acoustic regulations, and legacy radiator systems designed for high-temperature operation. Documentation is often incomplete, and the quality of prior planning varies, requiring installers to improvise on site.

Installers frequently hear demands from clients and residents for minimal disruption, quick completion, and reliable comfort. They receive specifications from planners that may not fully reflect on-site constraints, and manufacturer updates on new products, refrigerants, and controls. Their main pain points are the lack of standardised commissioning protocols for multi-storey systems, the challenge of integrating low-temperature systems into existing high-temperature networks, limited familiarity with digital monitoring and remote fault diagnosis, and difficulties in achieving Legionella-safe hot water temperatures without compromising efficiency.

Desired gains include step-by-step commissioning checklists and mobile applications for on-site support, training that bridges planning intent with practical constraints, skills for optimising systems under partial load, and early-stage involvement to identify logistical and technical risks.”

D2.4 complements these findings with a role-based view of the refurbishment process. Installers and contractors are expected to identify practical conditions relating to the existing system, access, space and the distribution network at an early stage; to assess constructability, hydraulic implications, serviceability, siting and commissioning requirements during variant and concept development; and to ensure reliable installation, hydraulic balancing, controls, commissioning and handover. Installer knowledge is therefore relevant not only during installation but already when refurbishment variants are explored – which is why the training material addresses integral planning topics in addition to installation-specific content.

3. Existing and new training material for installers

In order to offer a comprehensive course content for installers, learning materials on various topics are required.

The project consortium has extensive experience in training on topics related to energy-efficient construction and heat pumps. In particular, the project partners EIV, eza!, Klim, and THRo have experience in conducting courses and creating teaching materials.

A review of existing courses shows a cumulative total of approximately 1,000 presentation slides on the topic of heat pumps in buildings. Approximately 15 percent of the slides address KnowHowHP-specific topics such as "heat pumps in existing buildings," "dimensioning of heat pumps in existing buildings," or the integral planning process. New learning materials have been created for topics that are not covered, or are only rarely covered, in the existing slides. The current versions of the slides are attached to this report as Annex.

It should be noted that the training material is not a fixed, ready-made slide deck. It consists of basic material – slides, diagrams, worked examples, calculation tools and interactive files – from which trainers can compile a course according to the format, duration and target group. For each topic, the following sections therefore describe both the content and the didactic approach used to teach it, i.e. how the material is used to make the respective relationships understandable for installers.

The training material for installers (WP3) is closely linked to the digital toolbox and the training material for planners and energy consultants developed in WP4. Both are based on the integrated refurbishment approach of D2.4 and use the same reference building (Case study B, Test Case B of WP4), but they address different roles in the refurbishment process. WP4 supports planners in the pre-design and design phase: renovation levels and heat pump concepts are calculated, compared and optimised at building level, including distribution losses, electricity demand and economic evaluation, and dynamic simulation is used for detailed planning. The target group of WP3 are planning installers, i.e. installers and master heating engineers who not only install heat pump systems but also plan and dimension them – including the room-by-room heat load calculation, the selection and sizing of the heat pump and the design of the hydraulics. In smaller refurbishment projects, and in particular when the heat generator is replaced, they are often the only ones planning the system; in larger projects, they work on the basis of the planners' specifications, record the existing system on site and implement, adjust and commission it. The training material for installers therefore covers the planning steps that planning installers carry out themselves, with the methods and tools commonly used in the trade, and links them to the integral approach and to correct implementation. Building-level variant studies with dynamic simulation, distribution and storage losses and life-cycle cost evaluation, as supported by the WP4 toolbox, are typically carried out by planners and energy consultants; where material originally developed for planners or for a mixed audience is used, these parts are shown as results and referred to WP4. The introductions to sections 3.2 to 3.5 state where the focus for installers lies.

The individual topics are described in more detail in sections 3.1 to 3.6, which follow the structure of Table 1. Two case studies from the training material are used throughout to illustrate the methods. Case study A is an end-of-terrace single-family house built in 1981; as a simple and transparent example, it introduces the room-by-room calculation of the required supply temperature and the effect of renovation measures and radiator replacement. Case study B, the "9-apartment houses", is a multi-family building built in 1960 with three storeys of three apartments each; it transfers the approach to the multi-family buildings that are the focus of KnowHowHP. The following sections state explicitly which case study is referred to. Case study B corresponds to Test Case B defined in WP4, which is also used in the KnowHowHP Training Platform described in D2.4 (https://training.knowhowhp.eu/); Case study A is an additional introductory example and is not one of the WP4 test cases.

In line with the regional adaptation principles of D2.4, the material follows a common approach for Germany, Austria and Italy, while national standards and requirements are referenced where they differ, for example for the heat load calculation (see 3.2). Time-sensitive information used in the material, such as cost data, energy prices and subsidy conditions, should be checked, dated and provided with its source whenever the material is used in courses.

Table 1: Overview of the training topics

Topic	"existing or new"
Heat Pumps (general)	
How it works	existing
COP	existing
Refrigerant	existing
Max. supply temperature	existing
Cooling with heat pumps	existing
Dimensioning/Planning (Heat Pumps)	
Heat load calculation in refurbishments	existing and new
Placement and noise	existing
Dimensioning/Planning (Heat distribution system)	
Hydraulics (general)	existing and new
Options of DHW distribution	existing and new
Options of buffer tanks	existing and new
Implementing heat distribution system	existing and new
Dimensioning/Planning (Heat dissipation system)	
Heat load (room by room)	existing and new
Radiators (capacity) – general	existing
Radiators with various supply temperature	existing (rarely) and new
Radiators in combination with floor/wall heating systems	existing and new
Integral Planning Approach	
Interactions Heat Demand – Heating System	existing (rarely) and new
Renovation of the thermal envelope	existing and new
Renovation - new required supply temperature	existing (rarely) and new
Supply temperature (room by room)	existing (rarely) and new
Lowering supply temperature (specific rooms) (iterative)	existing (rarely) and new
Soft Skills	
Communication	existing and new
"Take Fear"	existing and new

3.1. Heat Pumps (general)

As there was already sufficient training material available on all general topics relating to heat pumps, these will only be briefly described here. In the courses, these basics serve as a short refresher: the operating principle and the influence of the temperature lift on the COP are explained with schematic diagrams and the COP map, which recurs throughout the following sections, so that all participants start from a common basis before the refurbishment-specific topics are addressed. The decrease in heating capacity with decreasing heat source temperature is also explained. In both respects, heat pumps differ fundamentally from boilers, with which installers have most of their experience – this requires a change in mindset.

How it works

This section introduces the principal operating concept and main components of a heat pump. It explains the vapour-compression refrigeration cycle - evaporator, compressor, condenser and expansion valve - and how the unit extracts low-temperature heat from an ambient source (air, ground or water) and raises it, through compression, to a temperature suitable for space heating and domestic hot water. The module also introduces the main heat pump types (air-to-water, brine-to-water and water-to-water) and their respective heat sources, giving installers a shared conceptual foundation regardless of the specific system they later work with on site.

COP

This section explains how the Coefficient of Performance (COP) of a heat pump is calculated, as the ratio of heat output delivered to electrical energy input at one defined, standardised operating point. It clarifies the difference between COP, a single laboratory test value, and the Seasonal Performance Factor (SPF), which reflects the real annual average efficiency of the installed system under varying weather and load conditions. The module also covers the practical factors that influence COP on site - the temperature lift between source and supply temperature, part-load operation, defrosting cycles and hydraulic integration - so installers understand how their installation choices directly affect the efficiency the customer will ultimately experience.

Refrigerant

This section introduces the different refrigerants used in heat pumps and their relevant properties, including Global Warming Potential (GWP), flammability classification (e.g. A1, A2L, A3), operating pressure level and critical temperature. Particular attention is given to why these properties matter in daily practice, for example for system sizing, refrigerant charge limits and installation safety, and to the growing role of natural refrigerants such as propane (R290), which combine a very low GWP with the ability to reach higher supply temperatures. The regulatory background driving this shift, in particular the phase-down under the F-Gas Regulation, is also addressed, so installers understand why refrigerant choice is becoming an important and increasingly routine part of their work.

Max. supply temperature

This section addresses the operating limits of heat pumps, in particular the maximum achievable supply temperature and the factors that constrain it, such as the refrigerant used, the compressor design, and an insufficient volume flow through the condenser. It explains the direct relationship between a higher supply temperature and a lower COP, since a larger temperature lift between the heat source and the heating system increases the compressor's workload. The module compares conventional refrigerants with propane-based heat pumps, which typically achieve markedly higher supply temperatures, and discusses the practical implications of this trade-off for renovation projects in which existing high-temperature radiators are retained.

Cooling with heat pumps

This section presents the options for using a heat pump to provide cooling. It explains the principle of active, reversible cooling, in which a reversing valve inverts the refrigerant cycle so that the same unit that heats the building in winter extracts heat from it in summer, and contrasts this with passive, natural cooling, where heat is dissipated directly through a ground or water loop without the compressor running. The module also discusses practical implications for installers, including dewpoint and condensation control, the compatibility of the heat distribution system (radiators versus underfloor or wall systems) with cooling operation, and the additional control logic needed to switch safely between heating and cooling modes.

3.2. Dimensioning/Planning (Heat Pumps)

This section addresses the dimensioning and planning of the heat pump unit itself in the context of multi-family building renovations. The teaching approach starts from the heat load of the existing building and shows graphically – using diagrams of heat load and heat pump output over the outdoor temperature – how the required capacity, the operating mode and the bivalence point are derived. Siting and noise are presented with reference to the respective national requirements. For planning installers, the focus is on determining the heat load of the building – by calculation according to the standard and by checking it against the fuel consumption of previous years – on avoiding oversizing and on selecting the operating mode and the heat pump on the basis of manufacturer data. The material builds on parts of a lecture on heat load and heat pump dimensioning by Energieinstitut Vorarlberg: the difference between room and building heat load, standard, measured and simulated heat load, the operating modes and the bivalence point of fixed-speed and modulating heat pumps, and an example building with eleven apartments in which four designs – from a monovalent heat pump to one covering 50 % of the design heat load – are compared with regard to the share of the electric heating element, the electricity demand and the efficiency. The dynamic simulation on which this comparison is based is not taught to installers; only its results are used to show how the sizing affects the share of the heating element and the electricity demand. The following topics are covered:

Heat load calculation in refurbishments

This module explains how the heat pump is dimensioned based on a heat load calculation of the existing building. It covers how the calculated design heat load at the design outdoor temperature determines the required heat pump capacity, and why oversizing must be avoided, as it leads to short-cycling, reduced efficiency and increased wear.

The module then introduces the operating modes of heating heat pumps. In monovalent operation, the heat pump is the sole heat generator; this is the standard design for single- and two-family houses with ground-source or groundwater heat pumps. In bivalent operation, a second heat generator is used in addition to the heat pump, for technical or economic reasons. This used to be necessary for fixed-speed air-source heat pumps, which could only be designed for approximately 60 to 80 % of the heat load, but is no longer necessarily the case with modern inverter air-source heat pumps. Monoenergetic operation is a special form of bivalent operation in which an electric heating element serves as the second heat generator. The bivalence point is the outdoor temperature at which the second heat generator is switched on. Using diagrams of heat load and heat pump output over the outdoor temperature, the module shows why the output of a brine-to-water heat pump remains almost constant, whereas the output of an air-to-water heat pump falls with decreasing outdoor temperature, and how the gap below the bivalence point has to be covered by the second generator. Installers learn to select the operating mode that best balances investment cost, efficiency and supply security for a given refurbishment.

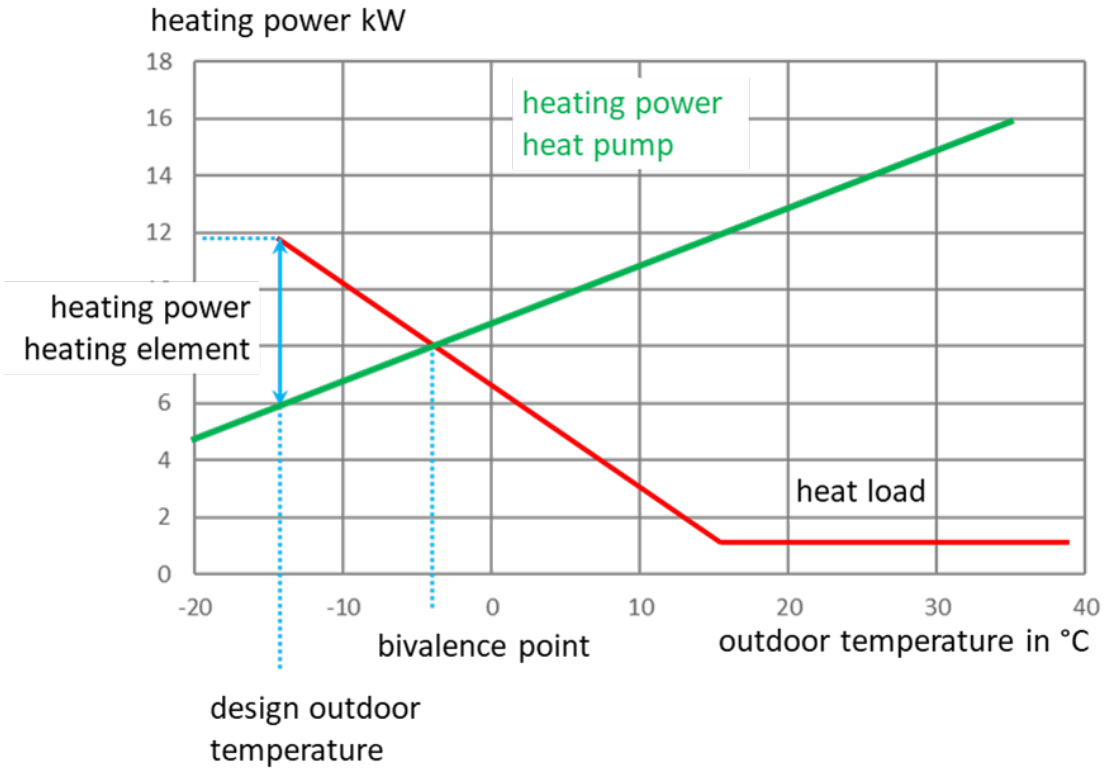

Figure 1: Heat load and heating output of an air-to-water heat pump over the outdoor temperature, with the bivalence point and the share covered by an electric heating element.

Placement and noise

This section addresses the correct placement of the (outdoor) unit and the acoustic requirements that must be observed, in particular the noise-protection limits set out in the applicable regulations (e.g. the German TA Lärm). It explains the relevant test and rating procedures for sound power and sound pressure levels, and how reflecting surfaces such as walls and corners can noticeably increase the perceived noise at the property boundary. Further practical aspects are covered, including the minimum separation distances required when flammable refrigerants such as propane are used, the risk of icing in front of the evaporator and how it is managed, the use of a night (silent) operating mode to reduce noise during sensitive hours, and the importance of a vibration- and sound-decoupled hydraulic and structural connection to prevent noise transmission into the building.

3.3. Dimensioning/Planning (Heat distribution system)

This section addresses the dimensioning and planning of the heat distribution system, i.e. the hydraulic integration of the heat pump into the building's heating network. The teaching approach is comparative: the four hydraulic concepts are presented side by side as schematics with their characteristic temperature levels, and their operating points are then plotted on the COP map. This allows installers to see directly how the choice of hydraulic concept determines the temperature level and thus the efficiency of the heat pump, and to assess which concept suits a given existing building. For installers, the emphasis is on recording the existing distribution system, selecting a suitable hydraulic concept, checking whether the existing network can carry the new flow rates, avoiding typical errors and implementing the system correctly. The following topics are covered:

Hydraulics (general)

This module introduces four hydraulic concepts for heat distribution in multi-family buildings. The options differ mainly in how space heating and domestic hot water (DHW) are distributed to the apartments, and therefore in the temperature level at which the heat pump has to operate. By these hydraulic examples, the installers should learn about the advantages and disadvantage of the different systems.

Option 1 is a 4-pipe system with central DHW preparation and DHW circulation. A central storage tank is charged at a high temperature, and DHW is distributed at around 60 °C with a circulation return of 55 °C, while the space heating circuit is supplied separately at a low temperature. Space heating can therefore run at a low temperature, but DHW preparation and circulation require high temperatures and cause additional circulation losses.

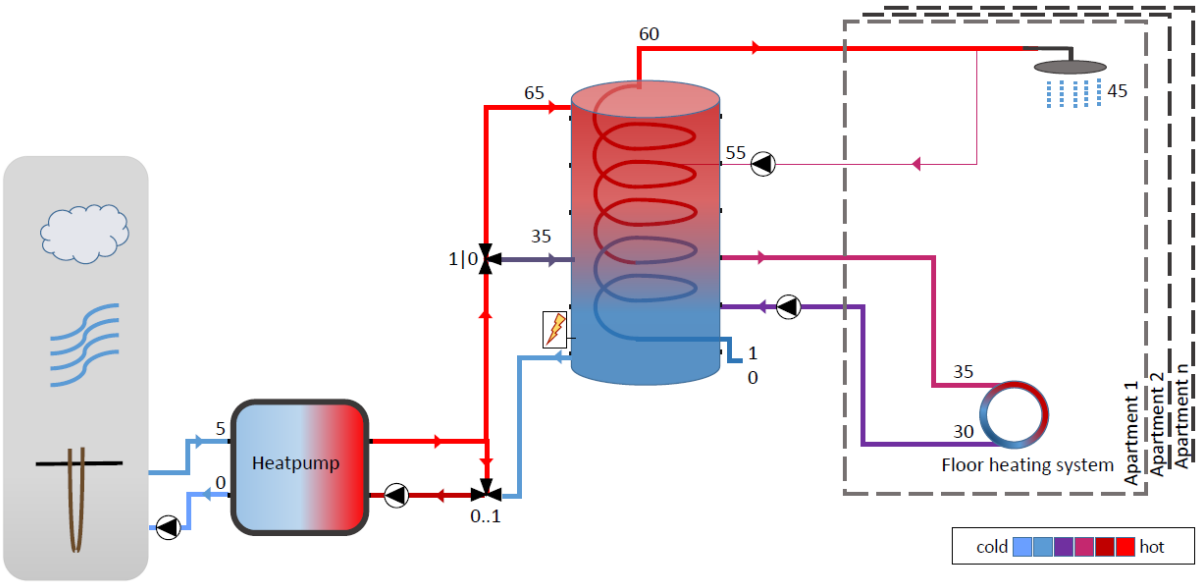

Figure 2: 4-pipe system with central DHW preparation and DHW circulation; Source: Project Interreg AB231, „Low Cost nZEB“, EIV, UIBK, THRo

Option 2 is a 2-pipe system with apartment fresh-water stations. A single network supplied from a buffer tank at around 50 °C feeds each apartment, where the fresh-water station heats DHW instantaneously and the space heating circuit is supplied via a mixing valve. This concept requires only two pipes and avoids stored DHW volumes and circulation lines, but the network must be kept at DHW temperature level all year round, which limits the efficiency of the heat pump.

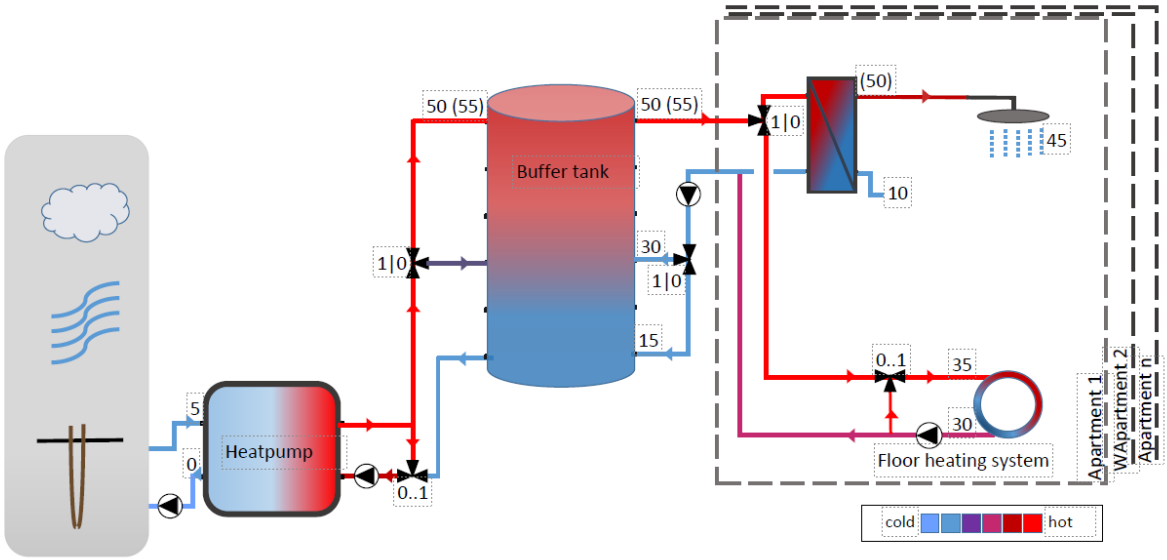

Figure 3: a 2-pipe system with apartment fresh-water stations; Source: Project Interreg AB231, „Low Cost nZEB“, EIV, UIBK, THRo

Option 3 is a 2-pipe system with decentralised electric boilers for DHW. The heat pump supplies only the space heating via a hydraulic separator and can therefore operate at the lowest possible temperature, while DHW is heated directly electrically in each apartment.

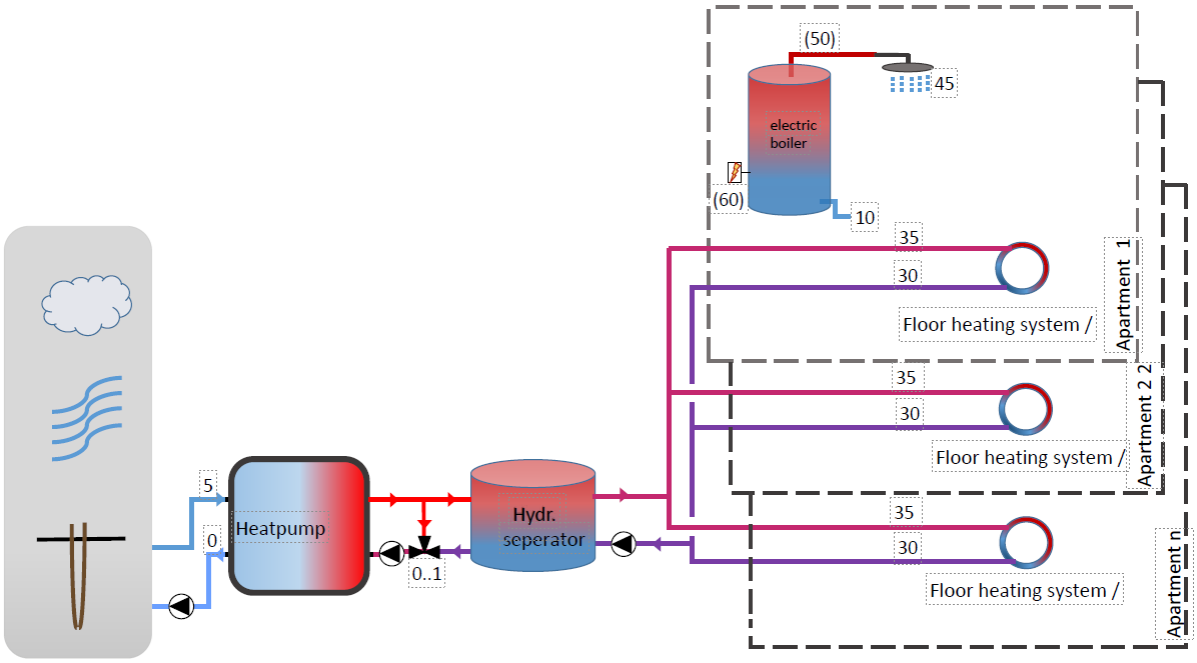

Figure 4: 2-pipe system with decentralised electric boilers for DHW; Source: Project Interreg AB231, „Low Cost nZEB“, EIV, UIBK, THRo

Option 4 is a 2+2-pipe system with apartment fresh-water stations. A separate DHW network from the buffer tank at around 50 °C supplies the fresh-water stations, while a second, low-temperature network supplies space heating via a hydraulic separator. Space heating and DHW are thus hydraulically decoupled, at the cost of an additional pair of pipes.

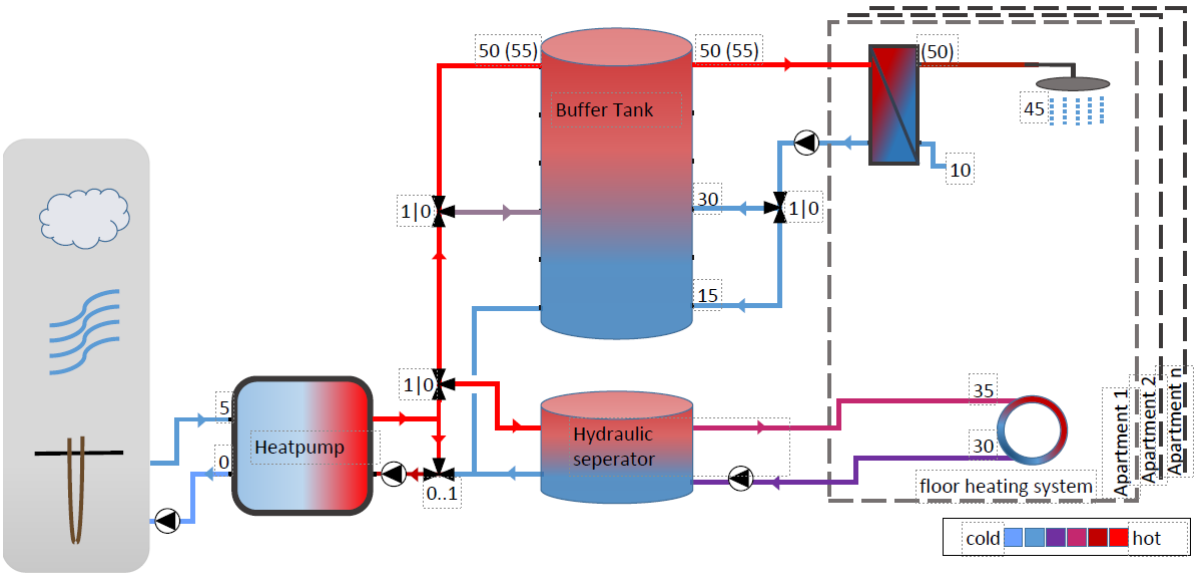

Figure 5: 2+2-pipe system with apartment fresh-water stations; Source: Project Interreg AB231, „Low Cost nZEB“, EIV, UIBK, THRo

For each option, the module explains under which conditions it is suitable for heat pumps in existing buildings. The 4-pipe system is suitable if the existing DHW distribution is already designed as a

circulation system. The 2-pipe system with fresh-water stations is suitable if the existing distribution system can be accessed centrally for each apartment and is particularly well suited to replacing existing decentralised electric boilers. The 2+2-pipe system can be used where the existing heating distribution cannot be accessed centrally for each apartment and additionally allows cooling. The 2-pipe system with decentralised electric boilers can always be supplied by a heat pump on a 1:1 basis.

Using the COP map of an air-to-water heat pump, the module then shows the operating temperatures that result from each concept. In the 2-pipe system (Figure 6) with fresh-water stations, the heat pump has to supply a constant network temperature of around 50 °C throughout the year, regardless of the outdoor temperature. In the 2+2-pipe system (Figure 7) and the 2-pipe system with decentralised electric boilers, the space heating circuit follows the heating curve, so the heat pump operates at low supply temperatures and a correspondingly high COP for most of the heating season. The module also discusses the consequences of each option for distribution losses, hygiene and installation effort in renovation projects. A key message for the integral planning approach is that the hydraulic concept determines whether lower space heating temperatures can actually be exploited: in option 2, the required DHW temperature sets a lower limit for the network temperature, whereas in options 3 and 4 any reduction of the required space heating supply temperature – through envelope measures or radiator replacement – directly improves the efficiency of the heat pump (see 3.5).

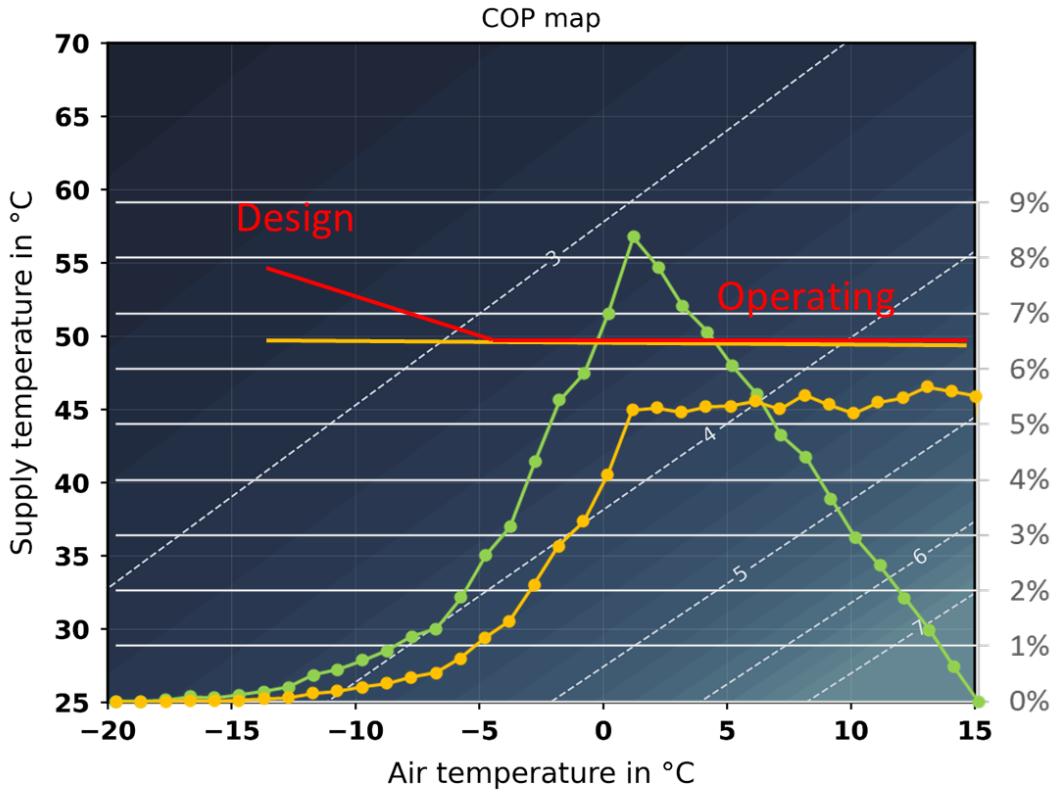

Figure 6: Design and operating points on the COP map (simplified Carnot model (η = 0.60, ΔT condenser 3 K, ΔT evaporator 6 K) of an air-to-water heat pump: constant network temperature of the 2-pipe system with fresh-water stations. (red line = radiator; yellow line = underfloor heating; green curve = proportional heating energy demand; yellow curve = heating hours)).

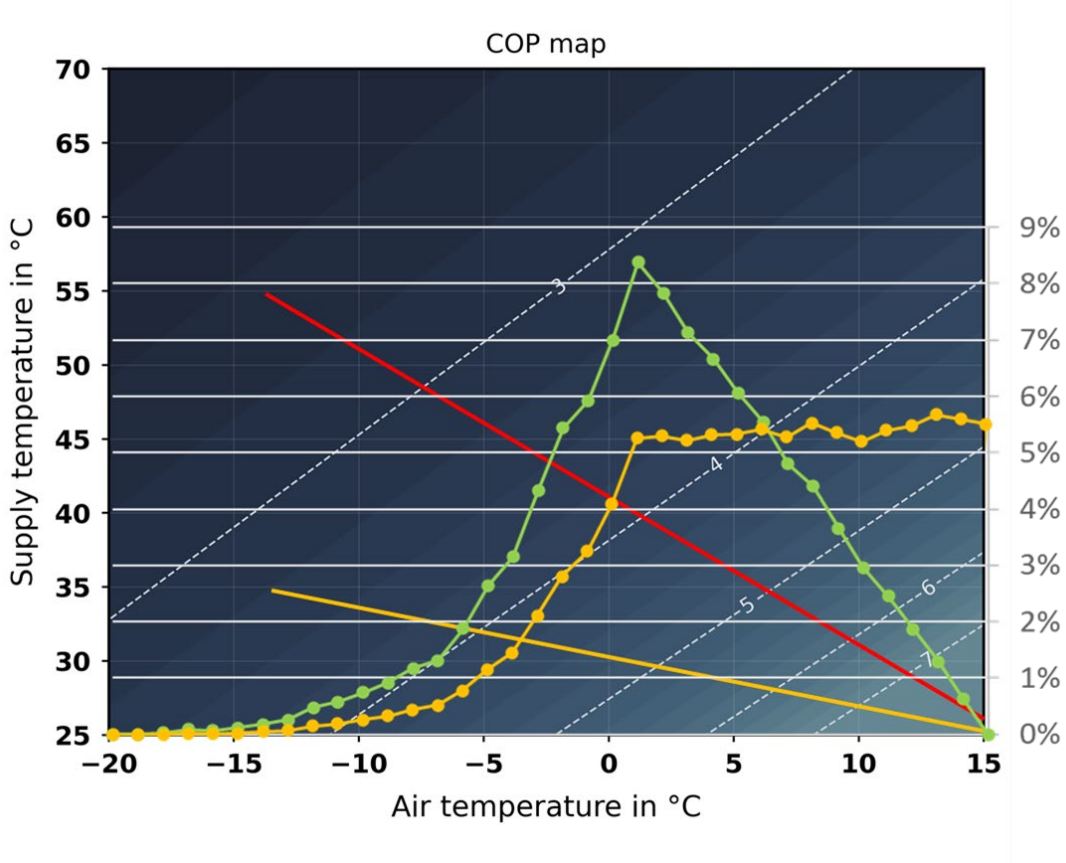

Figure 7: Design and operating points on the COP map (simplified Carnot model (η = 0.60, ΔT condenser 3 K, ΔT evaporator 6 K) of an air-to-water heat pump: the weather-compensated heating circuit of the 2+2-pipe system. (red line = radiator; yellow line = underfloor heating; green curve = proportional heating energy demand; yellow curve = heating hours)).

Options of DHW-Distribution

This section presents the different options for domestic hot water (DHW) preparation and distribution and their implications for heat pump operation. It contrasts decentralised and centralised DHW heating and introduces the main technical solutions: fresh-water stations, instantaneous water heaters, dedicated domestic hot water heat pumps, and systems with a circulation line. The module discusses the trade-offs of each option in terms of hygiene (in particular Legionella prevention), energy efficiency and the required temperature level, since a lower DHW temperature benefits the heat pump's efficiency but must be reconciled with hygiene requirements. Particular attention is given to how the choice of DHW concept affects the overall system temperature and therefore the efficiency of the heat pump. A further point specific to heat pumps concerns the DHW storage tank: tanks designed for boilers usually have an internal heat exchanger that is too small for heat pump operation. Because the heat pump supplies lower flow temperatures, the temperature difference between heating water and domestic hot water is small, so a considerably larger heat exchanger surface – for example a dedicated heat pump storage tank

with an enlarged coil, or an external plate heat exchanger – is required to reach the target DHW temperature and charging capacity without raising the flow temperature of the heat pump. Additionally the influence of the temperature spread on the COP for heating the DHW is discussed. Heating the DHW in one step from cold water to hot water temperature means the heat pump has to supply all of the DHW with the low COP of the final hot water temperature. There as heating the DHW gradually lowers the average supply temperature for DHW preparation significantly and in return improves the COP for DHW preparation.

Options of buffer tanks

This section explains the role of buffer and storage tanks in a heat pump system and the options available for their integration. It covers why buffer storage may be used - for example to guarantee minimum run times, to supply heat for defrost cycles, and to provide a heat reserve during blocking periods imposed by the grid operator - as well as the drawbacks of unnecessary or oversized storage, such as additional standby losses and higher return temperatures. Different storage concepts, including central buffer arrangements and their hydraulic connection, are presented so that installers can decide whether, where and how to include a buffer tank in a given renovation project. Particular attention is paid to mixing losses, which are especially critical in combination with heat pumps. If the volume flows on the heat pump side and the consumer side are not matched, or if the tank is poorly connected or oversized, warm and cold-water mix in the tank and the thermal stratification is destroyed. As a result, the heat pump has to produce a higher supply temperature to compensate for the mixing, and it receives a higher return temperature – both of which reduce its COP and, in unfavourable cases, can lead to high-pressure shutdowns or frequent cycling. Correct hydraulic connection, matched volume flows, suitable inlet arrangements that preserve stratification and a tank size based on the actual requirements (e.g. defrosting, minimum run times, blocking periods) are therefore essential.

Implementing heat distribution systems

This section deals with the practical implementation of the heat distribution system when integrating a heat pump into an existing building. It brings together the hydraulic concept, the domestic hot water solution and the buffer storage into a working installation, covering aspects such as hydraulic balancing of the network, correct pump and pipe sizing to keep distribution losses and return temperatures low, and the integration of the distribution system with the heat pump controls. The module highlights the typical constraints encountered on site in multi-apartment renovations - confined technical rooms, difficult access to distribution lines and incomplete documentation - and shows how to implement a distribution system that lets the heat pump operate reliably and at the lowest feasible temperature level.

3.4. Dimensioning/Planning (Heat dissipation system)

This section addresses the dimensioning and planning of the heat dissipation system, i.e. the heat emitters (radiators, floor and wall heating) that release the heat into the rooms. The teaching approach follows the calculation chain step by step – room heat load, radiator output, required supply temperature – and allows participants to carry it out themselves for individual rooms using the web-based heat load and radiator tool. Special situations such as single-pipe systems are explained with a worked example on the floor plan of a real apartment. The web-based tool has been developed in WP3 as part of the KnowHowHP toolbox. It is not intended as a planning tool for installers, but as a training tool: in the courses, participants use it to work through the calculation chain themselves and to understand how heat load, radiator output and supply temperature are related and how renovation measures and radiator replacement change the required supply temperature. Unlike the heating output calculator ("Heizleistungsrechner"; https://www.energieinstitut.at/tools/heizleistungsrechner/) of Energieinstitut Vorarlberg and Energie Tirol, which checks the most unfavourable room against the 55 °C limit according to ÖNORM H 7500-1, it covers whole apartments, renovation variants and radiator replacement. In addition, parts of a seminar on heat load and supply temperature by Energieinstitut Vorarlberg, originally held for planners and energy consultants, are used in this section and in section 3.5; for installers, only the room-by-room procedure is adopted. The following topics are covered:

Heat load (room by room)

This module explains the room-by-room heat load calculation, which forms the basis for dimensioning the heat emitters and for determining the required supply temperature in the existing building. It describes how the heat load of each individual room is determined from transmission and ventilation losses, and why a room-level analysis – rather than a single figure for the whole building – is essential in renovation projects, where insulation levels, room usage and heat emitter sizes vary considerably from room to room. The room-by-room result feeds directly into the subsequent design of radiators and the definition of the lowest feasible supply temperature.

The calculation is demonstrated according to EN 12831 and its Austrian national supplement ÖNORM H 7500-1, using the design outdoor temperature of the location and standard internal temperatures of 15 °C for WCs, hallways and heated staircases, 20 °C for living rooms, bedrooms and kitchens, and 24 °C for bathrooms. A point of particular importance in multi-family buildings is the assumption made for adjacent apartments. The standard (norm) heat load treats neighbouring apartments as unheated, with a temperature of only about 12 °C to 16 °C, which considerably increases the heat load of rooms bordering on other apartments and restricts any optimisation of the supply temperature. For the design of the supply temperature, the material therefore recommends an adjusted heat load in which the adjacent apartments are assumed to be heated to their normal room temperatures (20 °C to 24 °C). This reflects the actual operating conditions of a centrally heated building and avoids unnecessarily high supply temperatures.

Radiators (capacity) - general

This module covers the general principles of radiator capacity in existing buildings. Radiator outputs are specified as a standard heat output at standard conditions of 75/65/20 °C (flow, return and room temperature), which corresponds to a logarithmic mean temperature difference of 49.8 K. At lower supply temperatures, the output falls markedly, as described by the radiator exponent n (typically around 1.3 for panel radiators). This is a decisive factor when converting a building to a low-temperature heat pump.

The module shows how this relationship is reversed to calculate the required supply temperature of an existing radiator from the room-by-room heat load. The operating heat output is set equal to the room heat load, the required logarithmic mean temperature difference is derived from the ratio of heat load to standard output, and the supply temperature is then calculated for the respective room temperature and an assumed temperature spread (e.g. 10 K). Tables of standard outputs and radiator exponents for common radiator types and sizes support the calculation. Low-temperature (heat-pump) radiators are presented as an option for increasing emitter capacity at low supply temperatures, so installers can assess whether the existing emitters are sufficient or need to be upgraded.

Radiators with various supply temperature

In existing buildings the individual radiators have rarely been sized to a common design point: original emitters were often oversized, some rooms have already been partially renovated, and the heat load differs considerably from room to room. As a result, each radiator requires a different supply temperature to cover the heat load of its room. The module shows how this required supply temperature is determined by comparing the thermal output of the installed radiator – derived from its type, number of columns and sections, and height – with the room-by-room heat load. It then establishes the key principle for the whole heating circuit: the radiator with the highest required supply temperature determines the system supply temperature, because every room must reach its design temperature. Replacing or enlarging only the few limiting radiators can therefore lower the system supply temperature by several degrees.

To practise this procedure in the courses,, a web-based tool (“Heat Load & Radiator Tool”) has been developed as part of the training material. It runs in a standard web browser without installation, including on mobile devices, and is currently available in German and English; an Italian translation will follow. For an individual room, a simplified heat load calculation is first carried out according to EN 12831-1 (simplified method, Section 7, with the German national supplement DIN/TS 12831-1). Based on this heat load, the tool shows for each installed radiator – selected from radiator tables by type, size and number of sections – whether it covers the heat load at the existing design temperatures, which supply temperature would be required to do so and which output it delivers at the target temperature of the heat pump. Replacement radiators (panel radiators or heat pump radiators) are then proposed, and the effect of the replacement on the required supply temperature of the room is shown directly (see Figure 8). The use of the tool for whole apartments and renovation variants is described in section 3.5 under “Lowering supply temperature (specific rooms) (iterative)”. The tool is not yet fully completed: it is currently being tested and refined as

part of T3.3 and has therefore not yet been published online. It will be made available together with the teaching-ready training material

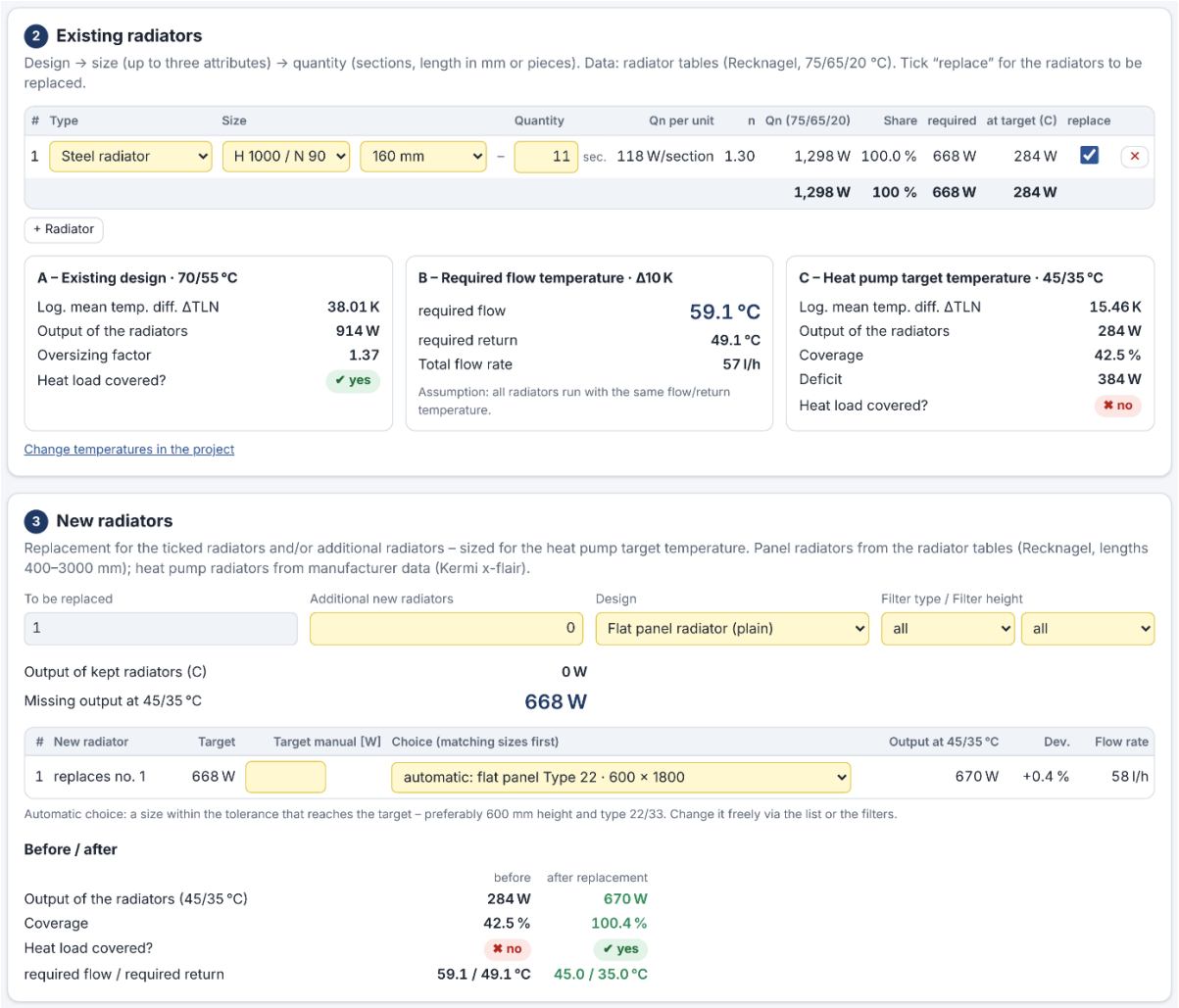

Figure 8: Web-based Heat Load & Radiator Tool (English version, bathroom of the example flat): existing radiator with output at the existing design temperatures (A), required flow temperature (B) and output at the heat pump target temperature (C), followed by the proposed replacement radiator and a before/after comparison; yellow fields = input values.

A special case addressed in the material is the single-pipe heating system, which is still found in many multi-family buildings. Here the radiators of each apartment are connected in series along a ring line fed from a vertical riser, so the heating water cools down as it passes through each radiator and downstream radiators receive a lower inlet temperature than upstream ones. The required supply temperature is therefore determined not only by the most demanding radiator but also by its position in the ring: the temperature drops across all upstream radiators have to be added on top. Applied to the top-floor apartment of Case study B (worst-case situation), the most demanding room requires 57 °C. With a temperature spread of 10 K, the kitchen and bathroom radiators located upstream in the ring add a further 1.5 K and 0.9 K, so the ring has to be supplied at 59.4 °C – well beyond the efficient operating range of a heat pump.

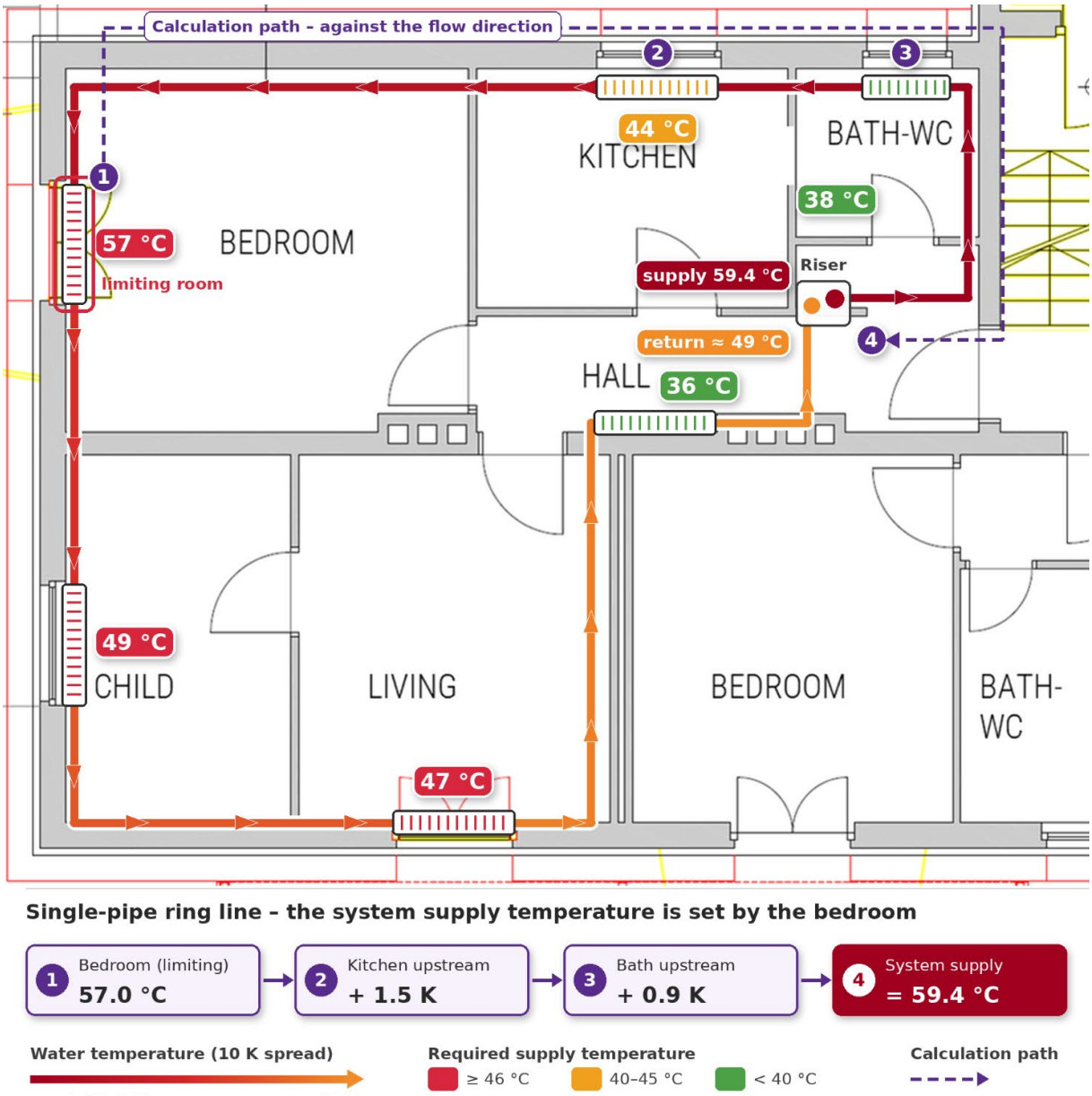

Figure 9: Single-pipe heating system with ring line per apartment and its effect on the required supply temperature in the top-floor apartment of Case study B.

Radiators in combination with floor/wall heating systems

This section addresses situations in which radiators are combined with floor or wall heating systems within the same building. It explains the option of operating separate high-temperature and low-temperature circuits, and why this arrangement should be carefully examined, since a mixed system can force the heat pump to serve the highest temperature demanded by any circuit. As with radiator-only systems, the emitters requiring the highest supply temperature - typically the radiators - determine the achievable system supply temperature. Installers learn how to evaluate such combined systems and how to configure or upgrade them so that the heat pump can operate at the lowest possible temperature level.

3.5. Integral Planning Approach

This section addresses the integral planning approach, which links the renovation of the building envelope with the design of the heating system in order to enable efficient low-temperature operation. The teaching approach is case-based: the interdependencies are first explained in principle and then worked through using Case study A and Case study B. Colour-coded floor plans and tables show the required supply temperature of every room, so that the effect of each measure and the shift of the limiting room become directly visible, and the interactive tool allows participants to explore combinations of measures themselves. The development and economic comparison of complete refurbishment variants for the building envelope remains part of the integral planning process with planners and energy consultants, supported by the WP4 toolbox. Planning installers should, however, be able to assess the effect of envelope measures and radiator replacement on the required supply temperature, identify the limiting rooms and explain realistic, step-by-step options to building owners – often they are the first to recognise such potential on site. The following topics are covered:

Interactions Heat Demand - Heating System

This module explains the fundamental interdependencies on which the integral planning approach is built. The energetic condition of the building determines the heat load; the heat load, together with the heat output of the installed radiators or heating surfaces, determines the supply temperature required to keep each room at its design temperature. Strictly speaking, it is the heat load (in kW) and not the annual heat demand (in kWh/a) that governs the supply temperature: any measure that reduces the room heat load, or increases the output of the heat emitters, allows the supply temperature to be lowered.

The module then links the supply temperature to heat pump efficiency. Using the COP map of an air-to-water heat pump as a function of outdoor air temperature and supply temperature, combined with the distribution of heating hours and the share of annual heating energy per outdoor temperature (DWD climate data), it shows that a radiator system with a design supply temperature of 55 °C operates at a markedly lower COP than a floor heating system designed for 35 °C, and that most of the annual heating energy is delivered at moderate outdoor temperatures around 0 °C rather than at the design outdoor temperature. As a guideline, good seasonal performance factors can be achieved with high-efficiency heat pumps below 55 °C, ideally below 45 °C (see Figure 7).

Finally, the module contrasts this with the reality in existing buildings, where the supply temperature is often higher than necessary: older buildings are rarely still in their original state (windows have often been replaced or the roof renovated, so the heat load is already reduced), the original radiators were frequently oversized, and hydraulic balancing is often missing. Installers therefore learn to determine the actually required supply temperature before planning – either by testing, i.e. gradually lowering the heating curve until rooms no longer reach their set temperature, or preferably by calculation.

Renovation of the thermal envelope

This module covers the renovation of the thermal building envelope and its effect on the heating system. The key principle is that the required supply temperature of a room correlates with its heat load. By reducing the heat load of individual rooms, the supply temperature of the whole building can be adjusted. Options for reducing the heat load include window replacement, external wall insulation, insulation of the roof or top-floor ceiling, basement ceiling insulation, and the installation of mechanical ventilation with heat recovery. The module emphasises that even a single, partial measure can have a considerable impact, but only if it acts on the rooms that limit the system supply temperature. It also points out two particularities of ventilation systems: heat recovery shifts the distribution of heat load between rooms, and an additional heating coil in the supply air lowers the room heat loads but not the heat load of the building as a whole.

Installers thus learn how targeted envelope measures reduce room heat loads and thereby lower the required supply temperature, so that even a step-by-step refurbishment can move a building progressively towards efficient low-temperature heat pump operation without a complete deep renovation being carried out at once.

Renovation - new required supply temperature

This module shows how renovation measures on the building envelope change the required supply temperature, and why this must be evaluated room by room. It stresses that there are many intermediate solutions between a pure boiler replacement and a deep renovation, and that partial measures can be combined with the installation of a heat pump. The approach is first demonstrated with Case study A, the end-of-terrace single-family house (built in 1981, roof already renovated, steel radiators designed for 70/55 °C, two-pipe system, gas boiler). The heat load is calculated room by room for the current state and for two renovation variants: variant 1 with new windows (Uw = 0.80 W/(m²K)) and basement ceiling insulation (8 cm PU rigid foam), and variant 2 additionally with an external thermal insulation composite system (16 cm). The building heat load falls from approximately 10.2 kW to 8.3 kW and 5.25 kW, and the required supply temperature of the building from 63.5 °C to 56.1 °C and 49.2 °C respectively. An annual energy balance according to VDI 4650 shows that the electricity demand of the heat pump decreases from about 7,400 kWh/a to 5,600 kWh/a and 4,100 kWh/a – partly because of the lower heat demand and partly because the lower supply temperature improves the seasonal performance factor.

The same approach is then applied to Case study B, the multi-family “9-apartment houses”: a building with three storeys of three apartments each, built in 1960, with box-type windows installed in 1990 (Uw = 2.20 W/(m²K)) and an insulated top-floor ceiling. Space heating is provided by a central oil-fired low-temperature boiler from 1990 supplying radiators designed for 70/55 °C (approx. 78,000 kWh or 7,800 litres of heating oil per year), while domestic hot water is prepared in decentralised, directly electrically heated storage tanks in each of the nine apartments (approx. 20,000 kWh of electricity per year). For each room, the required supply temperature is calculated for the unrenovated state and for individual measures: external wall insulation, window

replacement, mechanical ventilation with heat recovery (with and without an additional heating coil in the supply air at 30 °C), top-floor ceiling insulation and basement ceiling insulation.

	Required supply temperature in °C						
Renovation measure	**Unrenovated**	**External wall**	**Window replacement**	**MVHR**	**Top-floor ceiling**	**Basement ceiling**	**MVHR + HC (30 °C)**
GF_Apt1_Bedroom	54	43	53	51	54	51	48
GF_Apt1_Child	47	39	45	46	47	45	42
GF_Apt1_Kitchen	42	38	40	40	42	41	40
GF_Apt1_Bath/WC	37	34	35	36	37	36	36
GF_Apt1_Living	45	41	42	42	45	42	39
GF_Apt1_Hall	34	34	34	32	34	32	32
1F_Apt4_Hall	31	31	31	29	31	31	29
1F_Apt4_Living	41	38	38	39	41	41	35
1F_Apt4_Bath/WC	36	33	34	35	36	36	36
1F_Apt4_Kitchen	40	36	38	38	40	40	38
1F_Apt4_Child	45	36	43	44	44	44	40
1F_Apt4_Bedroom	50	39	48	48	50	50	45
2F_Apt7_Bedroom	57	47	55	49	51	57	46
2F_Apt7_Child	49	41	47	45	45	49	41
2F_Apt7_Kitchen	44	40	42	39	41	44	39
2F_Apt7_Bath/WC	38	35	36	36	36	38	36
2F_Apt7_Living	47	43	44	40	42	47	36
2F_Apt7_Hall	36	35	36	30	32	36	30

Figure 10: Required supply temperatures depending on different renovation measures in Case study B. (GF = ground floor, 1F = first floor, 2F = second floor, Apt = apartment, MVHR = mechanical ventilation with heat recovery; HC = additional heating coil in the supply air.)

The results (see Figure 10) show that the effect of a measure on the system supply temperature depends on whether it acts on the limiting room. In the unrenovated state, the parents' bedroom on the top floor requires 57 °C. External wall insulation lowers the highest required supply temperature in the building to 47 °C, while window replacement only achieves 55 °C. Top-floor ceiling insulation and ventilation with heat recovery considerably reduce the required temperature of the top-floor rooms, but the limiting room then shifts to the ground floor, so the system supply temperature only falls to 54 °C and 51 °C respectively; with an additional heating coil in the supply air, 48 °C is reached. Basement ceiling insulation benefits only the ground-floor rooms and leaves the system supply temperature unchanged at 57 °C.

Supply temperature (room by room)

This module presents the room-by-room determination of the supply temperature as a structured procedure. First, the heat load of each room is calculated for the planned final state, with or without renovation measures. Second, it is compared with the output of the radiator installed in that room. Third, the supply temperature required in each room is determined. The highest of these values is decisive for the system. In Case study A, the living room has a heat load of 2,130 W and is equipped with a steel radiator (5 columns, 40 sections, 450 mm height) with an operating heat output of 2,408 W, which results in a required supply temperature of 63.5 °C – the highest value in the

building. In Case study B, colour-coded result tables for all rooms (see Figure 10) make it immediately visible which ones limit the system.

The module also shows how the hydraulic concept influences the benefit of this room-by-room optimisation. In a 2-pipe system with apartment fresh-water stations, the distribution network has to be operated at around 50–55 °C for domestic hot water in any case, so lowering the space heating requirement below this level brings little benefit; only the rooms that require more than this temperature are relevant. In a 2+2-pipe system or a 2-pipe system with decentralised electric hot water heating, space heating is hydraulically decoupled from domestic hot water. Here the room-by-room required supply temperature directly determines the temperature of the heating circuit, so every degree gained through renovation or radiator replacement improves the efficiency of the heat pump.

Lowering supply temperature (specific rooms) (iterative)

This module presents the iterative procedure for lowering the system supply temperature by upgrading emitters in specific rooms. Starting from the room-by-room analysis, the radiator in the limiting room is replaced or enlarged, the required supply temperatures are recalculated, and the next limiting room is identified. This is repeated until the target temperature is reached – for example below 55 °C, ideally below 45 °C – or until further replacements are no longer economically justified. Because renovation measures change the ranking of the rooms, the iteration must always be carried out for the planned final state of the building: in Case study A, the living room is limiting in the current state, whereas the bathroom becomes limiting after the full envelope renovation of variant 2.

Case study A illustrates the effect. Because the limiting room changes with each renovation variant, a different set of radiators is replaced in each case. In the current state, replacing the radiators of the limiting rooms lowers the required supply temperature to a level comparable with that of variant 1 (new windows and basement ceiling insulation), but without any measure on the building envelope, and reduces the electricity demand of the heat pump accordingly. Combined with the envelope measures, radiator replacement lowers the required supply temperature further, to approximately 45 °C in variant 2, reducing the electricity demand to approximately 4,000 kWh/a and raising the seasonal performance factor from approximately 3.9 in the current state to approximately 4.4. Targeted radiator replacement is thus shown to be an inexpensive, low - disruption measure that can be implemented on its own or combined with envelope measures.

To support this iterative approach didactically, the training material includes an interactive, clickable PDF slide set and a web application (which is also suitable for mobile devices) developed by Energieinstitut Vorarlberg on the basis of Case study B (9-apartment houses). Participants can select renovation measures – window replacement, external wall insulation, top-floor ceiling insulation, basement ceiling insulation and radiator replacement – individually or in any combination, and the key figures update immediately: the required supply temperature of each room on colour-coded floor plans, the heat load, the heating energy demand, the electricity demand

of the heat pump, the investment costs and the annuity. The radiators to be replaced are highlighted directly in the floor plans. This allows installers to explore for themselves how envelope measures, radiator replacement and heat pump efficiency interact, and to compare the technical and economic effects of different renovation strategies. The exercise tool is intended for training purposes and is designed to illustrate interrelationships. It is not a calculation tool, and the results cannot be directly generalised. Without an introduction and additional information from the training course, the results cannot be directly applied. The annex contains a selection of these pages, showing the effect of each individual envelope measure combined with radiator replacement; the complete, clickable version is provided as part of the training material.

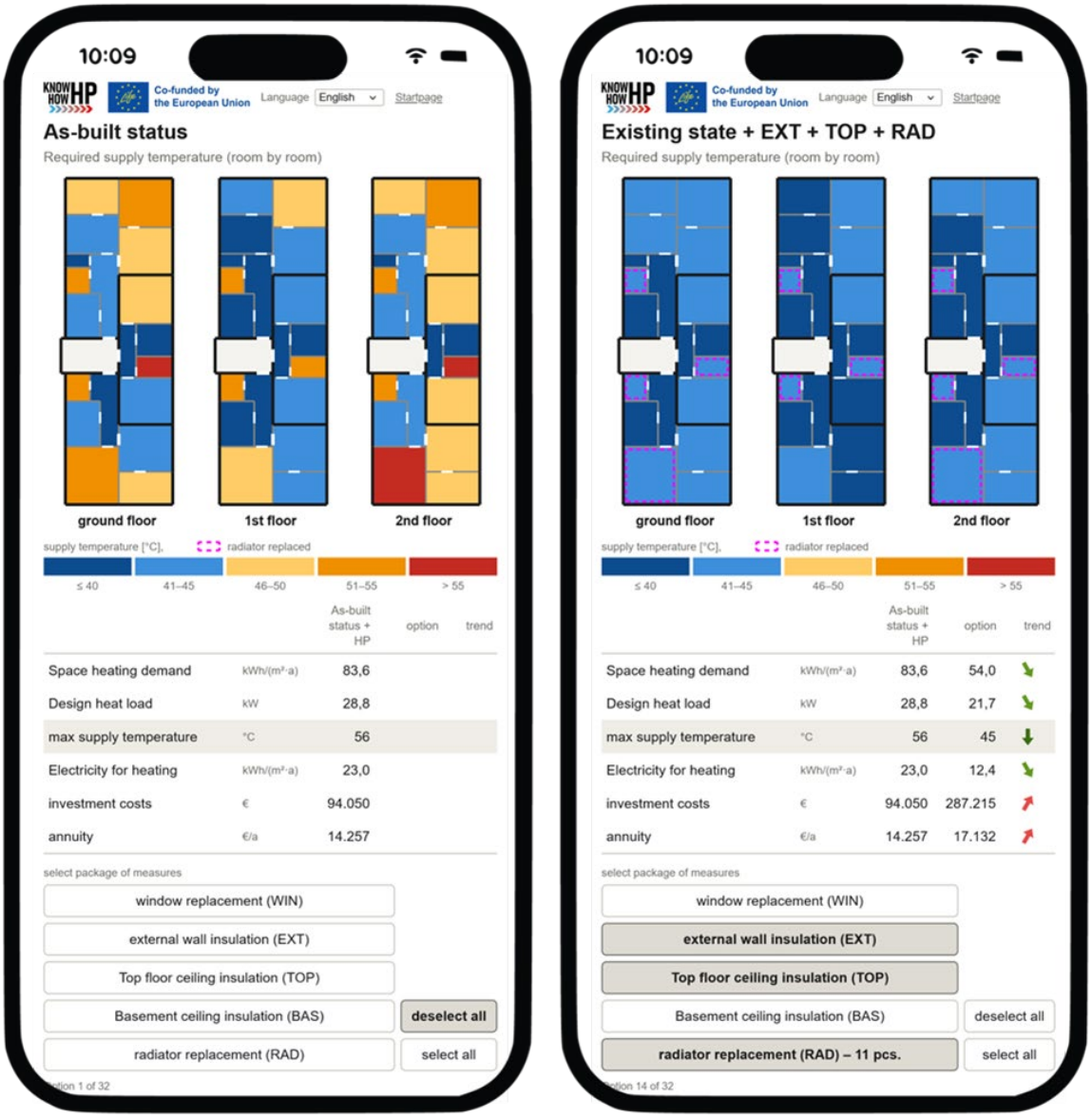

Figure 11: Interactive optimisation tool for Case study B (mobile view): as-built status (left) and combination of external wall insulation, top-floor ceiling insulation and replacement of 11 radiators (right).

While the interactive slide set and the web application of Energieinstitut Vorarlberg illustrate the interrelationships on the fixed Case study B, the web-based Heat Load & Radiator Tool described

in section 3.4 allows allows participants to practise the iterative procedure on their own example buildings. Renovation variants are defined by changing the U-values of individual building elements, and the tool calculates the heat load and the required supply temperature of each room for every variant. An overview of all rooms identifies the limiting room and the required system supply temperature, compares the variants and displays the results on a colour-coded, to-scale floor plan of the apartment (see Figure 12). Radiators marked for replacement are resized for the target supply temperature of the heat pump, and the overview immediately shows which room becomes limiting next, so that the replacement can be repeated room by room until the target temperature is reached. Unlike the exercise tool it performs a simplified calculation for training purposes for any building;; like the room-level functions described in section 3.4, these functions are still being finalised and are not yet available online. Beyond the apartment level, the web-based KnowHowHP Training Platform (https://training.knowhowhp.eu/), described in D2.4, places these questions in the context of the whole refurbishment process. Based on the WP4 test cases – including Test Case B– learners can inspect the building down to apartment and room level, combine envelope measures, heat-emission systems, domestic hot water concepts, hydraulics and heat pump systems, and follow guided scenarios, for example on the relationship between renovation depth and supply temperature. The training material for installers can therefore be combined with the platform: the room-by-room procedure is practised with the slides and the WP3 tool, while the platform shows its role in the overall refurbishment concept.

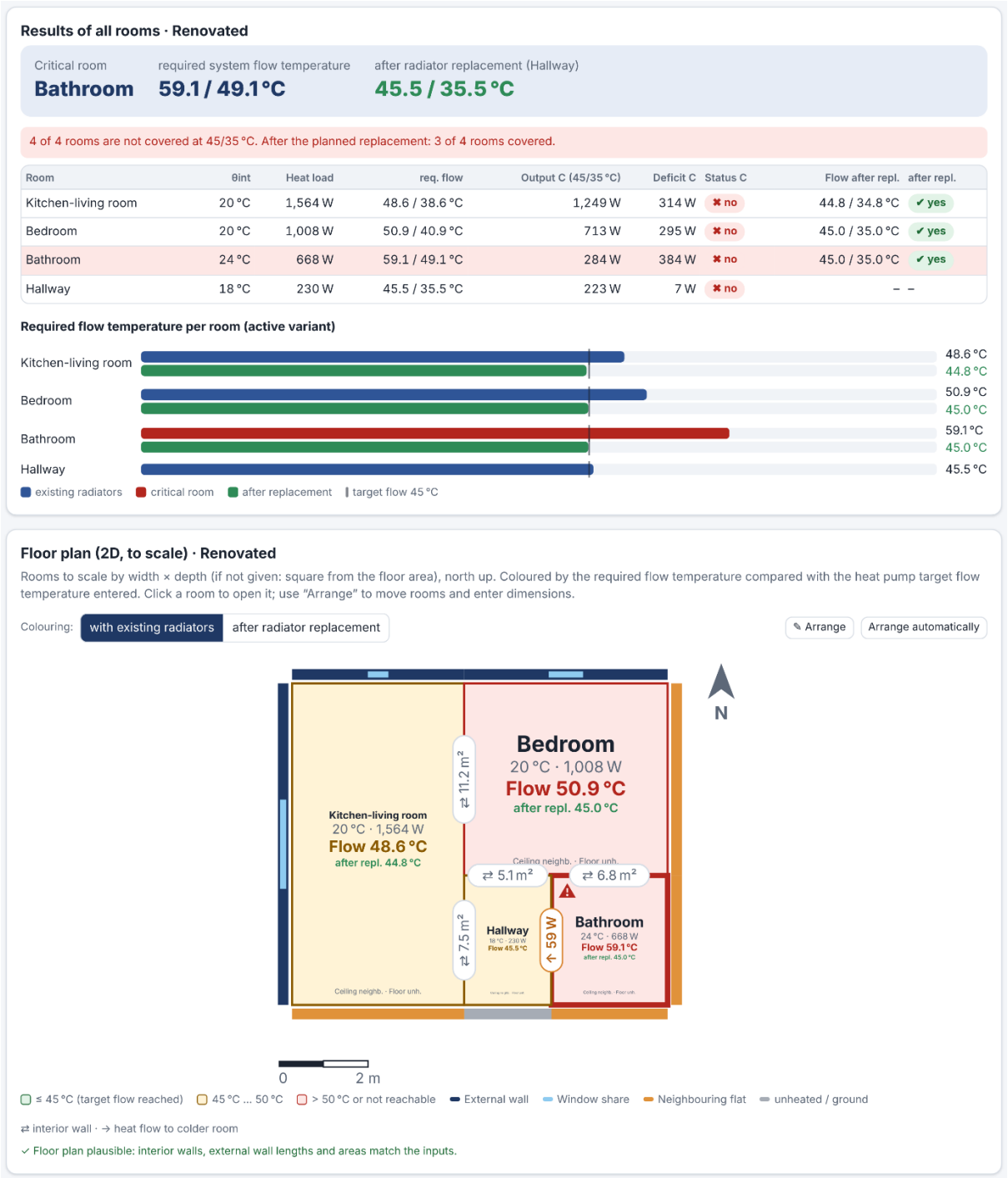

Figure 12: Web-based Heat Load & Radiator Tool, project overview (English version, example flat, renovated variant): results of all rooms with the limiting room before and after radiator replacement, required flow temperature per room and colour-coded floor plan.

3.6. Soft Skills

This section addresses the soft skills installers need for successful on-site communication with residents and other stakeholders during renovation projects. The following topics are covered:

Communication

This module addresses communication with the various stakeholders in a refurbishment project – building owners and owners' associations, property managers, residents, planners and other trades. In multi-family buildings, the decision for a heat pump is usually taken jointly, often at an owners' meeting, and depends not only on technical feasibility but also on how well the concept is explained. Installers are often the first point of contact and are perceived as practical experts, so their ability to explain the integral approach in an understandable way has a major influence on whether a heat pump solution is accepted.

A particular focus is on dealing with fears and resistance at owners' meetings. Typical concerns include doubts as to whether a heat pump works in an old building at all, fear of high investment and operating costs, worries about noise, comfort and space requirements, disruption during construction, and the uneven distribution of costs and benefits between owners and tenants. The module shows how these concerns can be addressed: by preparing the meeting together with the property management, by listening to objections and taking them up instead of dismissing them, by answering them with facts and comprehensible visualisations from the technical modules – for example the room-by-room supply temperatures or the comparison of measures and their costs – and by presenting realistic options and step-by-step paths instead of a single all-or-nothing solution. Clear, jargon-free language, references to comparable projects and an honest presentation of limitations and remaining risks help to build trust.

In addition, the module covers communication during implementation – informing residents in good time about the works, access to apartments and interruptions of heating or hot water – and at handover, when users are instructed in the correct operation of the system.

"Take Fear"

The module “Take Fear” addresses the reservations about heat pumps in existing multi-family buildings that frequently prevent projects from being realised – on the part of owners and residents as well as on the part of installers themselves. Widespread beliefs such as “heat pumps only work with underfloor heating”, “the building has to be completely renovated first” or “heat pumps are too loud for densely built-up areas” are compared with the findings of the technical modules and with experience from realised projects. These beliefs are addressed by openly explaining the causes of problems with earlier heat pump installations and by demonstrating that these causes have been eliminated – both by modern heat pump technology and by improved installation guidelines.

For installers, the module aims to reduce uncertainty about planning and implementing heat pumps in larger and more complex buildings, for example regarding dimensioning, hydraulic integration or responsibility for the efficiency achieved. It shows that these risks can be managed with the systematic approach taught in the course – a reliable heat load, the room-by-room determination of the supply temperature, a suitable hydraulic concept and careful commissioning – so that installers can recommend and implement heat pump solutions with confidence instead of advising against them as “not feasible”.

4. Outlook

This report describes the training material for installers developed in Work Package 3 (T3.2). The material has been completed in the form of presentation slides, a web-based calculation tool (still being finalised, see section 3.4)and interactive PDF files and has undergone a first round of evaluation by trainers in a first train-the-trainer workshop; a second workshop will follow as part of T3.3.

The current versions of the slides are attached to this report as Annex. Parts of the slide set were presented and discussed in the first train-the-trainer workshop; the slides are not yet teaching-ready: as part of Task T3.3 (Train the trainer for installers), the material will be further evaluated and adapted on the basis of the feedback from the train-the-trainer workshops and the first courses. Only the final, teaching-ready versions will be translated into the partners' languages (German and Italian) and supplemented by excerpts in the form of teaching videos. The web-based tool (see section 3.4) is not part of the annex, as it is still being finalised; it will be published online together with the teaching-ready material, including an Italian version of the tool and the slides.

The training courses themselves are not part of WP3. They are developed and delivered in Work Package 5 (Education and upskilling during the project period) by the dissemination partners, based on the teaching-ready material and the blended-learning teaching concept developed in T3.3, which combines classroom sessions with online self-study phases. Feedback from the courses in WP5 will be used to further improve the material.

Appendix