FuturHist

Conservation compatible solutions for HVAC and RES integration in Historic Buildings

Project Overview

Principal Authors
Marianna Muchorowska (UIBK), Federico Trentin (EURAC)

Contributing authors
Daniel Herrera-Avellanosa, Elena Poma, Alexandra Troi (EURAC), Michele Bianchi Janetti (UIBK), Marzena Nowak-Ocłoń, Małgorzata Fedorczak-Cisak, Kinga Racoń-Leja, Krzysztof Barnaś, Filip Suchoń (PK), Alejandro Moreno-Rangel (STRATH)

Internal reviewers
Philipp Hesse (ICOMOS), Marta Romero (AVRA)

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Executive Summary

This report presents a compilation of active retrofit systems suitable for historic buildings subjected to conservation requirements. Its primary objective is to gather the most commonly used HVAC integration solutions in such contexts. Each solution is evaluated according to a set of parameters defined during the task, including general information, technical and performance specifications, as well as installation and design aspects. This structured approach offers a comprehensive overview of available HVAC systems and supports the comparison and selection of the most suitable options across multiple criteria. The solutions are summarised in tables within the report, and an Excel version is also provided to enable filtering and sorting. In total, the report includes 47 active retrofit solutions.

Additionally, the collected retrofit solutions were evaluated for each building typology outlined in Deliverable 1.2. This evaluation was conducted during a collaborative workshop with project partners from FuturHist. The selection of suitable solutions was guided by various criteria, including construction characteristics, local regulations, and regional retrofit strategies. The result is a list of retrofit solutions deemed most appropriate for the specific needs and constraints of each building typology.

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Abbreviations and definitions

Active System	In this context, any system used to cover buildings' thermal needs. More specifically, any system used to cover heating, cooling, domestic hot water and ventilation demand of a building.
BACS	Building Automation and Control System
Building envelope	The "skin" of a building, consisting of exterior facing walls, roof, windows, and lower floor slab.
Building typology	A set of buildings with common properties (e.g., age of construction, geometry, thermo-physical properties, and energy performance) (IEE Project TABULA, 2012).
Demonstrator building	A real building belonging to a typology which is used to demonstrate retrofitting solutions (also referred to as "demo case" - DC).
DHN	District Heating Network
DHW	Domestic Hot Water, i.e., heating water for domestic or commercial purposes other than space heating and process requirements (ASHRAE, 2024).
Energy consumption for heating and cooling	Energy input required to satisfy the heating and cooling demand of a building. This quantity considers also efficiency and losses of systems and user behaviour (Hotmaps, 2020).
Energy demand for heating and cooling	Calculated amount of energy required to cover heating and cooling of a building (Hotmaps, 2020)
Energy retrofit	A general concept for all types of renovations where reduced energy consumption is the main goal for the renovation (Eriksson, 2021). It is used for the entire renovation process, from planning to evaluation, and is closely related to sustainable renovation (Thuvander et al., 2012). Sustainable renovation of existing buildings is a way of extending the lifespan of a building and improving its living and working conditions, which includes lowering the energy used for those purposes (Asdrubali and Desideri, 2018, chapter 9).
EU	European Union.
Flow type	In this context, it refers to the medium (generally water, eventually air, or refrigerant) flow in the heating/cooling distribution system. Using water distribution system as an example, constant flow means the mass flowrate of water in the distribution circuit is

	constant, meaning that the circulating pumps work at fixed speed. Variable flow, instead, indicates that the water mass flowrate in the distribution circuit is variable, meaning the circulating pumps can work at different speed.
Heritage value	Aspect of importance that individuals or society assign(s) to a building (EN 16883:2017). Note 1 to entry: Heritage values can be of aesthetic, historic, scientific, cultural, social or spiritual nature. These types of heritage values include various aspects, for example: architectural, artistic, economic, symbolic, technological, use, etc. Note 2 to entry: The heritage assigned value can change according to circumstance, e.g., how the judgement is made, the context and the moment in time. Value should always be indicated by its qualifying type.
HiBERatlas	Historic Building Energy Retrofit Atlas
Historic building (HB)	Building of heritage significance (EN 16883:2011) Note 1 to entry: A historic building does not necessarily have to be statutorily designated as cultural heritage. Note 2 to entry: Historic buildings are a specific form of objects, as defined in EN 15898:2011, 3.1.3.
HVAC	Heating, ventilation, and air conditioning
IEQ	Indoor Environmental Quality
Joule effect	It stands for the transformation of electrical energy into thermal energy in an emission unit. One example is an electric radiator, where an electrical resistance is used as the heating element.
Toolkit	Skills and knowledge that are useful for a particular purpose or activity, considered together (Cambridge dictionary). In the context of FuturHist a toolkit contains knowledge and guidance to support the decision-making process of implementing energy retrofits in historic buildings.
VRF	Variable Refrigerant Flow systems
WP	Work Package

1. Introduction

1.1. Background

FuturHist addresses a major challenge in Europe's path to climate neutrality: the energy retrofitting of historic buildings. Representing a significant share of European building stock, many of these buildings remain in active use as homes, offices, cultural institutions, and public facilities. Despite their cultural and architectural value, they often have poor energy performance due to outdated construction, limited thermal efficiency, and other economic, technical and legislative constraints. FuturHist aims to demonstrate that energy efficiency and heritage preservation are not mutually exclusive but can be successfully combined through the application of well-adapted retrofit strategies.

Reducing the energy demand of historic buildings can be approached from two complementary directions. On one hand, improvements to passive systems—such as better insulation of the building envelope, including walls, roofs, basements, and windows—can significantly reduce heat loss and improve indoor comfort. On the other hand, optimising or implementing active systems such as heating, ventilation, and air conditioning (HVAC) can further enhance energy performance, particularly when these systems are designed to work efficiently within the constraints of heritage buildings.

The principal goal of FuturHist is to facilitate the mass renovation of historic buildings across Europe, regardless of whether they fall under strict conservation regulations or not. While there are already many examples of successful retrofitting projects in historic buildings, these are often site-specific and rely heavily on expert knowledge and bespoke solutions. This makes it difficult to scale such interventions or to develop broadly applicable guidelines. FuturHist addresses this challenge by developing a methodology based on building typologies—groups of buildings that share common features such as construction period, climatic conditions, size, and architectural values (materials, geometry).

By focusing on typologies, the project aims to create tailored intervention strategies that can be applied more systematically, while still respecting the unique character of

each building. This typology-based approach makes it possible to recommend retrofit solutions that are both effective and compatible with heritage values, thus bridging the gap between energy performance and conservation.

Ultimately, FuturHist contributes to the broader goal of the sustainable transformation of Europe's existing building stock. Its outcomes are designed to support practitioners (such as architects and engineers), building owners, as well as policymakers, including planners and heritage authorities, in making informed decisions about energy retrofits. Researchers will also benefit from the databases and tools made available by the project to facilitate effective and sensitive renovation strategies for historic buildings across Europe.

1.2. Objectives

Task 3.1 focuses on assessing how historic buildings are conventionally retrofitted with regard to active systems, specifically ventilation, space heating and cooling, and domestic hot water preparation. The primary aim is to create a comprehensive set of existing retrofit solutions for active systems, including parameters that describe their performance and suitability. Secondly, these collected solutions will be evaluated according to the building typologies defined in Task 1.2, ensuring the assessment reflects the unique characteristics and requirements of each type. The outcomes of this task will form the foundation for developing a structured database of active retrofit solutions to support the subsequent stages of FuturHist.

1.2. Organization of this report

The report is organized as follows: Chapter 2 presents the methodology for selecting the active systems for retrofitting, with details about considered parameters, including technical and performance specifications, installation, and design aspects. Chapter 3 provides an analysis of the gathered solutions, with a comprehensive table of solutions and their parameters included in the annex. Chapter 4 discusses the potential applications and limitations of the collected solutions in relation to the defined building typologies. Finally, Chapter 5 offers conclusions and an outlook on future work.

2. Methodology

2.1. Selection of solutions

The HVAC solutions were primarily sourced from real-world cases documented in the *HiBERatlas* project (Eurac Research), with the aim of focusing on systems that are already in use rather than purely theoretical approaches. This approach has the advantage of having at least one existing real-world example of the considered solution. On the other hand, this limits the discussed solutions, and prevents the consideration of all theoretically possible options. It has been decided to use this approach as the presence of real examples has been assessed to be more important than having a collection of theoretically possible solutions without a clear connection to real cases.

The parameters used to describe these solutions were also mainly derived from the *HiBERatlas* project. Where necessary, additional information was gathered from other relevant sources to complete the dataset. The analysed resources include documents describing the active system renovation in specific historic buildings.

For each solution, a reference link with its actual application is reported.

2.2. Selection and definition of parameters

The selection of parameters used to describe the active systems was the result of discussions among project partners in Task 3.1. These parameters are grouped into three main categories: general information, technical and performance specifications, and installation and design aspects.

The goal was to structure the parameters as single/multiple choice options to allow for straightforward comparison across different systems. An overview of the parameters and their possible answers is provided in Table 1.

The following sub-sections describe the parameters used to describe the active systems, based on the three main categories mentioned above.

2.2.1. General information

For what regards the general information, each solution is described using three parameters. First, a solution name, specifically developed to include the main characteristics of the considered solution and for easy recognition and filtering of it in the database is developed. Second, a reference (a web link) with real application of the specific solution is included. Third, an example of a potential supplier of the solution is noted.

2.2.2. Technical and performance specifications

The first technical specification parameter refers to the identification of the building thermal needs that the active system should cover. The analysed solutions are meant to cover building thermal demand for space heating, space cooling, Domestic Hot Water (DHW), ventilation, or some combination thereof.

The second technical specification aims to identify the kind of active system used to cover the building thermal needs. Different options are considered, in particular, fossil fuel based (gas, oil boiler), electric heaters (based on Joule effect), renewables based (heat pumps, wood base boilers) mixed ones (hybrid systems, e.g., heat pump + gas boiler), and District Heating Network connection. Moreover, although less common, examples of systems with solar thermal panels or hydrogen have been found and reported. Finally, also the mechanical ventilation system is included in the list. There could be solutions in which the mechanical ventilation system acts in a synergic way with the system(s) delivering heating, cooling, and DHW, or it can be the only system present.

The third technical specification is strictly related to the second and aims to specify the fuel or energy sources used or consumed by the system. For some sources, such as gas, oil, wood boilers, solar thermal systems, and electrical boilers, the connection between the second and the third technical specification is quite straightforward. The definition of the source/fuel parameter is more important for heat pumps and hybrid systems. In fact, different heat pump systems can use different thermal sources (e.g., air, water, ground). Moreover, for heat pumps and hybrid systems also the fluid acting as heat transfer medium is also reported (air or water).

The fourth technical parameter is used to acquire a general indication of the

possibility of controlling the fluid (water or air) flowing in the distribution circuit. Although this information is often not available in the sources assessed, it gives a general idea about the control used and, eventually, applicable in the considered building. In fact, if the distribution system can work only with a constant flow, this, in principle, could limit some interventions to the heating system. As an example, it can be considered a building equipped with radiators and with circulating pumps that can work only at fixed speed. The eventual adoption of elements like thermostatic valves (a quite common intervention in existing buildings), with constant speed circulating pumps, can lead to problems in terms of thermal and acoustic comfort. These kinds of interventions can eventually be done with some modifications to the distribution system (in the previous example, the replacement of the circulating pumps with variable speed ones).

The fifth technical specification aims to characterize the distribution system. The distribution system is not always present by default, just in case a centralized solution is reported. It can be constituted by pipes or ducts based on the used heating medium (water/refrigerant or air). It is considered useful to evaluate if the distribution system is thermally insulated or not, as this influences the thermal losses. Moreover, the possibility to access and work on the distribution system is reported. This information is used to understand if the existing non-insulated distribution system can be thermally insulated to reduce its thermal losses.

The sixth technical parameter characterizes the emission system. The main choices are radiators, fan coils and radiant systems (which can be radiant floors, walls, ceilings). Nevertheless, in the analysed sources also air-based systems, split units and radiant panels (infrared panels) are used. If the emission system is composed of more than one technology (e.g., radiators + air-system) this is reported as “mixed”.

The seventh technical specification is used to characterize the control system and its level of automation. Although it is difficult to access this information in the analysed sources and, often, indications on this aspect are not available at all, there was an attempt to describe the control system based on the Building Automation and Control System (BACS) classification as defined in the EU directive 2018/844. This classification considers four classes. A simplified description of the different classes is:

- Class D: no automatic control
- Class C: automatic control at central level

- Class B: automatic control at single zone level
- Class A: automatic control at single zone level with also occupancy detection.

The eighth technical specification aims to understand which (if any) parameters related to Indoor Environmental Quality (IEQ) are monitored. This refers to indoor building temperature, relative humidity and CO_2 level.

The ninth technical parameter is similar to the eighth but focuses on the monitoring of energy consumption. It is considered useful to have a general understanding about which (if any) are the monitored energy consumption within the building.

The tenth technical parameter applies only to mechanical ventilation systems and aims to identify if there is any heat recovery system that can recover part of the thermal energy present in the exhaust air to pre-condition the air entering the building.

2.2.3. Installation and design aspects

The first installation and design aspect parameter aims to identify any requirements in terms of technical spaces to place the elements of the considered active system solution or part of them. Historic buildings have been constructed in periods when the active system solutions used nowadays were not available. This means that no specific spaces were accounted for and, in principle, this could limit the implementation of some active system solutions. For example, an air-water heat pump system often requires a small thermal storage tank to work properly. This parameter is kept generic (yes/no) to have a first understanding if the considered active system solution presents or not requirements on this aspect. More detailed assessments will be done in other phases of the renovation process, after evaluating the situation of the specific building.

The second parameter aims to identify if there are any constraints in terms of visibility of the active system solution elements. Historic buildings can present limitations on the installation of elements that alter the visual aspect. The definition of the parameter considers the possibility that the system is visible from outside or from inside or that is not visible from both, outside and inside.

The third installation and design aspect parameter aims to identify if the considered

solution is centralized (i.e., one or multiple heat generators installed generally in the same location and heat distributed to the building's zones through a distribution and then the emission system) or decentralized (i.e., multiple heat generators). To clarify the concept with an example, a centralized mechanical ventilation system is an example of centralized system, where air is treated by machines placed generally in the same place and then it is distributed to the conditioned building's zone. On the other side, single mechanical ventilation machines, installed in specific rooms, can be considered an example of a decentralized mechanical ventilation system. Regarding instead the heating generation unit, and considering, for example, a multi-family house, a possible centralized solution is represented by a centralized heat pump system delivering heating to all the flats in the building. On the other hand, a decentralized solution could be represented by a series of gas boilers serving one flat each.

The fourth installation and design aspect parameter is used to get a general indication about the disturbance to the occupants and or limitations/changes to the typical use of the building due to the installation of the different active systems or part of them. This parameter presents three possible answers: low, medium and high disturbance. Low disturbance can be associated with interventions that foresee a limited disturbance to the occupant as, for example, the installation of thermostatic valves on the radiators. Medium disturbance can be instead associated with interventions that present a higher disturbance for the occupants but that can be, in any case, concluded in limited time and do not foresee the users to temporarily leave their apartment. An example of medium disturbance can be associated to the replacement of radiators with fan coils. Finally, high disturbance can be associated with interventions that present a high disturbance for the occupants and a temporary (more than a couple of days) unavailability of the building in relation to its typical usage. An example of high disturbance for the occupants can be associated with the replacement of radiators with a radiant floor system.

The fifth installation and design aspect parameter aims to give a general indication about the cost of the considered solution. Three options are available: low, medium, and high. The cost of the active system is often not available in the checked sources and it should be normalized based on parameters as, for example, the conditioned area to have comparable results. In this context, an analysis based on the specific costs is used as the base to identify if a certain solution should be associated with low, medium or high cost (Fedrizzi et al.), (UBS Insights), (Cholewa et al.). The considered

cost accounts mainly for the generation units and their typology (see parameter 5, Heat Generator), as this is the main source of cost difference typically in active systems. The performed cost estimation considers mainly initial costs (investment and installation) but also some assessments have been done to also include time-dependent costs (mainly consumption and partly maintenance), as well as the lifespan of the generation system.

Table 1. Defining parameters to describe solutions in Task 3.1.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Description*
	2	Example of application	*Link to existing retrofitted building*
	3	Possible supplier	*Names of producers of active systems*
Technical and Performance Specifications	4	Function	*Multiple choice:* • *Heating* • *Cooling* • *Domestic Hot Water (DHW)* • *Ventilation*
	5	Heat generator	*Single choice:* • *Cascade Heat Pump* • *District Heating Connection* • *Electric heater* • *Electric + Gas* • *Electric + Heat pump* • *Gas boiler* • *Heat pump* • *Hydrogen-powered cogeneration system and heat pump* • *Oil boiler* • *Solar thermal panels* • *Ventilation unit* • *VRF unit* • *Wood-base boiler*
	6	Source/fuel	*Single choice:* • *air/air* • *air/water* • *District Heating Network* • *electricity* • *gas* • *ground/water* • *hybrid (air/air + electricity)* • *hybrid (air/air + gas)* • *hybrid (air/water + gas)* • *hybrid (ground/water + hydrogen)* • *oil* • *solar energy* • *water/air*

			• *water/water* • *wood-base*
	7	Flow type	*Single choice:* • *constant* • *variable*
	8	Distribution system	*Single choice:* • *not-accessible not-insulated* • *not-accessible insulated* • *accessible not-insulated* • *none*
	9	Emission system	*Single choice:* • *air-based system (AHU)* • *fan coils* • *mixed* • *panels* • *radiant ceiling system* • *radiant floor system* • *radiant wall system* • *radiators* • *split units* • *VRF indoor units*
	10	Control system	*Single choice:* • *no automatic control (BACS class D)* • *automatic control central (BACS class C)* • *automatic control multiple zones (BACS class B)* • *automatic control multiple zones with presence (BACS class A)*
	11	Monitoring system IEQ	*Multiple choice:* • *temperature* • *humidity* • *CO_2*
	12	Monitoring system Energy	*Multiple choice:* • *electric consumption* • *thermal energy consumption*
	13	Heat recovery	*Description of heat recovery options*
Installation and Design	14	Technical space required?	*Single choice:* • *yes* • *no*
	15	Visibility	*Single choice:* • *yes (from the outside)* • *yes (from the inside)* • *no*
	16	Centralized?	*Single choice:* • *centralized* • *decentralized*
	17	Installation	*Single choice:* • *low disturbance* • *medium disturbance* • *high disturbance*

	18	Cost	*Single choice:* • *low (€)* • *medium (€€)* • *high (€€€)*

3. Analysis of collected solutions

Review of active retrofit solutions is in Annex 1 and in Excel table.

This section reports a general analysis of the collected active system solutions.

The scope of this analysis is to extract some general indications about which heat generators, emission units, system control are used in the collected active system solutions.

It is important to specify here that this analysis does not represent the most common solutions adopted in general in historic buildings, as, the same solution, can be found in only one or in many buildings but is always reported as one solution.

This assessment does not consider how much the different solutions are connected with other parameters as the climate and the building typology. These correlations have been addressed through a specific workshop and the related results are reported in chapter 4.

3.1. Centralized or decentralized systems and typology of the heat generator

From the analysed resources it emerged that the majority of the systems are centralized (32 solutions), while decentralized systems are less common (15 solutions).

Regarding the heat generators in the analysed solutions, it is interesting to note that there is a variety of examples of heat pump systems in historic buildings. This may sound a bit strange to the common public as, in general, the integration of a heat pump system in an historic building is perceived as challenging if not problematic, mainly due to the high level of thermal demand historic buildings can present and to limitations to some interventions or positioning of one or some heat pump system's components. However, it is interesting to note that, with the proper intervention and accounting for the specification of the historic buildings, heat pump systems represent a viable solution that should not be excluded "a priori". In addition, the analysis found different kinds of heat pump systems in historic buildings, with air or ground as thermal source, and air or water as heating medium.

Moreover, also examples of the use of Variable Refrigerant Flow (VRF) systems have been found especially in those climatic contexts where space cooling is the dominant building's thermal demand, or where both space heating and cooling are similar (e.g., in Spain). The same VRF system can cover both space heating and cooling demand and, if properly designed, the same VRF system can deliver, at the same time, space heating and cooling to different parts of the building. In addition, there are specific system modules used to allow the VRF system to cover also the building's eventual DHW demand.

The wood-based boilers represent a more common choice in specific contexts, especially in rural areas. In the analysed resources, the majority of wood-based boiler applications refer to wood-pellet boilers.

Fossil fuel boilers (mainly gas and oil boilers) are still a feasible option in many countries, although there will be more stringent regulations in the next years, if not a complete ban of at least some of them.

Although we did not find many examples in the analysed resources, it is reasonable to imagine that gas boilers can still have a role in combination with heat pump systems in the hybrid systems (heat pump + gas boiler), especially in buildings presenting strong limitations on the possible interventions (e.g., for visual aspects) and with a high specific heating demand.

Finally, there are solutions using electricity that do not use this energy vector to run a heat pump. These kinds of solutions include both electrical systems based on Joule effect (electrical radiators), as well as infrared panels. In the sources analysed it was difficult to clearly understand if these solutions represent the main system to cover the building's space heating needs or if they work in support of a typical heating system (e.g., based on a gas boiler, a distribution circuit, and radiators as emission units).

The number of different heat generators found in the analysed resources are reported in percentage in Figure 1. The percentage is calculated by dividing the number of solutions with the considered heat generator by the number of solutions for which the indication of each heat generator is available. If not different specified, the percentage values reported also for the other analysed parameters are calculated in the same way.

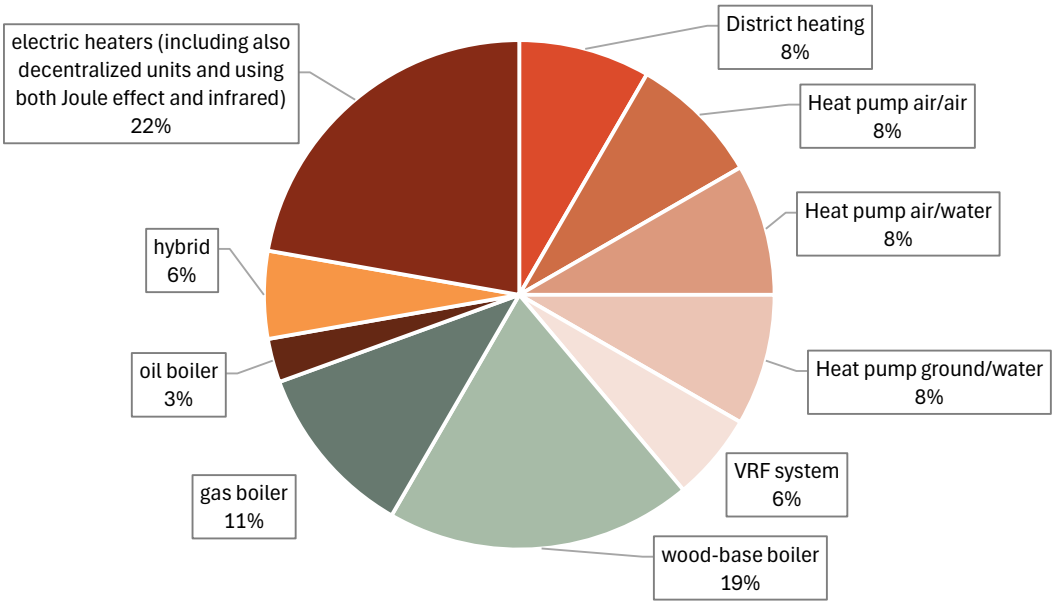

Figure 1 Distribution of the gathered active system solutions in terms of heat generator

3.2. Emission system

In the analysed resources there is a similar number of active system solutions that consider radiators and a radiant floor system. With radiators, in this context, we include not only typical radiators, heated by water, but also electrical radiators that can be found in few examples.

In addition to that, radiant wall and ceiling systems are also found as possible solutions in historic buildings renovation.

This is interesting as, similarly to heat pump systems, also radiant systems installation is, in general, perceived by the public as challenging if not problematic in a historic building. This analysis, however, proves that, with the due attention to the installation, and accounting also for the specificities of the historic building, radiant floor, wall, and ceiling systems are solutions that should not be excluded “a priori”.

Instead, the results of the analysis in terms of the use of fan coils should be interpreted carefully. In fact, this kind of emission unit presents advantages (e.g., the possibility to cover both space heating and cooling needs with the same unit), and, in some cases, they represent the best choice in terms of emission units. On the other hand, they also present limitations (e.g., occupants’ discomfort due to forced air

movement, possible noise). In the analysed resources, the fan coils are still not used extensively in historic building renovations, where, instead, radiators are the most adopted solutions. However, the possibility to cover not only space heating but also space cooling is a feature that is becoming more and more relevant, also in historic buildings, and not only in typically hot climates (e.g., Spain) but also in North Europe (e.g., Scotland).

Another solution used, especially in hot climates (e.g., Spain), where both space heating and cooling demands are important, is VRF systems. This implies that the emission units are those specific for this kind of system, using refrigerant as the heating medium. This kind of emission unit, similarly to fan coils, could be used to cover both space heating and cooling demand of a building. In addition, with a proper design of the system, it is possible to supply, at the same time, both space heating and space cooling to different parts of the same building using a unique VRF system.

Finally, in the analysed resources there are cases in which more than one emission system is installed in the building and both contribute to cover the heating and/or cooling building's thermal needs. An example of this kind of solution is represented by a building heated primarily by radiators but with electric heaters used as support heating units. All the cases with more than one emission system contributing to cover the building heating and/or cooling demand are reported as "mixed" emission system.

Figure 2 illustrates the distribution of the different emission systems found in the analysed resources.

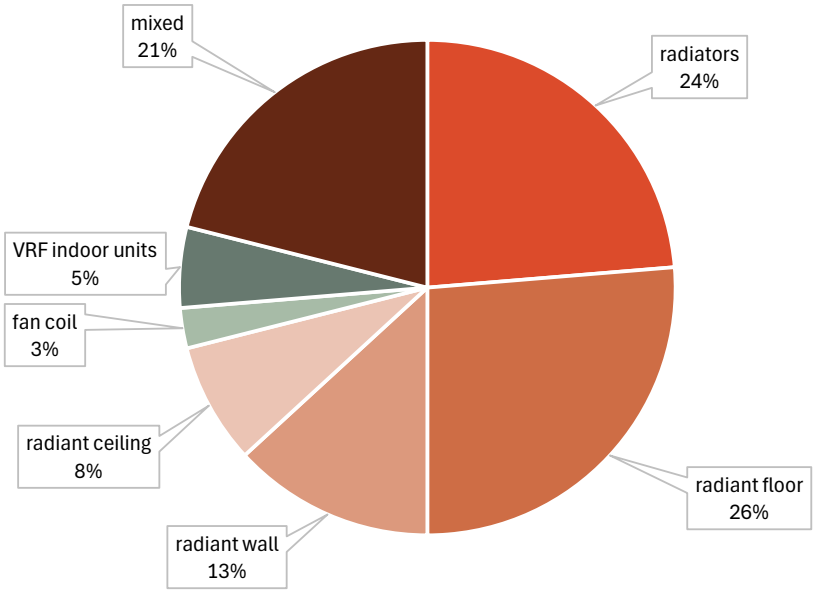

Figure 2 Distribution of the gathered active system solutions in terms of emission system

3.3. System control

In this work, the system control is classified based on its automation level as described by the BACS classification, better explained in section 2.2.2.

The majority of systems analysed have a centralized control (BACS class C). Less common are controls at single zone level (BACS class B), and even less common are those at single zone level that depend also on occupancy (BACS class A). Systems without automatic control (BACS class D) are the least common.

Figure 3 shows the percentage of different system control automation levels in the assessed cases.

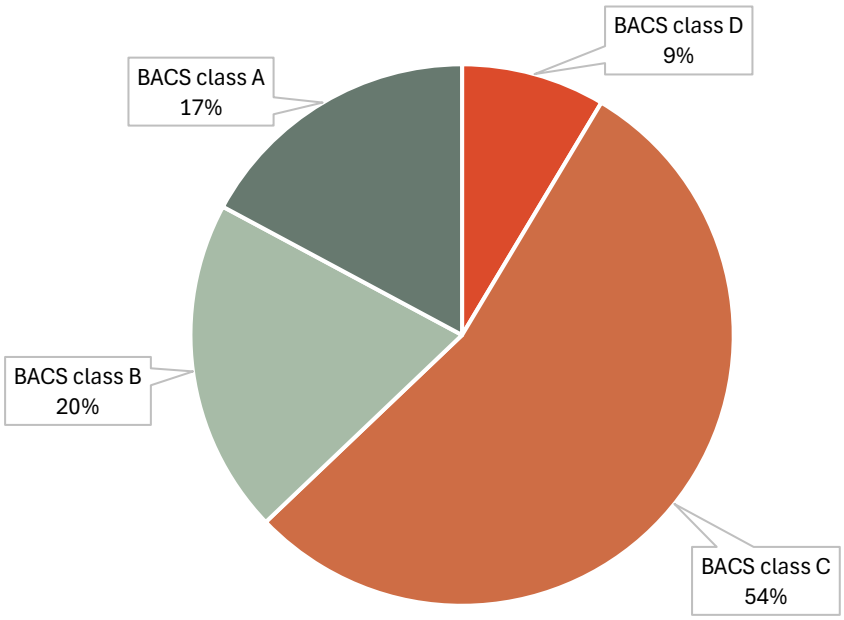

Figure 3 Distribution of the gathered active system solutions in terms of system control

4. Potential applications and limitations of results

The solutions collected in this task were subsequently evaluated against the typologies defined in Task 1.2. These typologies represent key historic residential and public building types from the respective countries. They are shown in Table 2.

Table 2. Labels used to describe each typology in Table 5.

Nr	Country	Name	Label
1	Spain	*Casa de pisos* — terraced tenement building (1600–1920)	ES 1
2	Spain	*Patio de vecinos* — terraced courtyard tenement building (1600–1920)	ES 2
3	Poland	*Kamienica* — terraced tenement building (1750–1945)	PL 1
4	Poland	*Willa miejska* — garden-city/urban villa (1900–1945)	PL 2
5	Sweden	*Monumentalbyggnad* — monumental public building (1850–1920)	SE 1
6	Sweden	*Flerbostadshus funktionalism* — functionalist multi-family housing block (1920–1945)	SE 2
7	Scotland	*Georgian cottage* — detached cottage (1750–1850)	SC 1
8	Scotland	*Georgian tenement* — terraced tenement building (1750–1850)	SC 2
9	Scotland	*Victorian terraced house* — terraced house (1850–1920)	SC 3

To gather detailed information on each typology, workshops were conducted both online and during the 4th project meeting held in Krakow, Poland. Participants included experts on the specific typologies mentioned above, local specialists, and other FuturHist partners involved with the demonstration cases from these countries.

A questionnaire covering insulation systems, windows, and active systems was used to collect data. The questions were tailored based on parameters gathered in earlier steps and were presented in a multiple-choice format, with mandatory comments required if any options were rejected. The part of questionnaire regarding active systems is included in Table 3. The part describing passive systems is described in Deliverable 2.1.

Answers and accompanying notes explaining the rationale for each system selection were collected and subsequently applied as filters to the comprehensive list of solutions. This process allowed assessment of the applicability of each solution to a given typology, categorizing them as 'possible, 'impossible, or 'depends'. A compilation of the notes gathered for each country and the full assessment of all active solutions are provided below.

Solution 46 *VRF system for cooling, DHW and ventilation* and Solution 47 *VRF for heating and cooling* were collected after the workshop and therefore are not part of this review of limitations.

Table 3. Questions regarding active systems in typology.

Nr	Checkpoint	Question	Options
1	**Function**	What are the building thermal needs the active system should cover?	• *Space heating* • *Space cooling* • *Domestic Hot Water* • *Ventilation*
2	**Heat generator**	Which are the heat generators suitable for the considered building?	• *District Heating Network (DHN)* • *Fossil fuel boilers (gas, oil)* • *Wood based boiler* • *Hydrogen boiler* • *Heat pumps (air-air, air-water, ground-water, water-water)* • *Hybrid (e.g., gas boiler + heat pump, heat pump + el. panels)*
3	**Source fuel**	Which source fuel are possible in the typology? Take into consideration also aspects like the necessity to have a dedicated storage for some fuels (oil, LPG, wood chips and pellets) and in general the rules/laws that can limit the usage of certain fuels. For electricity consider if there are specific limits you are aware off about maximum connection power.	• *District Heating Network (DHN)* • *Oil, gas* • *Electricity* • *Wood based* • *Air, water, ground* • *Hybrid*

4	**Distribution system**	Which are the features the distribution system should have? Should a distribution system (water or air) be present at all?	• *Present* • *Not present* •
		Should the system be thermally insulated?	• *Insulated* • *Not insulated*
		Should it be accessible for maintenance or inspection?	• *Accessible* • *Not accessible*
5	**Emission system**	Which emission units are an option for the considered building? If it makes sense to imagine re-planning the position of the emission units specify this aspect in the comments.	• *Radiators* • *Fan coils* • *Radiant floor, wall, ceiling* • *Mixed*
6	**Centralized / decentralized**	Is a centralized or decentralized system required? If so, please specify the details and any relevant considerations.	• *Centralized* • *Decentralized*
7	**Technical space requirements**	Different solutions require varying amounts of technical space. Are there any specific requirements for technical areas in this building (e.g., a dedicated technical room)? If so, please specify which requirements apply.	• *Yes* • *No*
8	**Heat recovery**	In the case of mechanical ventilation, is the integration of a heat recovery system feasible, mandatory or recommended? Please specify any relevant requirements or preferences.	• *Yes* • *No*
9	**Visibility**	Can the system components be visible? If it can be visible only in certain areas, please specify the locations (e.g., rooms, corridors) where this is acceptable and provide any additional relevant details.	• *No* • *Yes (from inside)* • *Yes (from outside)*
10	**Installation**	What is the approximate level of disturbance to the building or its users during installation? Remember we are referring to a building typology, not to a specific demo.	• *Low disturbance (e.g., replacement of radiators with a fan coil with similar size and without touching anything else)* • *Medium disturbance (e.g., replacement of radiators with another unit that needs also intervention on other parts, e.g., walls traces)* • *High disturbance (important interventions that implies for the users to temporarily leave the apartment e.g., replacement of radiators with radiant floor)*

11	**Cost**	What is the approximate price range of the solutions?	• *Low cost (e.g., budget-friendly options)* • *Mid-range cost (e.g., standard market pricing)* • *High cost (e.g., premium or specialized systems)*

4.1. Potential limitations on results regarding building typology

Table 4. Notes on active systems questions and typology assessments for each country

Nr	Question	Spain (ES)	Poland (PL)	Sweden (SE)	Scotland (SC)
1	**Function** What are the building thermal needs the active system should cover?	Heating, cooling and domestic hot water production (more attention should be given to cooling)	Mainly space heating and domestic hot water. In the future there might be need of space cooling. In most buildings there is gravitational ventilation, which doesn't require retrofit, but if possible - mechanical ventilation with recovery preferable.	Mainly space heating. In typology 1 (non-residential) DHW is a minor part. In typology 2 (residential), instead, DHW is important. In both typologies space cooling is actually not accounted for but, probably, will be important in the coming years due to climate change. In typology 1, Mech. vent. system is present only if the building undergone a renovation during the last years. Typology 2 instead generally present at least decentralized ventilation (extraction units) placed at least in the kitchen and in the bathroom.	Space heating and DHW are the main thermal needs of both Scottish typologies 1, 2, and 3. Regarding space cooling, actually, there are only some overheating issues, especially depending on building orientation and wall-to-window ratio. It is expected that space cooling will become more and more important in the coming years. Mechanical ventilation systems are present, but with decentralized solutions limited to air extraction in the kitchen and in the bathroom. The presence of a mech. vent. system is, in principle, also useful to manage moisture, especially in some building zones.
2	**Heat generator** Which are the heat generators suitable for the considered building?	All suitable, but wood-based boiler might have some limitations because of air pollution. DHN not common. System installations must be assessed due to heritage and urban restrictions.	Most wanted is District Heating Network (DHN), if available. Heat pumps are acceptable, but not common (problems with protected facade or change of existing emission system). Possible hybrid solutions with DHN, electric boilers, solar panel/PV.	DHN possible and welcome where the network is available. Heat pumps possible (both air and ground sources) but some limitations to the intervention depending on the level of protection (especially for typology 1). Pellet boilers are eventually possible but do not represent a	DHN possible and welcome where the network is available. Fossil fuel boilers are instead an actual solution but, based on the actual regulation, will be banned in the coming years (from 2040). Wood-based boilers could be a possible solution, but specific assessments should be made as air pollution

				common choice. Oil boilers possible nowadays but do not represent a common solution, plus they will be ban in some years (around 2035-2040). Gas boilers and hybrid systems (gas boiler + heat pump) are not common as gas network is not so developed. Hydrogen is not there actually. All these comments, if not differently specified, refer to the 2 typologies.	restrictions could be present. Hydrogen solutions could be, in principle, a potential solution, but this is very unlikely. Regarding heat pumps and hybrid systems, they are possible solutions, but some specific assessments should be made regarding the restrictions related to the level of protection of the specific building. Moreover, for typology 2, there could be some specific aspects to address (e.g., the centralized solution cannot be installed on the ground floor).
3	**Source/fuel** Which source fuel are possible in the typology?	Oil, gas, electricity, air/water/grounds, hybrid. DHN does not exist in this region, wood use is limited because of the particles production.	Main source is District Heating Network (DHN), less common are electricity, air, water, ground. PV panels and solar collectors can be installed only on not visible parts. In Typology 2 there's possibility of using gas and very rarely oil (only single-family houses). Wood-based fuels are forbidden.	See previous point. Gas network is not so developed in Sweden, therefore is not a common choice. Oil boiler possible but will be banned soon. Pellet boilers possible in some cases but do not represent a common choice. Heat pumps (air and ground source) and DHN used. Hydrogen as an option is not there actually and won't be there in the near future. This is valid for both typologies.	See previous point. For wood-based and oil-based solutions, the needed technical space for storing the fuel must be checked. Moreover, in general, fossil fuels (oil, gas) are not highly recommended and will be banned soon based on the actual regulations. Hydrogen as an option is not there actually.
4	**Distribution system** Which are the features the distribution system should have? Should a distribution system (water or air) be present at all? Should	The typologies don't have a distribution system, so these questions were not addressed.	System should be thermally insulated. Main connector should be accessible for maintenance. Only gas pipes have to be accessible for inspection.	Distribution system is basically always present and should be thermally insulated, especially if the building undergone a renovation in the last decades.	Distribution system is basically always present in typologies 2 and 3, while it depends on case by case in typology 1. Regarding the status (accessible/insulated) depends on the specific case, but in general, at least part of the distribution system

	the system be thermally insulated? Should it be accessible for maintenance or inspection?				is not accessible. The distribution system is generally thermally insulated also to avoid frosting.
5	**Emission system** Which emission units are an option for the considered building?	All suitable, but radiant floor, wall, ceiling only if space is available and if the installation is conservation compatible.	Usually there are existing radiators, it is not common to change to another emission system. Another option is radiant floor (if original wooden floor stays protected) or mixed solutions. Fan coils are not acceptable - too big change of existing building.	Radiators are the most common option for both typologies. Radiant systems (eventually radiant floor systems) are possible in general but due to high disturbance to occupants, technical and regulatory limitations their adoption must be verified. Fan coils are not used.	Radiators are the most common option. fan coils are not generally present in the considered typologies. Radiant solutions are possible but only considering infrared panels acting as the unique system or to complement existing radiators; therefore, no radiant water-based solutions, especially in typologies 2 and 3. Eventually, water-based radiant solutions could be in principle feasible eventually in typology 1, but some specific checks must be done (e.g., check height limits in case of a radiant ceiling system installation).
6	**Centralized / decentralized** Is a centralized or decentralized system required?	Centralized systems are not generally installed in social housing.	The goal is centralized system. In Typology 1 decentralized systems are most common, because parts of buildings have different owners.	Only centralized systems in the considered 2 building typologies.	Both are possible solutions for typology 1. Typology 2 (multi-apartment building) generally presents decentralized gas boilers (one per each flat), while typology 3 is a single-family house, meaning a central gas boiler for the entire building is the most common solution.

7	**Technical space requirements** Are there any specific requirements for technical areas in this building (e.g., a dedicated technical room)?	There is a legislation to regulate this.	No requirements – there is usually basement available.	As the two typologies have centralized solutions, a proper technical space is always available.	Typology 1 does not present problems outside. Inside, instead, there could be space limitations, and some systems could not be feasible. Typology 2 presents some space available to be used as a technical room (former communal toilets accessible from the stairwell). Typology 3 generally has a lot of rooms that can be used as a technical room.
8	**Heat recovery** In the case of mechanical ventilation, is the integration of a heat recovery system feasible, mandatory or recommended?	Heat recovery is not feasible as there is no mechanical ventilation.	Heat recovery recommended and wanted, but mechanical ventilation is rare.	Heat recovery recommended. Not clear if it is mandatory.	Heat recovery is possible and, in general, recommended. Nevertheless, the mech. Vent. Heat recovery efficiency will also depend on the building fabric (generally very leaky) and efficiency, and heritage considerations (pipes on ceiling possible?).
9	**Visibility** Can the system components be visible?	System components should not be in visible spaces. It is easier to place them if they are visible only from the inside. The rooftop is only used when it is not visible in historical areas (there are urban policies to follow).	System components can be visible from inside. System components can be visible from outside if it's not to the street side - final decision depends on the heritage institution.	It depends on the specific case and if the building is listed or not. No "a priori" limitations. In general, more limitations due to heritage value for typology 1.	For typology 1, there are more limitations on the external main facade, where system components cannot be installed generally. Eventually, they can be installed on the back facade. Regarding the interior, the main limitation is not only related to the visual aspect but also to the limited space inside. For typology 2 and 3, the most common situation is that the system, and in general, its components should not be visible. There might be exceptions depending on the

					rooms (some don't have mouldings), but this is quite rare. Moreover, it also depends on which element is visible (e.g., radiator pipe: ok, ventilation duct: not ok) and in general from the level of protection of the considered building (although it is rare that buildings from this typology are not protected).
10	**Installation** What is the approximate level of disturbance to the building or its users during installation?	High disturbance is more feasible in private properties, only possible if really needed for social housing	Low and medium level of disturbance preferrable. Bigger interference very rarely, and only if there are no changes to original wooden structure (floor/ceiling).	It depends on the specific building, its limitations and usage. Not possible to discard a priori some solutions.	No "a priori" limitations, but in general solutions with limited disturbance are welcome and, in some cases, the unique possible. This aspect mainly depends on the actual conditions, on the use and on the building system to be implemented. Regarding the building's use, it is important to underline that these buildings are generally rented out and, a high disturbance intervention, would imply the need to temporarily relocate the tenants.
11	**Cost** What is the approximate price range of the solutions?	It depends on the owner, but commonly it is a mid-range cost.	Commonly low and mid-range cost. Expensive systems are option in privately owned buildings in Typology 2.	It depends on the specific building. Not possible to discard a priori some solutions.	No "a priori" answers. This aspect depends on the client.

4.2. Review of limitations of solutions

Review of all active solutions regarding their limitations in each typology is shown in Table 5. Solutions are marked possible ✓, impossible X or possible with some restrictions ?. The number in brackets relates to the question in Table 4, where the reason for the assessment is noted.

Table 5. Assessment of active systems for each typology.

Nr	Solution	ES 1	ES 2	PL 1	PL 2	SE 1	SE 2	SC 1	SC 2	SC 3
1	Adiabatic ventilation system	X (1)	X (1)	? (1)	? (1)	X (1)	X (1)	X (1)	X (1)	X (1)
2	Boiler of pellet	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	X (2, 3)	? (2, 5)	? (2, 5)	? (2, 5)	? (2, 5, 6, 7)	? (2, 5)
3	Central heat generation system with boiler for biomass and ceiling heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	X (2, 3)	? (2, 5)	? (2, 5)	? (2, 5)	? (2, 5, 6, 7)	? (2, 5)
4	Central heat generation system with boiler for biomass and floor heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	X (2, 3)	? (2, 5)	? (2, 5)	? (2, 5)	? (2, 5, 6, 7)	? (2, 5)
5	Central heat generation system with boiler for biomass and mixed heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	X (2, 3)	? (2, 5)	? (2, 5)	? (2, 5)	? (2, 5, 6, 7)	? (2, 5)
6	Central heat generation system with boiler for biomass and radiators	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	X (2, 3)	? (2, 5)	? (2, 5)	? (2)	? (2, 6, 7)	? (2)
7	Central heat generation system with boiler for biomass and wall heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	X (2, 3)	X (5)	X (5)	? (2, 5)	? (2, 5, 6, 7)	? (2, 5)
8	Central heat generation system with external heat pump and floor heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5, 6, 9)	? (5, 9)	? (1, 5)	? (1, 5)	? (5)	? (5, 6)	? (5)
9	Central heat generation system with gas boiler and floor heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	? (2, 3, 5, 10)	? (1, 3, 5)	? (1, 3, 5)	? (2, 5)	? (2, 5, 6)	? (2, 5)
10	Central heat generation system with gas boiler and mixed heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	? (2, 3, 10)	? (1, 3, 5)	? (1, 3, 5)	? (1, 2, 5)	? (1, 2, 5, 6)	? (1, 2, 5)
11	Central heat generation system with gas boiler and radiators	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	? (2, 3, 10)	? (1, 3, 5)	? (1, 3, 5)	? (2)	? (2)	? (2)
12	Central heat generation system with gas boiler and wall heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	? (2, 3, 5, 10)	? (1, 3, 5)	? (1, 3, 5)	? (2, 5)	? (2, 5, 6)	? (2, 5)

Nr	Solution	ES 1	ES 2	PL 1	PL 2	SE 1	SE 2	SC 1	SC 2	SC 3
13	Central heat generation system with geothermal heat pump and floor heating	? (4, 5, 6, 7, 9, 10)	? (4, 5, 6, 7, 9, 10)	? (5, 6, 10, 11)	? (5, 10)	? (5)	? (5)	? (4, 5)	? (4, 5, 6, 7)	? (5)
14	Central heat generation system with heat pump and ceiling heating	? (4, 5, 6, 7, 9, 10)	? (4, 5, 6, 7, 9, 10)	? (5, 6, 11)	? (5)	X (1, 5)	? (5)	? (4, 5)	? (4, 5, 6, 7)	? (5)
15	Central heat generation system with heat pump and fans	? (4, 5, 6, 7, 9, 10)	? (4, 5, 6, 7, 9, 10)	? (5, 6)	? (5)	X (5)	X (5)	X (5)	X (5)	X (5)
16	Central heat generation system with heat pump and floor heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5, 6)	? (5)	? (5)	? (5)	? (5)	? (4, 5, 6, 7)	? (5)
17	Central heat generation system with oil boiler and floor heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	? (2, 3, 5)	? (1, 2, 3, 5)	? (1, 2, 3, 5)	? (2, 5)	? (2, 5, 6, 7)	? (2, 5)
18	Centralized mechanical ventilation	X (1)	X (1)	? (1, 5, 6, 10)	? (1, 5, 10)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 4, 5, 6, 7)	? (1, 5)
19	Centralized ventilation system	X (1)	X (1)	? (1, 5, 6)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 4, 5, 6, 7)	? (1, 5)
20	Combined ventilation (natural + mechanical with heat recovery)	X (1,8)	X (1,8)	? (1, 5, 6)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 4, 5, 6, 7)	? (1, 5)
21	Decentralized boiler for heating water	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	✓	✓	? (1, 5, 6)	? (1, 5, 6)	? (1, 5)	? (1, 5)	? (1, 5, 6)
22	Decentralized ventilation monoblocks	X (1)	X (1)	? (1, 5)	? (1, 5)	X (5, 6)	? (5, 6)	? (1, 5)	? (1, 5)	? (1, 5)
23	Decentralized ventilation system	X (1)	X (1)	? (1, 5)	? (1, 5)	X (1)	X (1)	? (1, 5)	? (1, 5)	? (1, 5)
24	District Heating Network with mixed heating	X (1, 3)	X (1, 3)	? (6)	✓	? (1, 5, 6)	? (1, 5, 6)	? (5)	? (5)	? (5)
25	District Heating Network with radiators	X (1, 3)	X (1, 3)	? (6)	✓	✓	✓	✓	✓	✓
26	District Heating Network with radiators (heating only)	X (1, 3)	X (1, 3)	? (6)	✓	? (1)	? (1)	? (1)	? (1)	? (1)

Nr	Solution	ES 1	ES 2	PL 1	PL 2	SE 1	SE 2	SC 1	SC 2	SC 3
27	Electric heater with radiators	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	✓	✓	X (4, 6)	X (4, 6)	? (2, 5, 6)	? (2, 5, 6)	? (2, 5, 6)
28	Electric storage heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	✓	✓	X (4, 6)	X (4, 6)	? (2, 5, 6)	? (2, 5, 6)	? (2, 5, 6)
29	Electric wallpaper	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5)	? (5)	X (4, 5, 6)	X (4, 5, 6)	? (2, 5, 6)	? (2, 5)	? (2, 5, 6)
30	Electrical boiler with floor heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5, 6)	? (5)	X (4, 5, 6)	X (4, 5, 6)	? (2, 5, 6)	? (2, 5, 6)	? (2, 5, 6)
31	Ground heat pump	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5, 6)	? (5)	? (5)	? (5)	? (2, 5, 6)	? (2, 5, 6)	? (2, 5)
32	Ground heat pump with mechanical ventilation	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5, 6, 10)	? (5, 10)	? (1, 5)	? (1, 5)	? (2, 5, 6)	? (2, 5, 6)	? (2, 5)
33	Heat pump with mechanical ventilation	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (6, 9)	? (9)	? (1)	? (1)	? (2, 5, 6)	? (2, 5, 6)	? (2, 5)
34	Hydrogen installation with energy storage, PV, solar collector with mixed heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2)	X (2)	X (2, 3)	X (2, 3)	X (2, 3)	X (2, 3)	X (2, 3)
35	Hydronic high-efficiency pew-based system with geothermal heat pump	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (6, 11)	✓	X (5)	X (5)	X (5)	X (5)	X (5)
36	Infra-red heating panels	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5)	? (5)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 5)
37	IR with ASHP	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (11)	✓	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 5)	? (1, 5)
38	Multi-source system: ground-source heat pump, hydrogen generator, energy storage, recuperation	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2)	X (2)	X (2, 3)	X (2, 3)	X (2, 3)	X (2, 3)	X (2, 3)
39	MVHR system with ASHP	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2)	X (2)	? (2, 3, 5)	? (2, 3, 5)	? (1, 5, 6)	? (1, 5, 6)	? (1, 5)

Nr	Solution	ES 1	ES 2	PL 1	PL 2	SE 1	SE 2	SC 1	SC 2	SC 3
40	MVHR system with gas boiler	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	? (2, 3)	? (2, 3, 5)	? (2, 3, 5)	? (1, 5, 6)	? (1, 5, 6)	? (1, 5)
41	Radiant heating	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (5)	? (5)	? (1, 5)	? (1, 5)	? (1, 2, 5)	? (1, 2, 5)	? (1, 2, 5)
42	Solar thermal panels	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (6, 9, 10)	? (9, 10)	X (1, 2, 3)	X (1, 2, 3)	X (1, 2, 7)	X (1, 2, 7)	X (1, 2, 7)
43	Solar thermal system with pellet boiler and radiators	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	X (2, 3)	X (2, 3)	? (1, 9)	? (1, 9)	? (2)	? (2, 6, 7)	? (2)
44	Solar thermal system with pellet boiler and wall heating	X (1)	X (1)	X (2, 3)	X (2, 3)	? (1, 5, 9)	? (1, 5, 9)	? (2, 5)	? (2, 5, 6, 7)	? (2, 5)
45	Ventilation units connected with windows	? (1, 4, 5, 6, 7, 9, 10)	? (1, 4, 5, 6, 7, 9, 10)	? (1, 5)	? (1, 5)	X (1)	X (1)	? (2, 5, 6)	? (2, 5, 6)	? (2, 5)

5. Conclusions and Outlook

The aim of this report was to compile various HVAC systems used in the retrofit of historic buildings and to describe them in general terms, without referring to individual case studies. This approach allows the results to be applied broadly and compared across different contexts without requiring detailed knowledge of specific buildings.

A total of 47 active solutions were collected, which have already been implemented in the retrofit of historic buildings—thus providing links to real-world case studies. The number and variety of these solutions demonstrate that multiple approaches are possible, depending on building-specific requirements, climatic conditions, and local constraints. The gathered solutions address different needs, including heating, cooling, ventilation, and domestic hot water preparation. This compilation enables informed selection of systems tailored to one or more of these requirements.

The solutions were parametrised based on general information, technical and performance specifications, as well as installation and design aspects. A compilation of these results is included in the report. For some systems, however, data are either unavailable or cannot be meaningfully described without detailed information about the specific solution and/or the renovated building.

The majority of systems are centralised; however, decentralised systems are still used in specific cases that require tailored approaches. Traditional systems such as gas, oil, and wood-based boilers remain common in historic buildings, largely due to their longstanding association with these structures. However, this trend may shift in response to evolving regulatory restrictions. Several examples of historic building retrofits using heat pumps are presented. Although heat pumps are typically associated with new buildings, with the right design strategy, they can also be adapted to meet the specific needs of historic structures. In some cases, hybrid systems are implemented—such as a combination of heat pump and gas boiler, or heat pump and electric heaters—to optimise performance and flexibility.

The emission systems of newly installed active technologies are most commonly radiators or radiant floor, wall, or ceiling systems. This is a noteworthy finding, as radiant floors are typically linked to new constructions, yet the collected examples show they can also be successfully integrated into historic buildings. Fan coil units are less frequently used, although they offer the advantage of providing both heating and

cooling. While cooling is not currently a major concern in northern Europe, it is expected to become increasingly important in the future.

During the workshop with FuturHist partners, potential limitations of the collected solutions were discussed. These limitations depend not only on the building typologies defined earlier in FuturHist but also on local regulations and restrictions. Where possible, each solution was labelled as 'possible' or 'impossible' for each typology. However, in various cases, the suitability of a solution depends on a range of context-specific parameters that cannot be generalised at this level. Therefore, many solutions were marked as 'optional'. A final assessment of active systems must still be carried out for each specific case.

The results indicate that most of collected active systems can be applied across different typologies, although with certain limitations. This means that the final choice of an HVAC system may vary depending on the individual characteristics of the building. Nonetheless, the proposed solutions should be considered during the decision-making process.

The collected solutions, along with their parameters, will be integrated into the next phases of FuturHist, including the development of a toolkit to support the selection of optimal retrofit solutions. Additionally, the outcomes of the workshop—particularly the assessment of solutions by country and building typology—will be used to guide the selection process for specific cases.

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7. Annex

Annex 1. Review of active solutions and their parameters.

Annex 1. Review of active solutions and their parameters.

Table 6. Solution 1: Adiabatic ventilation system.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Adiabatic ventilation system*
	2	Example of application	*Halle Bouchayer Viallet*
	3	Possible supplier	*Robur*
Tech. and Performance Specifications	4	Function	*Ventilation only*
	5	Heat generator	*not applicable*
	6	Source/fuel	*not applicable*
	7	Flow type	*not applicable*
	8	Distribution system	*none*
	9	Emission system	*none*
	10	Control system	*none*
	11	Monitoring system IEQ	*not applicable*
	12	Monitoring system Energy	*not applicable*
	13	Heat recovery	*not applicable*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*no*
	16	Centralized?	*decentralized*
	17	Installation	*not reported*
	18	Cost	*not reported*

Table 7. Solution 2: Boiler of pellet.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Boiler of pellet*
	2	Example of application	*Idrija mercury smelting plant*
	3	Possible supplier	• *ETA* • *Fröling* • *Hargassner* • *KWB*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*accessible insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*no automatic control (BACS class D)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the outside)*
	16	Centralized?	*decentralized*
	17	Installation	*high disturbance*
	18	Cost	*medium (€€)*

Table 8. Solution 3: Central heat generation system with boiler for biomass and ceiling heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with boiler for biomass and ceiling heating*
	2	Example of application	*Freihof Sulz*
	3	Possible supplier	• *ETA* • *Fröling* • *Hargassner* • *KWB*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant ceiling system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 9. Solution 4: Central heat generation system with boiler for biomass and floor heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with boiler for biomass and floor heating*
	2	Example of application	• *Ansitz Mairhof* • *Gasthof Adler Langenegg* • *Giatla house* • *House Pernter* • *Oberbergerhof*
	3	Possible supplier	*HERZ Energietechnik GmbH*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 10. Solution 5: Central heat generation system with boiler for biomass and mixed heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with boiler for biomass and mixed heating*
	2	Example of application	• *Ansitz Kofler* • *Halle Bouchayer Viallet* • *House Breuer, Tschagguns* • *Idrija mercury smelting plant* • *Rhine Valley House Irgang*
	3	Possible supplier	• *ETA* • *Fröling* • *Hargassner* • *KWB*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*mixed*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 11. Solution 6: Central heat generation system with boiler for biomass and radiators.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with boiler for biomass and radiators*
	2	Example of application	• *Apartment building Magnusstrasse - Zürich* • *Baur Residence, Lustenau* • *House of the Alpilles regional natural park* • *Kelchalm - Bochumer alpine hut* • *Notarjeva vila* • *Platzbon* • *Town Hall Bergrheinfeld*
	3	Possible supplier	*Hargassner*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiators*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 12. Solution 7: Central heat generation system with boiler for biomass and wall heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with boiler for biomass and wall heating*
	2	Example of application	• *Alte Schäfflerei at Benediktbeuern Monastery* • *Farmhouse Straub* • *Timber-framed house in Alsace, France*
	3	Possible supplier	• *ETA* • *Fröling* • *Hargassner* • *KWB*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant wall system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*medium (€€)*

Table 13. Solution 8: Central heat generation system with external heat pump and floor heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with external heat pump and floor heating*
	2	Example of application	*Doragno Castle - Rovio, Ticino, Switzerland*
	3	Possible supplier	*Daikin*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*air/air*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the outside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 14. Solution 9: Central heat generation system with gas boiler and floor heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with gas boiler and floor heating*
	2	Example of application	• *Ackerbürgerhäuschen* • *Casa Rossa Chemnitz* • *Mariahilferstrasse* • *Rainhof*
	3	Possible supplier	*Buderus*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Gas Boiler*
	6	Source/fuel	*gas*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*medium (€€)*

Table 15. Solution 10: Central heat generation system with gas boiler and mixed heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with gas boiler and mixed heating*
	2	Example of application	• *Elementary School in Mulhouse, France* • *Half-timberframed house in Alken, Belgium* • *Kasperhof*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Gas Boiler*
	6	Source/fuel	*gas*
	7	Flow type	*not reported*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*mixed*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*medium (€€)*

Table 16. Solution 11: Central heat generation system with gas boiler and radiators.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with gas boiler and radiators*
	2	Example of application	• *Maison Rubens* • *Oeconomy building Josef Weiss*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Gas Boiler*
	6	Source/fuel	*gas*
	7	Flow type	*not reported*
	8	Distribution system	*accessible not-insulated*
	9	Emission system	*radiators*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*medium (€€)*

Table 17. Solution 12: Central heat generation system with gas boiler and wall heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with gas boiler and wall heating*
	2	Example of application	*Town Hall Burgkunstadt*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating only*
	5	Heat generator	*Gas Boiler*
	6	Source/fuel	*gas*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant wall system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*medium (€€)*

Table 18. Solution 13: Central heat generation system with geothermal heat pump and floor heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with geothermal heat pump and floor heating*
	2	Example of application	• *Downie's Cottage* • *Farm house Trins* • *Glaserhaus - Affoltern im Emmental, Switzerland* • *Klitgaarden* • *Mercado del Val, Valladolid (Spain)* • *PalaCinema Locarno - Locarno, Switzerland* • *Single family House - Bern, Switzerland* • *Solar Villa* • *St. Franziskus Church - Ebmatingen, Switzerland* • *Villa Castelli*
	3	Possible supplier	• *BS2 AG* • *KIOTO Solar* • *Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & Cooling & DHW*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*ground/water*
	7	Flow type	*not reported*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control multiple zones (BACS class B)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*high (€€€)*

Table 19. Solution 14: Central heat generation system with heat pump and ceiling heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with heat pump and ceiling heating*
	2	Example of application	*House Moroder*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & Cooling*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*electricity*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant ceiling system*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 20. Solution 15: Central heat generation system with heat pump and fans.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with heat pump and fans*
	2	Example of application	*Ahmet Aga Mansion*
	3	Possible supplier	*Mitsubishi*
Tech. and Performance Specifications	4	Function	*Heating & Cooling*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*air/air*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible insulated*
	9	Emission system	*fan coils*
	10	Control system	*no automatic control (BACS class D)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 21. Solution 16: Central heat generation system with heat pump and floor heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with heat pump and floor heating*
	2	Example of application	• *Hof Neuhäusl* • *Sankt Christoph* • *Single Family House - Gstaad, Switzerland*
	3	Possible supplier	*drexel-weiss*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*air/water*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 22. Solution 17: Central heat generation system with oil boiler and floor heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Central heat generation system with oil boiler and floor heating*
	2	Example of application	*Timber-framed barn in the north of France*
	3	Possible supplier	*Buderus*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Oil Boiler*
	6	Source/fuel	*oil*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*no automatic control (BACS class D)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*low disturbance*
	18	Cost	*medium (€€)*

Table 23. Solution 18: Centralized mechanical ventilation.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Centralized mechanical ventilation*
	2	Example of application	• *House of the Alpilles regional natural park* • *PalaCinema Locarno - Locarno, Switzerland* • *Ritterhof* • *Trikåfabriken*
	3	Possible supplier	• *Johann Wernig KG* • *J. Pichler GmbH* • *Lindab* • *Zehnder*
Tech. and Performance Specifications	4	Function	*Ventilation & Cooling*
	5	Heat generator	*Ventilation unit*
	6	Source/fuel	*electricity*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*fan coils*
	10	Control system	*automatic control multiple zones with presence (BACS class A)*
	11	Monitoring system IEQ	*temperature humidity and CO2*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*not reported*

Table 24. Solution 19: Centralized ventilation system.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Centralized ventilation system*
	2	Example of application	• *Ansitz Kofler* • *Ansitz Mairhof* • *Apartment building Magnusstrasse - Zürich* • *Community Hall Zwischenwasser* • *Doragno Castle - Rovio, Ticino, Switzerland* • *Elementary School in Mulhouse, France* • *Farm house Trins* • *Freihof Sulz* • *Giatla house* • *Half-timberframed house in Alken, Belgium* • *Hof Neuhäusl* • *House Breuer, Tschagguns* • *Klostergebäude Kaiserstrasse* • *Magasinet i Varvsstaden, Malmö* • *Maison Rubens* • *Mariahilferstrasse* • *Musikschule Velden* • *Oeconomy building Josef Weiss* • *Rackarberget, Student housing* • *Residential and commercial building Feldbergstrasse - Basel* • *Ryesgade 30 A-C* • *Single family House - Bern, Switzerland* • *Solar Villa* • *Timber-framed house in Alsace, France* • *Town Hall Bergrheinfeld* • *Town Hall Burgkunstadt* • *Villa Castelli*
	3	Possible supplier	• *Aermec* • *J. Pichler GmbH* • *Johann Wernig KG* • *Zehnder*
Tech. and Performance Specifications	4	Function	*Ventilation only*
	5	Heat generator	*Ventilation unit*
	6	Source/fuel	*electricity*
	7	Flow type	*not reported*
	8	Distribution system	*accessible insulated*
	9	Emission system	*fan coils*
	10	Control system	*automatic control multiple zones with presence (BACS class A)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 25. Solution 20: Combined ventilation (natural + mechanical with heat recovery).

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Combined ventilation (natural + mechanical with heat recovery)*
	2	Example of application	• *Mercado del Val, Valladolid (Spain)* • *Osramhuset (The Osram Building)*
	3	Possible supplier	*Aermec*
Tech. and Performance Specifications	4	Function	*Ventilation only*
	5	Heat generator	*Ventilation unit*
	6	Source/fuel	*electricity*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*fan coils*
	10	Control system	*automatic control multiple zones (BACS class B)*
	11	Monitoring system IEQ	*CO2 only*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 26. Solution 21: Decentralized boiler for heating water.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Decentralized boiler for heating water*
	2	Example of application	• *Alte Schäfflerei at Benediktbeuern Monastery* • *Community Hall Zwischenwasser* • *Downie's Cottage* • *Klostergebäude Kaiserstrasse* • *Maison Rubens* • *Town Hall Burgkunstadt*
	3	Possible supplier	• *Clage* • *Vaillant*
Tech. and Performance Specifications	4	Function	*DHW only*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*electricity*
	7	Flow type	*not reported*
	8	Distribution system	*accessible insulated*
	9	Emission system	*not applicable*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no / yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*low disturbance*
	18	Cost	*low (€)*

Table 27. Solution 22: Decentralized ventilation monoblocks.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Decentralized ventilation monoblocks*
	2	Example of application	*Kindergarten and apartments - Chur, Switzerland*
	3	Possible supplier	*drexel-weiss*
Tech. and Performance Specifications	4	Function	*Ventilation & Cooling*
	5	Heat generator	*Ventilation unit*
	6	Source/fuel	*electricity*
	7	Flow type	*variable*
	8	Distribution system	*accessible insulated*
	9	Emission system	*fan coils*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*no*
	16	Centralized?	*decentralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 28. Solution 23: Decentralized ventilation system.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Decentralized ventilation system*
	2	Example of application	• *Ackerbürgerhäuschen* • *Alte Schäfflerei at Benediktbeuern Monastery* • *Casa Rossa Chemnitz* • *Kelchalm - Bochumer alpine hut* • *Kohlerhaus* • *Musikschule Velden*
	3	Possible supplier	*inVENTer*
Tech. and Performance Specifications	4	Function	*Ventilation only*
	5	Heat generator	*Ventilation unit*
	6	Source/fuel	*electricity*
	7	Flow type	*constant*
	8	Distribution system	*accessible insulated*
	9	Emission system	*fan coils*
	10	Control system	*automatic control multiple zones (BACS class B)*
	11	Monitoring system IEQ	*humidity and CO2*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*medium disturbance*
	18	Cost	*low (€)*

Table 29. Solution 24: District Heating Network with mixed heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*District Heating Network with mixed heating*
	2	Example of application	• *Klostergebäude Kaiserstrasse* • *Kohlerhaus* • *Musikschule Velden*
	3	Possible supplier	• *Danfoss for the connection elements between DHN and building heating circuits* • *Eurotherm for the mech. ventilation*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*District heating connection*
	6	Source/fuel	*district heating network*
	7	Flow type	*not reported*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*mixed*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*thermal energy consumption*
	13	Heat recovery	*no / yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*low disturbance*
	18	Cost	*low (€)*

Table 30. Solution 25: District Heating Network with radiators.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*District Heating Network with radiators*
	2	Example of application	• *Magasinet i Varvsstaden, Malmö* • *Osramhuset (The Osram Building)* • *Solar silo in Gundeldinger Feld - Basel* • *Teatr im. Juliusza Słowackiego, Kraków* • *Trikåfabriken*
	3	Possible supplier	• *Danfoss for the connection elements between DHN and building heating circuits* • *Eurotherm for the mech. ventilation*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*District heating connection*
	6	Source/fuel	*district heating network*
	7	Flow type	*variable*
	8	Distribution system	*accessible not-insulated*
	9	Emission system	*radiators*
	10	Control system	*automatic control multiple zones with presence (BACS class A)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*thermal energy consumption*
	13	Heat recovery	*no / yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*low disturbance*
	18	Cost	*low (€)*

Table 31. Solution 26: District Heating Network with radiators (heating only).

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*District Heating Network with radiators (heating only)*
	2	Example of application	• *Kraków - Celna 5 (POLAND)* • *Kraków - Czarnieckiego 6 (POLAND)* • *Kraków - Do Wilgi 11 (POLAND)* • *Kraków - Kiełkowskiego 15 (POLAND)* • *Kraków - Prokocimska 47-51 (POLAND)*
	3	Possible supplier	• *Danfoss for the connection elements between DHN and building heating circuits* • *Eurotherm for the mech. ventilation*
Tech. and Performance Specifications	4	Function	*Heating only*
	5	Heat generator	*District heating connection*
	6	Source/fuel	*district heating network*
	7	Flow type	*variable*
	8	Distribution system	*accessible insulated*
	9	Emission system	*radiators*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*thermal energy consumption*
	13	Heat recovery	*no / yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*low disturbance*
	18	Cost	*low (€)*

Table 32. Solution 27: Electric heater with radiators.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Electric heater with radiators*
	2	Example of application	*3encult Demo Case*
	3	Possible supplier	*fondital*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*electricity*
	7	Flow type	*constant*
	8	Distribution system	*accessible not-insulated*
	9	Emission system	*radiators*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*thermal and electric consumption*
	13	Heat recovery	*not reported*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€)*

Table 33. Solution 28: Electric storage heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Electric storage heating*
	2	Example of application	*Aberdeen, UK*
	3	Possible supplier	*Storage Heaters Direct*
Tech. and Performance Specifications	4	Function	*Heating only*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*electricity*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiators*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*low disturbance*
	18	Cost	*medium (€€)*

Table 34. Solution 29: Electric wallpaper.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Electric wallpaper*
	2	Example of application	*Pilot project in Glasgow*
	3	Possible supplier	*NexGen Heating*
Tech. and Performance Specifications	4	Function	*Heating only*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*electricity*
	7	Flow type	*not applicable*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant ceiling system*
	10	Control system	*automatic control multiple zones (BACS class B)*
	11	Monitoring system IEQ	*temperature and humidity*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*low disturbance*
	18	Cost	*medium (€€)*

Table 35. Solution 30: Electrical boiler with floor heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Electrical boiler with floor heating*
	2	Example of application	*Farm house Huber*
	3	Possible supplier	*NORDIK radiant*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*electricity*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*low disturbance*
	18	Cost	*medium (€€)*

Table 36. Solution 31: Ground heat pump.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Ground heat pump*
	2	Example of application	*Buków, Poland*
	3	Possible supplier	*Daikin*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*ground/water*
	7	Flow type	*variable*
	8	Distribution system	*accessible insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control multiple zones with presence (BACS class A)*
	11	Monitoring system IEQ	*temperature and humidity*
	12	Monitoring system Energy	*thermal and electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*high (€€€)*

Table 37. Solution 32: Ground heat pump with mechanical ventilation.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Ground heat pump with mechanical ventilation*
	2	Example of application	*Bukowiec, Poland*
	3	Possible supplier	• *Aermec (mech. vent)* • *Daikin (heat pump)*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*ground/water*
	7	Flow type	*variable*
	8	Distribution system	*accessible insulated*
	9	Emission system	*radiant floor system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*thermal and electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*high (€€€)*

Table 38. Solution 33: Heat pump with mechanical ventilation.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Heat pump with mechanical ventilation*
	2	Example of application	*Uzdrowiskowy Dom Kultury, Lądek Zdrój*
	3	Possible supplier	• *Aermec (mech. vent)* • *Daikin (heat pump)*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*air/water*
	7	Flow type	*variable*
	8	Distribution system	*accessible insulated*
	9	Emission system	*radiators*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*not reported*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the outside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 39. Solution 34: Hydrogen installation with energy storage, PV, solar collector with mixed heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Hydrogen installation with energy storage, PV, solar collector with mixed heating*
	2	Example of application	*Rzuchów, Poland*
	3	Possible supplier	*none*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Hydrogen-powered cogeneration system and heat pump*
	6	Source/fuel	*hybrid (ground/water + hydrogen)*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible insulated*
	9	Emission system	*mixed*
	10	Control system	*automatic control multiple zones (BACS class B)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*thermal and electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*decentralized*
	17	Installation	*high disturbance*
	18	Cost	*high (€€€)*

Table 40. Solution 35: Hydronic high-efficiency pew-based system with geothermal heat pump.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Hydronic high-efficiency pew-based system with geothermal heat pump*
	2	Example of application	*Basilica di Santa Maria di Collemaggio*
	3	Possible supplier	• *Daikin (heat pump)* • *izoterma (pew-based system)*
Tech. and Performance Specifications	4	Function	*Heating only*
	5	Heat generator	*Heat pump*
	6	Source/fuel	*air/water*
	7	Flow type	*variable*
	8	Distribution system	*not reported*
	9	Emission system	*not reported*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*not reported*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*no*
	16	Centralized?	*centralized*
	17	Installation	*low disturbance*
	18	Cost	*high (€€€)*

Table 41. Solution 36: Infra-red heating panels.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Infra-red heating panels*
	2	Example of application	*Holyrood Park Lodge*
	3	Possible supplier	• *celsius* • *Herschel Infrared*
Tech. and Performance Specifications	4	Function	*Heating only*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*electricity*
	7	Flow type	*not applicable*
	8	Distribution system	*accessible not-insulated*
	9	Emission system	*radiant wall system*
	10	Control system	*automatic control multiple zones (BACS class B)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*no*
	16	Centralized?	*decentralized*
	17	Installation	*low disturbance*
	18	Cost	*medium (€€)*

Table 42. Solution 37: IR with ASHP.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*IR with ASHP*
	2	Example of application	*Kilmelford Church*
	3	Possible supplier	*none*
Tech. and Performance Specifications	4	Function	*Heating & ventilation*
	5	Heat generator	*Electric + Heat pump*
	6	Source/fuel	*Hybrid (air/air + electricity)*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible insulated*
	9	Emission system	*mixed*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*medium disturbance*
	18	Cost	*high (€€€)*

Table 43. Solution 38: Multi-source system: ground-source heat pump, hydrogen generator, energy storage, recuperation.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Multi-source system: ground-source heat pump, hydrogen generator, energy storage, recuperation*
	2	Example of application	*Article 1: Zrównoważona rewitalizacja pałacu w Rzuchowie*
	3	Possible supplier	*none*
Tech. and Performance Specifications	4	Function	*Heating & DHW & Ventilation*
	5	Heat generator	*Hydrogen-powered cogeneration system and heat pump*
	6	Source/fuel	*hybrid (hydrogen and ground/water)*
	7	Flow type	*variable*
	8	Distribution system	*accessible insulated*
	9	Emission system	*mixed*
	10	Control system	*automatic control multiple zones with presence (BACS class A)*
	11	Monitoring system IEQ	*temperature humidity and CO2*
	12	Monitoring system Energy	*thermal and electric consumption*
	13	Heat recovery	*not reported*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*high (€€€)*

Table 44. Solution 39: MVHR system with ASHP.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*MVHR system with ASHP*
	2	Example of application	*Niddrie Road, Glasgow*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & ventilation*
	5	Heat generator	*Electric + Heat pump*
	6	Source/fuel	*hybrid (hydrogen and ground/water)*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible insulated*
	9	Emission system	*mixed*
	10	Control system	*automatic control multiple zones with presence (BACS class A)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*high disturbance*
	18	Cost	*high (€€€)*

Table 45. Solution 40: MVHR system with gas boiler.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*MVHR system with gas boiler*
	2	Example of application	*Niddrie Road, Glasgow*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & ventilation*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*hybrid (air/air + gas)*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible insulated*
	9	Emission system	*mixed*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*not reported*
	16	Centralized?	*decentralized*
	17	Installation	*not reported*
	18	Cost	*medium (€€)*

Table 46. Solution 41: Radiant heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Radiant heating*
	2	Example of application	*Scotstarvit Tower Cottage, Cupar*
	3	Possible supplier	*Eurotherm*
Tech. and Performance Specifications	4	Function	*Heating only*
	5	Heat generator	*Electric heater*
	6	Source/fuel	*electricity*
	7	Flow type	*not applicable*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant wall system*
	10	Control system	*automatic control multiple zones (BACS class B)*
	11	Monitoring system IEQ	*temperature only*
	12	Monitoring system Energy	*electric consumption*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*yes (from the inside)*
	16	Centralized?	*decentralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 47. Solution 42: Solar thermal panels.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Solar thermal panels*
	2	Example of application	*Residential and commercial building Feldbergstrasse - Basel*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Solar thermal panels*
	6	Source/fuel	*solar energy*
	7	Flow type	*constant*
	8	Distribution system	*not applicable*
	9	Emission system	*radiators*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*yes (from the outside)*
	16	Centralized?	*centralized*
	17	Installation	*high disturbance*
	18	Cost	*medium (€€)*

Table 48. Solution 43: Solar thermal system with pellet boiler and radiators.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Solar thermal system with pellet boiler and radiators*
	2	Example of application	*Kindergarten and apartments - Chur, Switzerland*
	3	Possible supplier	• *KWB* • *Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiators*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the outside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 49. Solution 44: Solar thermal system with pellet boiler and wall heating.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Solar thermal system with pellet boiler and wall heating*
	2	Example of application	*Ritterhof*
	3	Possible supplier	*Viessmann*
Tech. and Performance Specifications	4	Function	*Heating & DHW*
	5	Heat generator	*Wood-base boiler*
	6	Source/fuel	*wood-base*
	7	Flow type	*constant*
	8	Distribution system	*not-accessible not-insulated*
	9	Emission system	*radiant wall system*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*no*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the outside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 50. Solution 45: Ventilation units connected with windows.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*Ventilation units connected with windows*
	2	Example of application	*House Moroder*
	3	Possible supplier	• *Eurotherm* • *Viessmann* *(in connection with the windows manufacturer for the air intake and exhaust ducts that pass through the windows)*
Tech. and Performance Specifications	4	Function	*Ventilation only*
	5	Heat generator	*Ventilation unit*
	6	Source/fuel	*electricity*
	7	Flow type	*constant*
	8	Distribution system	*accessible insulated*
	9	Emission system	*fan coils*
	10	Control system	*automatic control central (BACS class C)*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*no*
	15	Visibility	*no*
	16	Centralized?	*decentralized*
	17	Installation	*medium disturbance*
	18	Cost	*low (€)*

Table 51. Solution 46: VRF system for cooling, DHW and ventilation.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*VRF system for cooling, DHW and ventilation*
	2	Example of application	*Proyectos con Europa - AVRA - Junta de Andalucía - Agencia de Vivienda y Rehabilitación de Andalucía*
	3	Possible supplier	*HITACHI*
Tech. and Performance Specifications	4	Function	*Cooling & DHW*
	5	Heat generator	*VRF unit*
	6	Source/fuel	*electricity*
	7	Flow type	*variable*
	8	Distribution system	*accessible insulated*
	9	Emission system	*VRF indoor units*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes, (from the outside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

Table 52. Solution 47: VRF for heating and cooling.

Type	Nr	Parameter	Definition of the Parameter
General Information	1	Solution name	*VRF for heating and cooling*
	2	Example of application	*Proyectos con Europa - AVRA - Junta de Andalucía - Agencia de Vivienda y Rehabilitación de Andalucía*
	3	Possible supplier	*Daikin*
Tech. and Performance Specifications	4	Function	*Heating & Cooling*
	5	Heat generator	*VRF unit*
	6	Source/fuel	*electricity*
	7	Flow type	*variable*
	8	Distribution system	*not-accessible insulated*
	9	Emission system	*VRF indoor units*
	10	Control system	*not reported*
	11	Monitoring system IEQ	*not reported*
	12	Monitoring system Energy	*not reported*
	13	Heat recovery	*yes (heat exchanger)*
Installation and Design	14	Technical space required?	*yes*
	15	Visibility	*yes (from the outside)*
	16	Centralized?	*centralized*
	17	Installation	*medium disturbance*
	18	Cost	*medium (€€)*

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Tailored intervention solutions for future-proofing historic buildings

At FuturHist, we research and test energy-efficient retrofit interventions tailored to historic building typologies. We implement these solutions in real-life demonstration cases in Poland, Spain, Sweden and the UK. We focus on innovative solutions such as bio-based materials, internal insulation systems, window retrofits, HVAC, and RES integration.

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