FuturHist

Guidelines for RES Integration

Project Overview

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Executive Summary

To truly futureproof historic buildings, it is necessary to scale up actions and ensure the uptake of any solutions that are proposed. This can be achieved by raising awareness of good practices among the right audiences. This report consists of two major parts: a guide concerning the implementation of heat pumps, and a guide to implementing photovoltaics. Both guides are addressed to architects and are intended to facilitate the uptake of RES-based solutions investigated as a part of WP3.

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Disclaimer

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Abbreviations and definitions

Archetype building	Theoretically defined building based on the typical or average census values (Berg, 2015).
Authenticity	Grade of preservation of original state of a property in terms of function and use, form and materials, and environment (Code Wallon Du Patrimoine, 2023).
BAPV	Building-applied photovoltaics
BIPV	Building-integrated photovoltaic
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).
DHW	Domestic Hot Water, i.e., heating water for domestic or commercial purposes other than space heating and process requirements (*ASHRAE Terminology*, 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 Project*, 2020).
Energy demand for heating and cooling	Calculated amount of energy required to cover heating and cooling of a building (*Hotmaps Project*, 2020).
Energy retrofit	A general concept for all types of renovations where reduced energy consumption is the main goal for the renovation (Eriksson & Johansson, 2021). It is used for the entire renovation process, from planning to evaluation, and is closely related to sustainable renovation (Thuvander et al., 2011). 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 (“Energy Efficiency in Building Renovation,” 2019).
EPC	Energy Performance Certificate.
EU	European Union.
Floor area (of a building)	Area of the floor surface of indoor spaces of a building.

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.
HIA	Heritage Impact Assessment
Historic building (HB)	Building of heritage significance as per EN 16883:2017 (European Committee for Standardization, 2017) 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.
HP	Heat pump
HVAC	Heating, ventilation, and air conditioning
Integrity	Grade of homogeneity and coherence of a property in terms of physical integrity of the building. This criterion evaluates the condition of the building compared to what it was at the time of its construction, from the point of view of the physical composition of the materials and the construction techniques of the building period (Code Wallon Du Patrimoine, 2023)
IPV	Independent Photovoltaics
KPI	Key performance indicator
PV	Photovoltaic
Rarity	Grade of uniqueness of a property in terms of typology, style, dating, or interest, whether social or historic (Code Wallon Du Patrimoine, 2023)
Reference building	Actual building designated to represent a building stock by data obtained from statistics or surveys, with the condition that the sample size is sufficiently large (Berg, 2015). FuturHist demonstrator buildings are reference buildings within their respective typologies
Representativeness	Grade of preservation of property’s architectural characteristics linked to a specific function (Code Wallon Du Patrimoine, 2023)
U-value	Thermal transmittance value, i.e., the rate of transfer of heat through a structure
WP	Work Package

1. Introduction

1.1. Background and objectives

Among the aims of the FuturHist project is to enhance the energy efficiency of historic buildings via the application of active systems, preferably those based on renewable energy sources (RES). It can be argued that to fully take advantage of the project's findings with respect to such active systems, a widespread awareness of their specificity as pertains to historic buildings must be attained so that uptake can be achieved. It is therefore necessary to present the insight gained on the application of active systems in historic buildings, specifically heat pumps and photovoltaic installations, in an easy-to-digest manner to architectural professionals so they can leverage this knowledge in advising their clients on how to proceed with the retrofitting of historic buildings.

The objective of this report is to present two separate guidelines intended for use by architects: one for heat pump systems (also called simply heat pumps in the following) and one for photovoltaics. Two distinct forms were adopted for each set of guidelines, both with online publication in mind: the heat pump guidelines were designed to be short and publishable as an online article in an architectural magazine (e.g., *Dezeen*) that could serve as a teaser for a more comprehensive, longer text or document, while the photovoltaics guidelines were intended to follow the structure of a wiki, namely of several articles that could be linked together based on relevance, and could be integrated with the WP4 Toolkit.

Specifically, the decision to opt for an architectural online magazine as an outlet for the guidelines was motivated by the significant popularity of such outlets among architects, especially younger members of the profession. Therefore, targeting the readership of such outlets is sensible as this is a population that is more likely to engage with guidelines in general due to its own perceived inexperience and the largely case-specific nature of approaching HBs, which lends itself to an opinion that it is a hard-to-approach subject matter.

The reasoning behind the choice of heat pumps and photovoltaic systems as the feature technologies was dictated by their near-universal applicability and the absence of reliance on external energy sources that may be geographically or otherwise constrained, such as hydropower. Solar thermal solutions can also be applicable to historic buildings, however we elected to focus on PV solutions, which in terms of aesthetics and acceptability have seen a rapid development in recent years.

In addition, this choice was motivated by the presence of external units in these technologies, whose aesthetic integration with heritage may prove problematic, and therefore merits an architect's involvement to the greatest degree. The two guidelines were given different formats. The heat pump guidelines were envisioned as a short-form, web-based article that could be uploaded to the website of an architectural trade web portal. The length of these guidelines was dictated by the degree of an architect's involvement in choosing and placing a heat pump system, and it can be argued that there is a smaller number of architectural factors at play when planning these systems. In the case of the photovoltaics guidelines, we opted for a wiki-based format that could accommodate a greater amount of content and could be linked to other Work Packages' outputs, most notably those of Work Package 4.

It is also possible to rearrange the content of the PV guidelines into an online article as well, as the wiki format allows for this. It is expected that this could take place as a result of discussions with the editors of architectural magazines that would be interested in publishing the guidelines presented.

1.2. Organisation of this report

This report is divided into four main sections, excluding this introduction. The Methodology section explains the process by which the guidelines were conceptually developed and written and is followed by the two main guidelines sections: the heat pump guidelines and the photovoltaic systems guidelines, in this order. The heat pump guidelines is written as a web article and therefore a continuous text. It is also structured in the form of seven steps to be followed in sequence. The photovoltaic systems guidelines are structured in a wiki format, which means that they are a collection of articles that link to each other. This means that, technically, while there is a suggested reading order for the main articles that deal with the major elements of the recommended approach, there are also smaller articles that can be read alongside them, but in no particular order.

The final section offers a set of conclusions and an outlook of how this report contributes to the overall project, specifying the main fields affected and the report's potential later uses.

2. Methodology

As this report's objective was not to present research findings, no strict research methodology was used. Instead, two structured approaches were used to draft the guidelines presented, and both were preceded by a literature review that covered both academic and trade literature.

The main findings of the brief investigation into existing guides that would specifically address heat pumps and photovoltaic systems in historic buildings and be addressed to architects found that they were relatively few and not many were suitable for architects as the main target group. Of note was the number of guidance notes and publications by Historic England (Historic England, n.d.-a, n.d.-b, 2025b) and the Norwegian Riksantikvaren (Riksantikvaren, n.d.-a), which specifically discussed heat pumps. The situation was the same with photovoltaic systems, as these two institutions once again had guides that were specific and easy to digest for architects (Historic England, 2024c, 2024d, 2024e, 2024f; Riksantikvaren, n.d.-b).

In the countries hosting the demonstration buildings, we found little in the way of dedicated guides that would meet the criteria mentioned. Of note here is a guide by Historic Environment Scotland (Curtis & Jenkins, 2023), the Spanish IDAE guide to heat pumps (Instituto para la Diversificación y Ahorro de la Energía, 2023) and the guides by the Swedish National Heritage Board (Riksantikvarieämbetet, 2025). In the case of Poland, official guidelines were limited to PV systems and came in the form of a letter from the Secretary of State in the Ministry of Culture and National Heritage to the Voivodeship Conservators of Monuments (Sellin, 2023).

The guides produced in this report also drew from information and data collected during previous tasks, most notably those that were part of WP1 and WP3.

2.1. Heat pump guidelines methodology

2.1.1. Delphi Design Sprint

The guidelines for heat pumps were formulated using an abridged and modified version of the Delphi Design Sprint methodology proposed by Thoring, Klöckner and Mueller (Thoring et al., 2022). A simplified overview of this method has been presented in Figure 1.

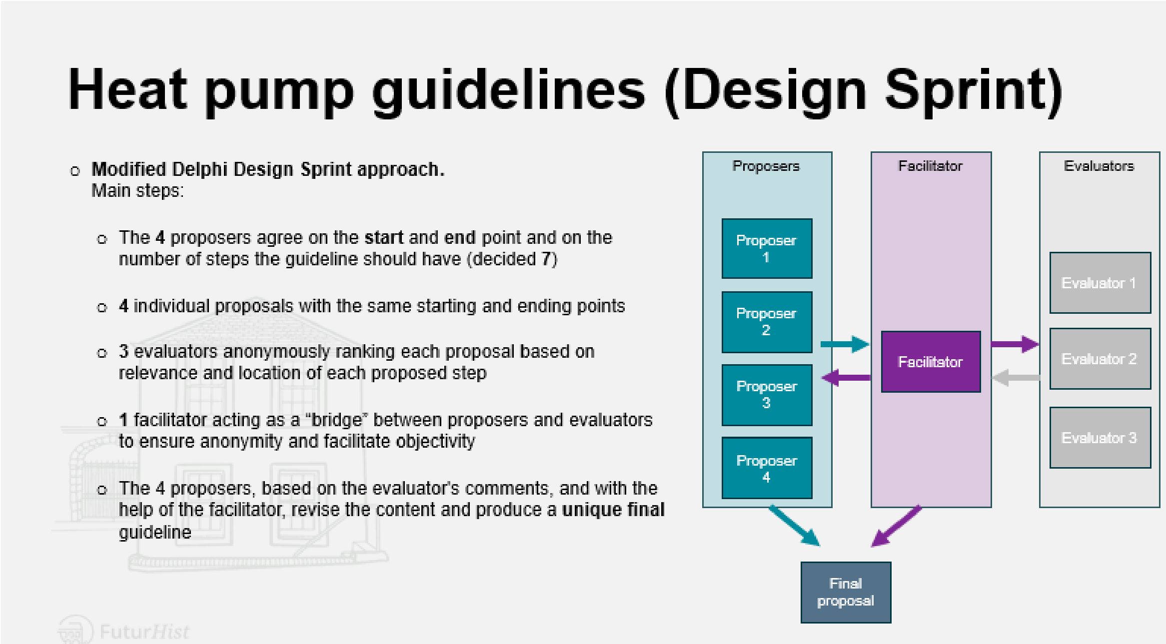

Figure 1. Diagram showing the Design Sprint methodology used to write the Heat Pump Guidelines

The Delphi Design Sprint method was selected due to its potential use in approaches of so-called 'writing by committee', wherein several authors contribute to a single text that does not have distinct, autonomous sections. In the version of the method used, four proposal writers were selected from among the researchers working on Task 3.1. These researchers, with different technical backgrounds, went through several rounds of joint brainstorming to arrive at a specific start and end point for the guidelines and reach a decision on the number of steps the guidelines should have.

Afterwards, the proposal writers were tasked with preparing a proposal for the guide, complete with an introduction, the seven steps, and closing remarks. At the same time, a facilitator was selected from among the researchers working on the project otherwise not involved with the task. The facilitator was to act as a bridge between the proposal writers and the evaluators, who were to perform a double-blind review of each proposal.

The evaluators rated each proposal's step for significance, which was defined as a step's overall usefulness for the guidelines' stated purpose and within the proposal itself. This was rated on a Likert scale, from entirely insignificant (and meriting removal) to highly significant. The steps were also rated for placement within the guideline sequence, namely whether a given step was in the right place. This was also rated on a Likert scale, but this time a rating of 1 meant a given step would fit much, much earlier than its current position, a rating of 3 meant the position did not need changing, and a rating of 5 meant the step would best be moved significantly towards the end of the sequence.

The evaluators also gave linguistic comments on every proposal and every individual step in those proposals. The facilitator communicated the results of the evaluation to the proposal writers, who then reached a decision to take the proposal with the highest consistency in terms of sequence (rated by all evaluators as having the correct sequence for all steps) and, via identifying the best features of all the other proposals, modify that proposal so that it would better display those features while improving clarity and accessibility.

2.2. Photovoltaic systems guidelines methodology

The guidelines for photovoltaic systems were developed following a literature review and an investigation of existing guidelines available online, both in the countries hosting the demonstration cases and others, as well as collective brainstorming to design the guidelines' structure and content (Svenlin & Jusslin, 2023; Wilson, 2013). This investigation was mostly informal and sought to establish the degree of deficiency in the accessibility of official guidelines, specifically those issued by state heritage authorities, with an intent to create a sort of middle ground that would combine informativeness, generality and accessibility.

Furthermore, as the guidelines were meant for use by architects, the contributing authors performed several rounds of brainstorming with regards to what content to present and how to format them. It was ultimately decided that, due to overlapping nature of certain steps, it would be best to present the readers with a wiki structure that consists of several articles that can be read in an order chosen by the reader depending on their familiarity with each subject (Hadjerrouit, 2014). This also meant that it was possible to create both longer, substantive articles that would detail certain actions or steps in the approach recommended in the guidelines, and shorter ones that would explain certain terms or provide context.

3. Heat Pump Guidelines

3.1 Heat Pumps in Historic Buildings: A Seven-Step Guide for Architects

Historic buildings are often challenging when it comes to modernising systems for energy efficiency. However, integrating heat pump technology can be a sustainable solution for enhancing energy efficiency without compromising the historic significance of the building. Heat pumps are efficient and environmentally friendly systems, but careful consideration is required to select the best option for a historic setting.

Replacing gas boilers and other fossil based energy sources with heat pumps is a key to the decarbonization of existing buildings. Doing this in buildings of heritage significance requires careful planning. There is no blanket solution that fits every building, but the steps in this guideline will be the same for a 20th century terrace and a 17th century manor. By following the guideline you will understand whether a heat pump solution is feasible for your project, and have drafted an initial concept for a suitable heat pump system.

This guide outlines seven key steps that can be used to determine the most suitable heat pump solution for historic buildings, balancing energy and environmental needs with preservation. The heat pump guides from Riksantikvaren and Historic England are recommended reading alongside this Seven Step Guide.

Recommended guidelines on the use of heat pumps in buildings listed and worthy of preservation - Riksantikvaren

Installing Heat Pumps in Historic Buildings | Historic England

This guide is intentionally light on detail and covers several aspects related to different fields (from heritage value to specific thermal demand of the considered building) that need to be considered in an initial assessment.

All aspects reported in the following should be assessed more deeply with the help of specialists, such as a heating engineer, and always in contact with the necessary heritage authorities and the client.

These guidelines adopt the following perspective:

Starting point: I am an architect working on an energy retrofit of a historic building and I am wondering whether a heat pump system would be right for my project, but I haven't decided that yet and I want to understand whether it is a proper option.

End point: I now understand whether a heat pump is a feasible solution for achieving the project's objectives, and I have an initial concept for a heat pump system that's suitable.

Step 1: Define what you want

Every properly planned project starts with a well-defined set of goals. In the case of historic buildings, these goals are not only the clients', but also, in some cases, those of the heritage officer and other stakeholders such as end users, heritage NGOs, neighbours. Keeping these in perspective when following this set of guidelines can lead to a beneficial outcome.

What does your client want to achieve? There might be several objectives, and they will vary between projects. Important to consider here is how different alternatives should be assessed later. Think about the criteria that could be used to measure and compare your options and alternatives and how much each criterion matters in the project. Consider weighting these criteria and using a decision support method.

These objectives could be:

- Being environmentally friendly – Consider metrics like greenhouse gas emissions.
- Saving money – Consider the total cost across the system's life cycle.
- Improve the indoor climate – Monitor temperature and humidity, ask users if they're satisfied with the current state.
- Preserving character – Consider presenting alternatives to stakeholders so they can rate this.
- Reversibility – your heritage officer or specialist may guide you in whether and where this is important.

The list of objectives may vary depending on the project, but it is important to be explicit about the project objectives and that these are communicated to everyone involved in the planning process.

Outcome: By the end of this step, the project goals and their priorities should be clearly defined.

Step 2: Check what you have

Start analysing the characteristics of the building in terms of at least:

Technical status of the building and the heating system:

A building condition survey and a technical survey of the existing heating and ventilation system is necessary to understand the potential for accommodating a heat pump system.

Such a survey should include, specifically, at minimum:

Quantitative aspects:

Building envelope thermal characteristics such as:

Insulation Levels: Determine the current state of insulation and areas where heat loss may be occurring (e.g., poor windows, uninsulated walls, or attic spaces).

Thermal Mass: Historic buildings often have heavy, solid construction materials (brick, stone) that can store heat and release it slowly. This can influence the type and capacity of the heat pump.

Air Tightness: Older buildings may have gaps and drafts that reduce efficiency. Conduct a blower door test to identify leaks and areas of air infiltration.

Identify the building's thermal needs: space heating, space cooling, DHW is the first step in selecting an appropriate heat pump system.

It is always advisable to see if any improvements could be made to the building to reduce thermal loads. Minimising these will not only reduce the size of the heating plant required, but also the costs of running the heat pump and its carbon impact.

Check if an EPC has been issued for the building.

Qualitative aspects:

How does the building’s use contribute to its thermal characteristics? Is the building used only in some specific periods, such as a church?

Are all of the building's parts subject to the same thermal requirements?

Is there any space that may be available for installing the heat pump system's components such as a balcony or technical room?

What is the condition of the thermal envelope? Does it need repairing?

Existing HVAC system, check at least:

Heat source(s): kind (e.g., gas or coal-fired boiler), status (functioning/not functioning), configuration (centralised/decentralised), and, if possible, nominal thermal power

Heat distribution system: check at least if a heat distribution system is present, if it is thermally insulated, its location, and which fluid (water, glycol) is circulating.

Heat emitters: e.g., radiators, fan coils, radiant floor system; check whether the emitter can be used for both heating and cooling.

Mechanical ventilation system: check at least if this system is present, status (functioning/not functioning), configuration (centralised/decentralised), with or without heat recovery.

Energy performance and indoor climate: Determine how much energy is currently used in the building for heating and cooling in its existing state. Compare the stated uses of each space with their required indoor climate parameters such as temperature and humidity and check whether they match. This is important as energy use is dependent on, among others, indoor temperatures and ventilation rates. Identify incorrect or unjustified energy use.

Heritage significance

In the case of listed buildings, heritage significance and elements under protection should be identified by contacting the relevant conservation authorities. When faced with a non-listed historic building, heritage significance should be investigated and the elements that are of value and that merit preservation identified. You can consult your country's prevalent heritage assessment methodologies and apply them to the building.

Budget constraints

Define the budget limit for the project. Keep this in mind when assessing options.

Outcome: A comprehensive understanding of the technical status of the building and its heating, cooling, and ventilation systems. An initial understanding of the heritage significance of the building and what building elements are in need of preservation. A baseline assessment of energy performance and indoor climate. Preliminary budget constraints.

Step 3: Understand your constraints and potentials

Identify limits and circumstances that either positively or negatively affect heat pump system selection.

Constraints

Are there constraints that limit what you can do and where you can do it? These can generally be divided into legal, technical, economic, and heritage-related constraints.

<u>Legal constraints:</u> Identify key legal constraints the local building code places on interventions inside and outside the building, such as minimum distances, nuisances, etc.

<u>Technical constraints:</u> Identify key structural and technical obstacles like poor load-bearing capacity or the need for additional repairs or reinforcement that could strain the budget, which is an <u>economic constraint</u>.

<u>Heritage-related constraints:</u> Elements under protection or that are of value must be defined, and any interventions designed to take these into account.

Potentials

Potentials are features or circumstances that either enable you to do something, expand your range of options, or enhance certain options, making them perform better.

Some features of the building or the site can inform the available set of heat pump systems as options. The presence of water bodies, watercourses, or groundwater can make water-source heat pump systems feasible, while an overall large site can make a ground heat exchanger viable.

Certain heritage features or the building’s overall form may facilitate the hiding of external and internal system elements from view so as not to unduly disturb the building’s character.

Evaluate a series of interventions that would be beneficial for heat pump system operation:

Always start considering energy efficiency first. Before designing the heat pump system evaluate the possibility of reducing the building's thermal needs by improving thermal envelope efficiency.

If the existing emitter system uses water at high temperatures (radiators), assess the feasibility of replacing the radiators with a radiant system (floor/ceiling/wall) that operates at lower water temperatures.

The new heat pump system should be designed to cover the updated building's thermal demand after the thermal envelope improvements and, preferably, using a radiant system operating at low water temperatures as heat pumps operate most efficiently with such systems.

Outcome: It should become clear what the legal, technical, and heritage-related constraints of the project are. Interventions that can improve the building's performance without violating the constraints should emerge.

Step 4: Identify your options

Consider the following points:

Different heat pump system types are available. Ground- and water-source systems are more efficient but generally more costly and need specific works. For these kinds of systems, the contribution of a specialist is needed starting from the beginning of the planning phase.

In contrast, air–water and air–air heat pump systems are simpler to assess and can often be initially evaluated by architects during the conceptual design phase. These systems are simpler and are seen as lower-cost variants.

Check various heat pump models that meet the thermal power requirements of your building and consider the following:

<u>Visual aspect</u> (also explore strategies to mitigate visual impact)

<u>Noise level</u> emitted by the system.

<u>Reversibility / fabric disturbance intensity</u> – what impact will the system's installation have on the building fabric, heritage significance and the occupants?

Collective / communal heat pumps – is it possible to place a centralised unit in the nearby area that is not as sensitive in terms of heritage values, and which could also supply other buildings? This could prevent having several smaller heat pump units installed on the facades.

Factor in the systems' needs in terms of user and technician training, builder competencies, inspections, maintenance and its remote monitoring and control functionalities. Ensure the development of a comprehensive maintenance plan that includes regular inspections and outlines the necessary steps to establish an effective remote monitoring system for proper system operation and control.

Below you will find a general list of the types of heat pumps.

- **Air Source Heat Pumps (ASHP)**
    - **Air-to-Air Heat Pumps**: Extract heat from outdoor air and transfer it directly into indoor air via a fan system. Common in homes without a water-based heating system. Multiple units will be required in a bigger building.
    - **Air-to-Water Heat Pumps**: Extract heat from outdoor air and transfer it to a water-based heating system (radiators, underfloor heating, and/or domestic hot water).
    - The air source heat pump has an outdoor unit that can be difficult to accommodate for aesthetic reasons. There might also be limitations due to the ducting required.
- **Ground Source Heat Pumps (GSHP)**
    - Use underground pipes to extract heat from the ground.
    - Can be vertical (deep boreholes) or horizontal (shallow loops in a large trench).
    - Provide stable efficiency since underground temperatures are relatively constant year-round.
- **Water Source Heat Pumps (WSHP)**
    - Extract heat from a nearby water body (lake, river, well, or aquifer).
    - Highly efficient but requires access to a suitable water source.

- **Hybrid Heat Pumps**
    - Combine a heat pump with another heating system (e.g., gas boiler or solar thermal) to optimize performance and reduce reliance on electricity during peak demand.
- **Exhaust Air Heat Pumps**
    - Reuse heat from indoor ventilation air, often combined with mechanical ventilation systems.

Outcome: The outcome of this step should be a list of options (heat pump systems) that are investigated to the same degree and can serve as alternatives for making the final decision on which system to adopt.

Step 5: Evaluate synergies

This step aims to evaluate potential synergies between heat pumps and other aspects, allowing for further reduction of the running costs of the heat pump system. The list of potential synergies presented is by no means exhaustive, and not all synergies may be present or have the same characteristics in every project.

Renewables:

For historic buildings aiming to maximise sustainability, integrating renewable energy sources with the heat pump system is worthy of consideration. The use of renewables can lead to lower emissions, and/or lower operational costs of the heat pump system. This might involve the use of:

<u>Solar Panels:</u> Supplementing the energy demand of the heat pump system with eg. photovoltaic (PV) panels can reduce reliance on grid supplied electricity and lead to lower operational costs.

<u>Wind Energy:</u> If the site is suitable, small wind turbines may help offset electricity consumption.

By using renewable energy options, the overall environmental impact of the building's energy system can be minimised, particularly where the grid supplied electricity is from fossil-fuelled sources. However, these solutions are not without visual and other impacts and may only be acceptable to stakeholders if the installation is designed in a way that avoids harm to the heritage significance of the building e.g. By installing the PV panels on an outbuilding, or in the garden etc.

Energy storage:

Assess the potential benefit associated with the installation of electric and/or thermal storage.

Smart energy solutions:

Consider whether smart solutions and automation could enable your system to intelligently and automatically take advantage of energy tariffs that vary during the day.

District heating:

Consider if it is possible to supplement the overall energy system of the building with district heating, especially if the project goals emphasise LCA indicators and cost.

Outcome: After this step, it should be clear what measures and options can enhance the operation and feasibility of the heat pump system.

Step 6: Perform an economic analysis

After establishing that a heat pump system is theoretically feasible (at this conceptual stage) based on the previous steps, check if it is viable from an economic perspective.

Take into account that the upfront cost of heat pump installation in a historic building can vary based on complexity and the type of system chosen. Therefore, consider:

Upfront Capital Investment: Calculate the initial costs for equipment, installation, and any necessary modifications to the building.

Cost Savings: Estimate the reduction in running costs (heating, cooling, maintenance) over time to determine the Return On Investment (ROI), factoring in that fossil energy prices may fluctuate.

Available Incentives: Explore financial incentives, rebates, or tax credits for retrofitting historic buildings with energy-efficient systems.

Outcome: Initial assessment of the economic viability of using the solutions identified in the previous steps.

Step 7: Make your decision

Guided by the initial objectives set out in step 1, determine if any of the potential solutions identified in the previous steps are suitable and rank them. If not, go back to step 1 and revise your objectives. Document the planning process so far and, after having consulted the necessary specialists, share your results with the client and stakeholders.

Outcome: you should now be able to make an informed initial decision on whether to adopt a heat pump system in your project, and if so, then what type and what other supporting systems might be suitable to install.

Closing remarks:

The 7 steps presented above cover several aspects that are essential when dealing with historic buildings.

After following these steps, an architect should have a clearer idea about whether a heat pump system is a feasible and proper solution for the building considered and what are the main next steps to follow, in alignment with the project's stated goals.

As stated in the introduction, all aspects must be analysed more deeply in the next phases of the process, with the help of specialists and in consultation with heritage authorities and your client.

Related information from external sources

- Historic England, Adapting Historic Buildings for Energy and Carbon Efficiency, Historic England Advice Note 18 (Historic England, 2024a);
- Historic England, Installing Heat Pumps in Historic Buildings (Historic England, n.d.-a);
- Historic England, Heat Pumps in Historic Buildings: Addressing Myths and Misconceptions (Historic England, 2025b);
- The Guardian, Heat Pump Mythbusters (The Guardian, 2024);
- Historic England, Low and Zero Carbon Technologies (Historic England, n.d.-b);
- Riksantikvaren, Recommended guidelines on the use of heat pumps in buildings listed and worth of preservation (Riksantikvaren, n.d.-a);

- Riksantikvaren, The Norwegian Directorate for Cultural Heritage's Guide on Solar Energy Systems for Existing Buildings (Riksantikvaren, n.d.-b).
- IDAE, La bomba de calor en la rehabilitación energética de edificios (Instituto para la Diversificación y Ahorro de la Energía, 2023)

4. Photovoltaics Guidelines

How to read this section

Each numbered section acts as an independent article that can be viewed on a website, potentially hosted by one of the partners (such as the ICOMOS knowledge hub) or alongside the WP4 toolkit. Within some of the sections there are terms written in **bold** with section numbers written in parentheses like so **(4.n)**. This denotes that the term in bold is to serve as a link to an article that, in this document, can be found in the section numbered.

4.1. Introduction (Landing Page)

Introduction

Welcome to the Guidelines on the Use of Photovoltaics in Historic Buildings developed by FuturHist, which will guide you through the process of approaching **historic building (4.3)** retrofit projects that aim for the inclusion of **renewable solar energy (4.4)** in the building's energy mix. As a part of this guide, you will:

- Learn the basics of goal-setting and criteria formulation with respect to applying photovoltaics in historic buildings from the perspective of decision problems;
- Gain a general familiarity with the various types of photovoltaic systems and their related interventions;
- Learn the basics of how to navigate, balance and leverage heritage features and constraints;
- Obtain a fundamental understanding of building features that impact photovoltaic power generation;
- Gain essential insight into how to negotiate heritage and power generation considerations for results that can satisfy your project objectives;

Process structure

As a part of these guidelines, we treat the question of installing a PV system on a historic building or in its vicinity as a **decision problem (4.2)**, in which several factors need to be appraised, quantified and compared. To properly go through it, one must first familiarise themselves with the **types of PV systems (4.4)** and potential **intervention categories (4.8).**

This should be followed by clearly delineating the objectives of the energy retrofit project and how important they are, thus setting up the decision to install PVs as a **multi-criteria decision problem (4.2)**, with its own criteria and their respective weights. Once this has been done, it is recommended to appraise the historic building and **its curtilage (4.10; 4.11)** in terms of:

- **Heritage value and impact (4.9)**;
- **PV potential of the HB and curtilage's geometric surfaces (4.12);**

Once this is done, you should have an overview of where you can put PV elements on your site and building, and how well suited these surfaces are for power generation should they be equipped with said elements.

Knowing this, and having the project criteria clearly identified, it is now possible to **appraise the PV products (4.13)** that can form retrofit packages and thus decision alternatives. This appraisal requires its own set of decision criteria, as PV products may differ significantly from one another in many areas that may be key to the project.

Once this has been done, all the pieces to finalise the decision problem are in place, and a ranking of suitable project alternatives can be compiled, thus facilitating the decision on what type of PV system to use in the project.

The section **Installing BIPV and PV Panels on, and within the Curtilage of a Historic Building (4.11)** includes its own proposal for a structured approach that can be used to approach PV systems on an HB itself. Either approach can be used depending on whether you find it easier to follow.

4.2. The Project as a Multi-Criteria Decision Problem

Project objectives

To truly take advantage of the opportunities offered by photovoltaic systems in historic buildings, it is first essential to be clearly aware of our project's goals. These can vary and may stem from different considerations, and are usually articulated by the project's main actors: you as the architect, your Client, your Consultants, the relevant Heritage Authority, the Planning Authority and any other Stakeholders that may be applicable to the project. Below is a sample, non-exhaustive list of the objectives that may apply to a historic building energy retrofit project:

- Preserving the original appearance of the building, but not necessarily its substance;
- Preserving the original substance of the building, but not necessarily its external appearance;
- Obtaining as much renewable energy as possible while keeping maintenance costs down;

Decision alternatives

A project's objectives can be achieved in many different ways and means, and it is crucial to know what our options are. This is where decision alternatives come into play. Here, an alternative is a solution or a package of solutions that can be compared or rated against other similar elements, with the end goal being to identify the one that ranks highest from the perspective of our project's key performance indicators.

Decision criteria

Once you have the project objectives formulated, it is time to look at the various types of criteria that can be used to measure success in achieving them and how significant they are to your project's success. Some of these criteria can be relatively easy to measure, such as power output, purchase and installation cost, maintenance cost, or warranty period length, while others may be more complicated to rate, such as visibility, heritage impact or environmental impact.

Weights

Not all criteria will be equally critical to your project, and this needs to be expressed in some way. The most common method is to ascribe weights to them. A high-weighing criterion will be more important to the overall ranking of alternatives and, conversely, a low-weighing criterion may be insignificant, but may nevertheless tip the scales in favour of one of the alternatives.

Ranking

The final step of a decision process is to rank the alternatives by aggregating their performance in each criterion and factoring in the weights. This aggregation may be skipped, especially in the case of projects where a single criterion is seen as decisive and others play a more informative role, but can be a great aid when the situation is more complex and requires a more detailed approach.

4.3. Historic Building

For the purposes of these guidelines, a historic building (HB) can refer to any building that can be considered historic, whether listed as a heritage site of any form or not, that is deemed worthy of preservation **and may require a heritage impact assessment (4.9)**.

4.4. Photovoltaics

In these guidelines, photovoltaics (PV) is understood as any element that can be used to generate electricity at the site of a building. Photovoltaics can be generally divided into **Building-Applied Photovoltaics (BAPVs) (4.5)**, **Building-Integrated Photovoltaics (BIPVs) (4.6)** and **Independent Photovoltaics (IPV) (4.7)**.

4.5. Building-Applied Photovoltaics

Building-Applied Photovoltaics consist of PV solutions that are directly mounted, generally in the form of panels or film, to a building's external surfaces, chiefly roofs and facades. They can come in different forms, with different options for colour, form, reflectivity and texture, which can aid in blending them with the architecture of an HB. The fixings can also come in different types, from more overt and visible ones, and others that are more discrete and hidden.

From a heritage preservation perspective, their use may be constrained or outright restricted by the relevant conservation authority. However, they are also more likely to be considered more easily reversible or a sign of their times.

Generally, this type of solution is seen as more cost-effective and easier to maintain or replace than **BIPV solutions (4.6)**.

4.6. Building-Integrated Photovoltaics

Building-Integrated Photovoltaics consist of PV solutions that replace a part of a building with an equivalent that generates electricity, and in some cases are virtually indistinguishable from the building elements that they replace. These include elements such as roof tiles, sheet-metal roofing, façade panels and siding, and window glazing. As their intended purpose is to "mimic" a building's existing element, it may be easier to convince heritage conservation authorities to approve their application in a project, although potential conflicts with reversibility and a desire for material authenticity may arise in some cases.

However, the improved aesthetic is somewhat counterbalanced by the bespoke nature of such solutions, as conservation authorities may request that they be shaped and coloured in ways specific to the HB they are to be installed on, which can make them more costly and less efficient than BAPVs. It must also be noted that BIPV elements will have their orientation with respect to the sun's angle of incidence determined by the building elements they replace, and this may not always offer the highest performance.

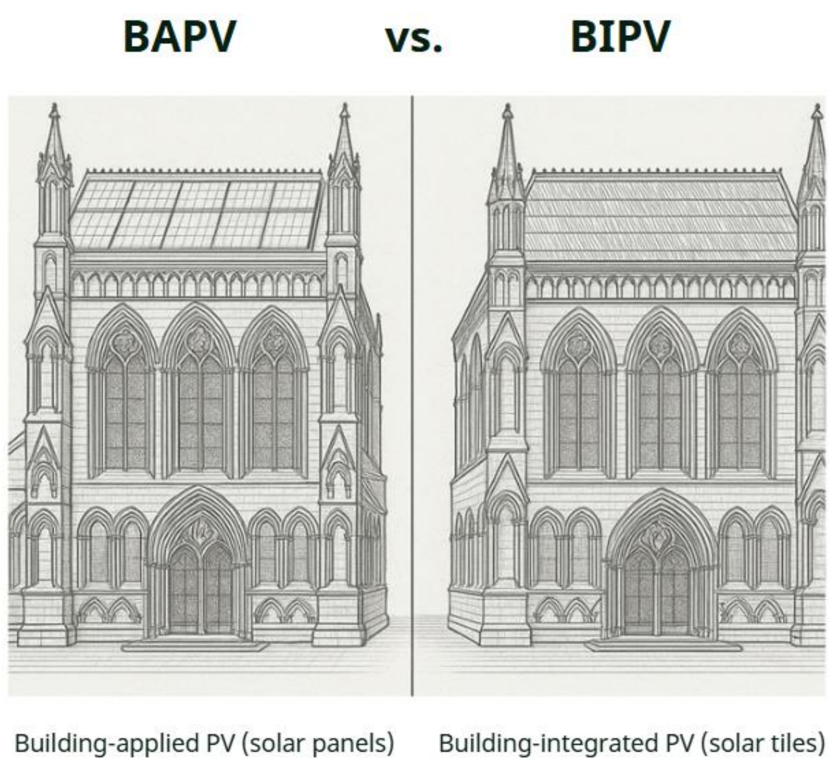

Figure 2. BAPV vs. BIPV

4.7. Independent Photovoltaics

Independent Photovoltaics consist of PV solutions mounted directly on the ground or on freestanding structures that are not buildings.

4.8. Intervention types

Introduction

The integration of photovoltaic (PV) technologies into heritage settings presents unique challenges and opportunities. This section provides guidance and inspiration for the deployment of **Building-Integrated Photovoltaics (BIPV) (4.6)** and **Building-Applied Photovoltaics (BAPV) (4.5)** in historically sensitive environments, evaluating their respective advantages and application scenarios. It presents six suggested categories/strategies for PV interventions: Addition, Replacement, Extension/Completion, Independent, Artistic, and Mobile/Temporary. These were inspired by the intervention categories outlined in the research "New Lightweight Structures and Historical Heavyweight Structures in Conservation" by A. Mosseri (Mosseri, 2021).

Addition (Building Applied Photovoltaics)

Building-Applied Photovoltaics (BAPV) refers to PV systems installed as an additional layer on top of existing building structures, such as roofs or façades. These systems are generally fitted over pre-existing surfaces and are usually visually distinguishable from the underlying architectural elements (but can be aesthetically integrated to varying degrees, e.g., by colour matching). In cases where the original roof covering is considered worthy of preservation and sensitive to change, this may be the preferred approach.

See the **King's College, Cambridge (4.14)** case for an example of an "Addition" intervention.

Replacement (Building-Integrated Photovoltaics)

Building-Integrated Photovoltaics (BIPV) systems, in contrast, are embedded into the building envelope itself, replacing conventional building materials (e.g. roof tiles, sheet-metal or cladding). This approach offers a more seamless, less visually intrusive integration which can be particularly relevant in heritage contexts.

Considerations

While BIPV may involve higher initial costs, these may be partially offset during major refurbishments by the reduced need for traditional cladding or roofing materials. BIPV solutions are often more suitable for projects where conservation, planning, and visual integrity are key factors. However, it is important to note that this is not always the case, and it is important to have a discussion with the relevant heritage authority about which might be the preferred approach, at an early stage.

See the **York Minster Refectory (4.14)** case for an example of a "Replacement" intervention.

Extension/Completion (of the existing structure)

In instances where new extensions to, or major remodelling of, parts of a building are being planned (or have already been carried out) such newer structures may provide suitable opportunities to accommodate BIPV or BAPV solutions, provided they are designed sensitively and comply with any planning, conservation area or heritage constraints.

See the **Chur, Switzerland, (4.14)** case for an example of an "Extension/Completion" intervention.

Independent (within the curtilage or near vicinity)

The use of PV technology may be more permissible if located within the curtilage of a heritage site than on the main structure itself. If space permits this can include freestanding installations such as ground-mounted PV, or on freestanding structures (e.g., a garden pergola or carport).

Installing PVs in the vicinity, in locations that may be less sensitive to change than the main building, is worthy of consideration. Such interventions may be more acceptable and represent less harm to heritage significance, provided they are designed sensitively and comply with any conservation area or listing constraints.

Considerations

- Confirm the heritage designation of any ancillary buildings—as existing structures within the curtilage may carry the same protection as the main building.

- Evaluate the visual impact of PV installations on the setting and character of the principal heritage asset.
- Engage with local planning and heritage officers early in the design process.

See the **Chippenham Hall, UK**, **(4.14)** case for an example of an "Independent" intervention.

Artistic (either permanent or temporary)

Recent innovations in PV technology now allow for highly creative and context-sensitive installations. Options include:

- Coloured or semi-transparent PV panels that contribute aesthetically to the setting.
- Printed PV imagery used in public art or temporary exhibitions.
- Art-integrated BIPV elements incorporated directly into new architectural features.

These installations can offer both temporary or permanent PV solutions that can enhance public engagement and awareness around sustainability, while preserving the site's historic character.

See the **Queen Ingrid's Garden (4.14)** in Oslo case as an example of an "Artistic" intervention.

Mobile / Temporary

Installations that are temporary or mobile can in many cases be assessed differently in terms of planning and heritage legislation. It is quite common to see tents and other temporary structures installed within the setting of heritage assets during popular events such as concerts, weddings etc. Where heritage assets have seasonal uses, e.g., with increased tourism during summer months, it may be worth considering the use of temporary or mobile PV installations to offset the energy consumed at these events. These can even take the form of artistically designed mobile / temporary PV structures, or even PV fabrics used in tents or canopies.

Considerations:

- Consider ways to mitigate the visual impact on the setting and character of the principal heritage asset, even with temporary installations.

- Engage with local planning and heritage officers early in the planning process.

See the **Urban Oasis (4.14)** case as an example of a "Mobile/Temporary" intervention.

Conclusion

When carefully designed and sensitively implemented, PV technologies can offer viable pathways for integrating renewable energy into heritage environments. It can be useful to consider creative solutions that explore the potential within the curtilage and near vicinity of the heritage asset as well as on the main building. However, each project must be evaluated on a case-by-case basis, considering visual impact, architectural integrity, planning regulations, and heritage significance, as well as costs and benefits.

See guidance note on **heritage impact assessments (4.9)**.

References:

(Court et al., 2022)

(Historic Environment Scotland, 2023)

(Dreith, 2023)

(Fedorczak-Cisak et al., 2024)

(Matich, 2022)

4.9. Heritage Impact Assessment

This section considers conducting a Heritage Impact Assessment (HIA) for historic Buildings with Guidance from the UK, Sweden, Poland, and Spain.

Introduction

Heritage Impact Assessments (HIAs) are increasingly required across Europe to manage change within the historic environment. While UNESCO and ICOMOS provide the international foundation, national authorities apply and adapt these principles in varied legal and cultural contexts. Below we briefly outline a practical and policy-aligned methodology for HIAs, integrating guidance from Historic England, Historic Environment Scotland, RAÄ (Sweden), NID (Poland), IPCE (Spain) and the European standard EN16883 (European Committee for Standardization, 2017).

Policy and Legal Framework

International Guidance

- UNESCO World Heritage Convention (1972): Obligates States to assess and mitigate threats to cultural heritage.
- ICOMOS (2011): Offers detailed guidance on HIAs for World Heritage properties with emphasis on authenticity, integrity, and values.

National Frameworks and tools

- Historic England (UK): Managing Significance in Decision-Taking in the Historic Environment - Historic Environment Good Practice Advice in Planning: 2 (Historic England, 2015)

  And, Historic England Good Practice Advice Note 3. The Setting of Heritage Assets - Historic Environment Good Practice Advice in Planning: 3 (2nd Edition) (Historic England, 2017)

- Historic Environment Scotland (HES): Managing Change in the Historic Environment
  (Historic Environment Scotland, n.d.)
- RAÄ – Sweden: Bases assessments on Kulturmiljölagen using cultural-historical value models (Kulturmiljölag, 2024).
- NID – Poland: Uses national inventories under Ustawa o ochronie zabytków (Narodowy Instytut Dziedzictwa, n.d.; Ustawa z Dnia 23 Lipca 2003 r. o Ochronie Zabytków i Opiece Nad Zabytkami, 2024)
- IPCE – Spain: Requires HIAs under Ley 16/1985, focusing on visual, spatial, and contextual impacts (Ley 16/1985, de 25 de Junio, Del Patrimonio Histórico Español, 2021).
- SAVE (Survey of Architectural Values in the Environment) – used in Denmark (Tennesen et al., n.d.).

Core Steps of a Heritage Impact Assessment

Step 1: Understand the Heritage Asset

- Conduct baseline study using documentation and field surveys.
- Identify any legal constraints (including if listed building consent is needed)
- Develop a *Statement of Significance* based on national criteria. (The statement of significance should aim to link heritage values to "character-defining elements" to make it more actionable and precise).
- Conduct a "sensitivity/vulnerability to change" assessment.
- Ensure that the owners'/stakeholders' priorities are considered (for a non-listed building it could be the case that there is no heritage expertise involved)

Step 2: Describe the Proposed Change, (and any options under consideration)**.**

- Provide plans, drawings, and visual simulations.
- If there are options available present their relative merits.

Step 3: Assess the Impact

- Analyse the *material, visual, spatial* impacts and *reversibility* of the proposed change.

Material impact

The extent to which the physical interventions introduced during a retrofit alter the historic building's existing fabric or its setting — and how this affects the heritage significance of the building and its settings.

Visual impact

The extent of visual alterations to the building and its setting, both internally and externally, such as changes in color, style, or the addition of new visual elements that affect its character — and how this affects the heritage significance of the building and its settings

Spatial impact

Spatial impact evaluates how the retrofit intervention alters the building's interior layout, volume, or external footprint, affecting its historic function, spatial experience, and relationship with its surroundings — and how this affects the heritage significance of the building and its settings.

Reversibility
The potential of retrofit measures (materials, components, or alterations) to be removed, dismantled, or reversed without causing physical damage to the historic building's structure, finishes, or setting. Note: inappropriate retrofit interventions that would undermine the heritage significance of the building, even if they are reversible, should be discarded. Where there are options, analyse and compare their relative impacts.

Step 4: Explore Alternatives and Mitigation

- Identify ways to minimise harm through design, materials, and reversibility.
- At this stage it may be necessary to explore further alternatives if none of the options presented are deemed acceptable.

Step 5: Engage Stakeholders

- Consult public, professionals, and authorities, as necessary.

Step 6: Conclusion and Recommendations

- Summarise and classify impact; provide a justified decision.

Conclusion

A Heritage Impact Assessment is a valuable mechanism to ensure that development and change respect the cultural significance of historic buildings. Drawing from international standards and enriched by national practices in Scotland, England, Sweden, Poland, and Spain, this methodology provides a robust and adaptable framework. By integrating heritage values early in the planning process and maintaining a transparent, evidence-led approach, HIAs promote sustainable conservation outcomes for Europe's shared heritage.

4.10. Curtilage

For the purposes of these guidelines, *curtilage* refers to any land, buildings or structures that belong to the same property as the historic building intended for retrofitting and can be incorporated into the project by the Client.

4.11. Installing BIPV and PV Panels on, and within the Curtilage of a Historic Building

When considering the options for the use of photovoltaics in connection with historic and listed buildings it can be useful to not only explore interventions on the main building structure itself but also within the curtilage of the building and in the near vicinity.

This section is intended to help architects and design teams navigate the planning, heritage, technical and aesthetic considerations Building-Integrated Photovoltaics (BIPV) or conventional photovoltaic (PV). The workflow below outlines the key stages and decision points for those considering the integration of BIPV or conventional PV panels on, and within (or near) the curtilage of, a listed or historic building. It ensures that such installations respect heritage values while contributing to sustainability objectives.

Project Inception

- Identify the listed building and define the curtilage (and area of search if greater).
- Establish client, project and sustainability goals (e.g., energy reduction, net-zero targets, cost reductions).
- Assemble project team including heritage consultant and M&E engineer / BIPV specialist.

Initial Heritage Appraisal

- Review statutory listing, conservation area appraisals, and planning history. Prepare or update a Statement of Significance (this may require input from a heritage specialist).
- Identify the sensitivity of attributes, views, materials, and the heritage setting.

Site Survey and Technical Feasibility

- Assess available roof/wall/garden and other surfaces for solar irradiation and feasibility.
- Identify opportunities for installation within the curtilage or less sensitive zones in the near vicinity.
- Consider load-bearing capacity, roof orientation, shading/solar irradiation levels, electrical capacity, condition of the building.

Concept Design & Option Appraisal

- Develop and compare different BIPV/PV locations in terms of both heritage impact and solar availability.
- Develop and compare strategies and products (e.g., BIPV vs BAPV, materials, layout, mounting)
- Select BIPV/PV products and installation methods.
- Create 3D visualisations and photomontages of alternative options.
- Evaluate and compare the impact on visual amenity and historic character of each option
- Evaluate and compare the technical and economic viability of each option.

Heritage Impact Assessment (HIA)

- Assess how the proposed installation affects heritage significance.
- Evaluate direct and indirect impacts (e.g., views, setting, historic materials).
- Propose mitigation measures (e.g., positioning, materials, detailing).

Stakeholder Engagement

- Pre-application discussions with conservation/planning officers.
- Engage relevant heritage bodies (e.g., Historic England or Historic Environment Scotland), Sweden (RAÄ), Poland (NID), and Spain (IPCE

- Liaise with client, neighbours, and local interest groups where necessary.
- Respond to consultation feedback and revert to step 4 if needed.

If it is still proving difficult to find an acceptable solution at this stage it might be worth considering whether there are any additions / extensions to the building /or within the curtilage that are planned soon that might be more suitable for BIPV/PVs. Another alternative approach that might be worthy of consideration is an artistic/mobile/temporary PV installation (**see examples in section 4.14**).

Planning & Consent Submission

- Prepare full application including HIA, method statement, and visual material.
- Submit planning application and listed building consent as required. Respond to consultation feedback and revise proposals if necessary.

Detailed Design & Procurement

- Specify final BIPV/PV products and installation methods.
- Confirm any requirement for non-invasive fixings and reversibility.
- Coordinate electrical design and permissions (e.g., grid connection).
- Check proposals against the goals established in step 1.

Installation & Supervision

- Supervise works to avoid damage to historic fabric.
- Record installation for heritage documentation.
- Ensure compliance with consents and approved details.

Monitoring & Maintenance

- Monitor energy performance and visual impact.
- Establish routine maintenance procedures.
- Document lessons learned and update management plans if necessary.

4.12. Understanding the PV Potential of Surfaces

Before committing to a single PV solutions package, it is key to understand the fundamentals of how a PV element's placement affects its power output. This is crucial as—together with heritage considerations—it allows us to determine which locations on or around a building are feasible for PV placement.

The key factors that affect PV power output are sun position, solar irradiance, surface slope and orientation, temperature, and shading.

Sun position/path

To be able to assess the potential of surfaces for PV placement we must first know the sun positions and paths for our site. This can be done by generating sunpath diagrams, using solar calculators or other methods such as the so-called solar ruler. Many dedicated architectural design programs, especially those with native rendering capabilities, have in-built solar positioning functionality that can be leveraged here.

Global horizontal irradiation

Global horizontal irradiation, measured in kilowatthours per square metre (kWh/m^2) can be consulted to gauge a location's potential for energy generation using PVs and is available in atlas form online. It considers factors like direct and diffuse irradiation received by a horizontal surface, generalised for a given geographic area. It should be kept in mind that this is a generalised measure and other, more site-specific elements need to be considered.

Solar irradiance

Solar irradiance is the intensity of sunlight that can reach a PV element. It depends on a host of different factors, ranging from average weather conditions and geographic location to less obvious contributors such as the reflectivity of surfaces located in a potential PV element site's vicinity. Surfaces with a high yearly average irradiance work best for PV element placement.

Surface slope and orientation

Surface slope and orientation is relatively self-explanatory. Surfaces with a slope and orientation that allows for a more direct angle of incidence of solar rays are more suited for PV application or integration. The optimal orientation and angle will depend on the historic building's geographical location, as the sunlight's angle of incidence and azimuth differ across the globe and especially between the northern and southern hemispheres.

Temperature

Temperature is also a factor that requires consideration, as most PV systems work have a recommended operating temperature around 25°C. Care should be taken to avoid placing PV systems in areas prone to overheating, or to address this before a PV system is installed.

Shading

Finally, shading is crucial to the performance and longevity of a PV system, as even a partially shaded PV element can register a significant drop in power output. Be especially wary of situations where a PV element's surface is part-shaded and part-lit. A hard shadow that falls on some a panel or element's cells while leaving others fully irradiated can lead to spot overheating of the shaded cells, causing material stress within the element, which can lead to microcracking and damage, necessitating replacement.

Useful tools

Tools that can aid architects in determining potentially high-performance surfaces for PV placement include solar studies that can aid in visualising the parts of a building or site that can receive the greatest amount of sunlight and that are not prone to shading. In addition, rendering tools that use ray-tracing and realistic material reflectance parameters can aid in determining highly irradiated areas. These can be combined with PV daily per-hour performance charts from open-source websites to get general estimates of PV performance.

4.13. PV System Assessment

Before committing to a single PV solutions package, it is key to understand the fundamentals of how a PV element's placement affects its power output. This is crucial as—together with heritage considerations—it allows us to determine which locations on or around a building can ultimately be used to place PV systems on.

BIPV and BAPV product selection, some things to consider

Once the strategic approaches have been considered and the preferred location and approach decided it is time to assess the various technologies and products available that can best meet the aesthetic, heritage preservation and technical requirements.

Some useful guidance can be found here:

(Historic England, 2024f), (Historic England, 2024e)

Once suitable products and their manufacturers have been identified it is useful to make comparisons between similar products. Below is a non-exhaustive list of some of the aspects to consider.

Reversibility

Careful planning and the careful selection of the PV product and any associated fixing systems is needed to minimise damage to the existing building fabric when installing BIPVs or BAPVs on the historic building. A method statement that describes in detail how the PVs will be installed and removed or replaced at the end of life might be a planning requirement. Non-invasive and/or reversible methods of installation should be considered, and where possible the product and installation method chosen that can best meet such requirements.

Product longevity and Warranties

One of the important things to consider when replacing original materials or building elements with modern PV products is the durability and longevity of the materials and technical components used. Traditional roofing materials such as metal, slate, stone and clay tiles are often very durable with lifespans of decades and in some cases hundreds of years.

The useful life of PV cells can be up to 25 years after which their performance drops. The design life of the materials and components may not be much longer than this, and in the case of technical components such as inverters it can be much less.

Most PV product manufacturers provide performance warranties, and it can be useful to compare these when deciding which products are likely to be most durable.

Product and installer certification

In some cases in order to qualify for state subsidy scheme's that can improve the economic viability of PV installations, such as capital grants or feed-in-tariffs (FITs) it is essential to use products that have been certified under specific schemes. The same can also be the case for the company that is contracted to install the products. One example of this is the MCS scheme in the UK.

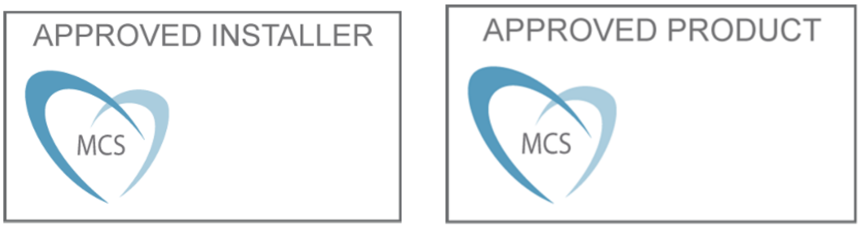

Figure 3. PV products and their installers may need to meet certain certification standards

Environmental Product Declarations (EPDs)

An Environmental Product Declaration, also known as an EPD, is an independently verified document that quantifies a product's environmental impact. It includes details about the product's, embodied carbon, water use and waste generation throughout its lifecycle. The purpose of an EPD is not to say whether a product is environmentally sustainable or not. Instead, EPDs provide the details that architects and specifiers need to make informed decisions. With an EPD, a specifier can evaluate a product's sustainability credentials, compare similar products and choose a product that aligns with the project's overall sustainability goals.

EPD's are not yet mandatory, and not all PV manufacturers provide them for all their products. But where they do exist, they can be helpful to compare the environmental impact between different product choices.

EPDs are produced in a standardised format according to ISO 14025:2006, which covers environmental labels and declarations, and EN 15804:2012+A2:2019/AC:2021, which covers sustainability of construction works

Source: (Marley, 2025).

CE Markings, Equipment Standards and Certifications

Equipment deployed in European solar installations must meet stringent standards and certifications to ensure safety, reliability, and performance. PV panels and associated equipment must carry the CE marking, indicating compliance with EU health, safety, and environmental protection standards. This mandatory certification demonstrates that products meet the requirements of applicable EU directives, including the Low Voltage Directive (LVD) and Electromagnetic Compatibility (EMC) Directive.

For photovoltaic modules, IEC 61215 certification is essential, verifying their design qualification and type approval. Additionally, IEC 61730 certification ensures module safety qualification, covering electrical and mechanical safety requirements. Inverters must comply with EN 50549, which specifies requirements for connecting to the power distribution network.

Mounting systems should have EuroCode compliance, ensuring structural integrity under various environmental conditions.

Source: (Inox Solar, 2025).

Recyclability and Circularity aspects

As one of the key arguments for installing PVs is the environmental benefits of harnessing solar energy it is important to consider recycling and disposal to mitigate environmental impacts at the end of their life.

Recycling of life-expired PV panels ensures safe disposal and provides raw materials for repurposing. It is possible to recycle 90% of the glass and 95% of the semi-conductor materials, which can be used in the manufacture of new PV cells.

Producers of PV panels may offer take-back and recycling programmes. The end-of-life recycling should be factored in when making product choices.

For further information see (Historic England, 2024d).

Weight and structural loading of PV's

Different PV products can have quite different characteristics when it comes to the weight of the products and their associated fixings. With building mounted installations, it is important to check the relative weights of the PV systems being compared and, in all cases, checks need to be made that the sub-structure can support the additional wind, snow and static load imposed by the PV panels, and that the installation complies with local Building Regulations.

BIM data availability

Historic/Heritage Building Information Modelling (HBIM) is a multi-disciplinary process that requires the input and collaboration of professionals with very different skillsets. It is a fast-developing field in terms of research, official guidance, standards and professional practice. Many manufacturers of building products now provide BIM files to support architects and building designers. As BIPVs are still an emerging field not all manufacturers yet provide BIM files for their products. But in cases where the use of HBIM is required or important the availability of product BIM files may increasingly be an important factor in product selection.

For further information see (Antonopoulou & Bryan, 2017).

LCA and LLC's

There is a growing interest in the use of Life Cycle Assessments (LCA) and Life Cycle Costings (LCC) when comparing different renovation scenarios for historic buildings. The same is likely to be the case when comparing the different the PV approaches and products for use in historic environments. However, using these approaches when working with historic buildings Is not without its challenges. Any estimation of construction costs for the renovation of a historic building (listed or not) must always be caveated with a wide range of assumptions. The true scope and therefore cost of repairing or retrofitting an old building is difficult to predict and often only becomes clear once work starts on site.

However, LCA and LCC methods can be useful to compare alternative approaches. A summary of LCA and LCC and some of the challenges is given below:

Life Cycle Assessment (LCA):

- Evaluates the environmental impacts of a building over its entire life cycle—from material extraction to demolition.
- EN 15978:2011 is the key standard referenced, offering a framework for assessing environmental performance.

Challenges:

- Limited data on historic materials.
- Uncertainty in estimating future scenarios (e.g., maintenance, energy use, carbon intensity of energy supplies).
- Difficulty in defining system boundaries (e.g., what to include in the assessment).

Life Cycle Costing (LCC):

- Focuses on the economic performance over the building's life span.
- Includes costs like initial investment, operation, maintenance, and disposal.

Challenges:

- Incomplete comparative cost data.
- Inflation and discount rate assumptions.
- Estimating future energy prices and maintenance needs.

Useful resources:

This IEA-SHC Task 59 Fact Sheet text presents tools and guidelines for life cycle analysis (LCA) and life cycle cost (LCC) (Broström, n.d.).

4.14. Cases

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King's College Chapel, University of Cambridge, UK (Addition)

Figure 4. King's College Chapel, University of Cambridge, general view. Source: caroe.com

General information

King's College Chapel in Cambridge UK is a Grade I-listed building built between 1446 and 1515 and is among the finest gothic structures in Europe. Every Christmas Eve, millions of people switch on their televisions to watch the traditional carol service from King's College Chapel, Cambridge, one of the UK's most revered buildings. The 438 PV panels are part of the renovation of the 1950s lead roof of the Chapel, which was no longer watertight. The College recognised a once-in-a-generation opportunity to install the PVs, as the Chapel roof is the single largest potential opportunity for renewable electricity generation on the main College site.

Intervention Category: Addition (BAPV)

Each of the 438 PV panels are installed as **additional (**and reversible) elements on top of the refurbished lead roof.

Figure 5. The panels are part of the renovation of the 1950s lead roof of the Chapel, which was no longer watertight. Source: Maxfordham.com,

Photovoltaics solutions

The 438 King's College chapel solar panels have the potential to generate 123,000 kWh of electricity per year. Each panel is clamped to an independent aluminium frame system supported on metal posts that sit on baseplates anchored to timber boards. Lead upstands and caps waterproof the posts. The total potential peak output of the panels is 100 kWp.

Figure 6. The shallow 25° roof pitch meant that the north and south slopes were suitable for PVs. Source: Cibsejournal.com

Architect: Caroe architecture with Max Fordham

Sources:

(“Renewing Tradition: Installing PVs on King’s College Chapel,” 2024)

(Caroe Architecture, n.d.)

(Armitage, 2024)

(Barkham, 2023)

York Minster, Refectory, York, UK (Replacement)

General information

The Refectory is a Grade II listed former York Minster School. The school was established in 1903 in a building that was initially built for St Peter’s School within the

Minster's Precinct in 1833. It is located just a stone's throw from the Grade I York Minster Cathedral.

Intervention Category: Replacement (BIPV)

The PV slates on the roofs of the refectory are a **replacement** for the original slates and will support the Minster's ambitions to achieve operational net zero carbon, as outlined in the Neighbourhood Plan.

Figure 7. The main refectory roof with the PV slates installed. Source: gb-sol.co.uk

Figure 8. The Refectory is in the shadow of the Grade I listed York Minster Cathedral; the solar slates are visible

on the roof slope in the left-hand side of the image, with traditional slates surrounding them. Source: thenorthernecho.co.uk (Duncan Lomax)

Photovoltaics solutions

The discreetly placed solar slates were supplied by UK manufacturer GB-Sol. They will produce approximately 10,000 kWh of electrical energy per year. In 2022 it represented the first time that solar tiles had been installed on a listed building in the city and followed extensive consultations between York Minster, City of York Council and Historic England.

Figure 9. A ceremony was held to mark the installation of solar slates on the roof of its Refectory building. Source: thenorthernecho.co.uk (Duncan Lomax)

Architect: Caroe architecture

Sources:

(York Minster Refectory, n.d.)

(GB-Sol, n.d.) (Caroe Architecture, n.d.)

Chippenham Hall, Cambridgeshire, UK (Independent)

General information

The property is a stately home and landscaped park located in Chippenham; a village located in east Cambridgeshire. The Hall was built about 1886, on the original site of the early C17 mansion and incorporating the fabric of two later C17 and C18 houses. The Architect is unknown. The building is listed (Grade II) for its special architectural or historic interest. The park and garden are also Grade II listed. The project focused on changes to the registered park and garden. The park dates from 1702 and has undergone several changes throughout the centuries.

Figure 10. Chippenham Hall principal elevation. Source: Historic England

Figure 11. View from the south showing solar panels in the grounds of Chippenham Hall, with the west wing of the building in the background. Source: Historic England

Figure 12. Aerial view of the Hall and gardens before installation. Source: Historic England

Intervention Category: Independent

The 32 ground-mounted solar panels comprising the PV installation are placed **independent** of the main building structures and discretely sited close by within the historic gardens, providing power to the estate.

Photovoltaics solutions

The Hall owners wanted to reduce their electricity bills through the installation of a new ground-mounted solar array covering approximately 0.025 hectares, consisting of 32 ground-mounted solar panels. According to Historic England the physical and visual impact of the solar panels is minimal. This is due to the sensitive planting of hedgerows around the solar arrays to screen them from view.

Figure 13. Alternative view showing the screening, PV panels and supporting framework. Source: Historic England

Sources:

(Historic England, 2024b)

Useful Links:

(Historic England, 2025a)

(Historic England, 2024c)

(Clissitt, 2025)

Kindergarten and apartments, Chur, Switzerland (Extension/Completion)

Figure 14. The original buildings at Calandastrasse 48/50. Source: hiberatlas.eurac.edu

General information

The original building at Calandastrasse 48/50 was built in 1914 designed by architects Schäfer + Risch as a residential and commercial building. The building is not protected nor in a conservation area. However, the owner (City of Chur) wanted to make it an exemplar for integration of energy saving and energy production in a refurbishment project.

The residential and commercial building is divided into two main parts. The 3-story residential building is characterised by the design of its elegant Heimatstil façade. The adjoining commercial building is lower and, with its L-shaped geometry, forms an entrance courtyard. The specifications of the City of Chur as the client were clear. The architecturally valuable urban ensemble was to be preserved in its original form and the earlier alterations to the main residential building were to be reversed.

Architects Pfleger + Stöckli Architektur were tasked with the transformation and have succeeded in preserving and enhancing the high-quality Heimatstil ensemble, creating a beacon of renovation.

Much of the original character of the 3-story residential building has been restored, whilst the roofscape of the annex buildings have transformed with the addition of five new large dormer windows. Solar panels and BIPVs have been integrated into these roofs rather than on the architecturally more refined residential building.

Intervention Category: Extension/Completion

This project is an interesting example of the **Extension/Completion** approach. It demonstrates how solar technologies have been incorporated in a way that has enabled the architectural character of the main residential building to be enhanced with both it and the kindergarten benefiting from solar energy produced on the remodelled lower roofscape.

The project was awarded the Swiss Solar Prize Diploma 2016.

Figure 15. The roofs of the annex buildings have been remodelled incorporating solar thermal and PV panels and the volume extended with 5 large dormer windows. Source: hiberatlas.eurac.edu

Photovoltaics solutions

During the transformation and renovation both BIPVs and solar thermal panels have been incorporated as part of the remodelling. An 8.6 kWp, 54 m² BIPV system, generates 9,000 kWh/y of solar power. The combination of BIPV and solar thermal installation covers 95% of energy demand (NZEB). The surplus solar energy generated by the annex roofs is transferred to the adjoining main residential building.

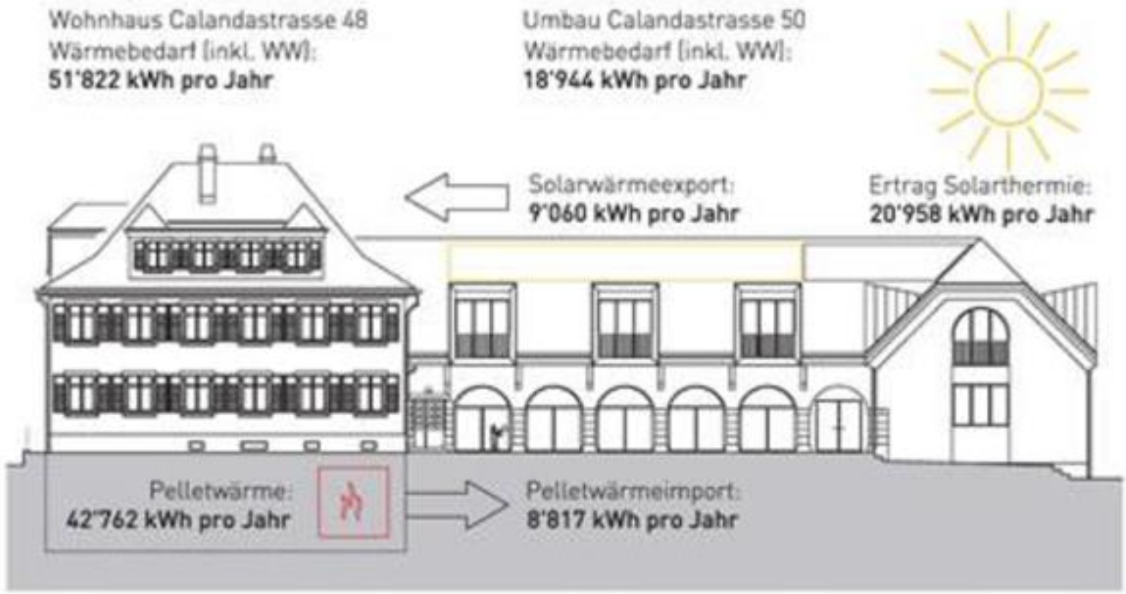

Figure 16. Surplus energy is shared between the annex and the main building, Source: TEC21

Architect:

Pfleger + Stöckli Architektur GmbH

Sources:

(Hiberatlas, n.d.)

Useful Links:

(*EIN LEUCHTTURM IN SACHEN SANIERUNG MITTEN IN CHUR*, 2019)

Dronning Ingrids Hage, Oslo (ARTISTIC)

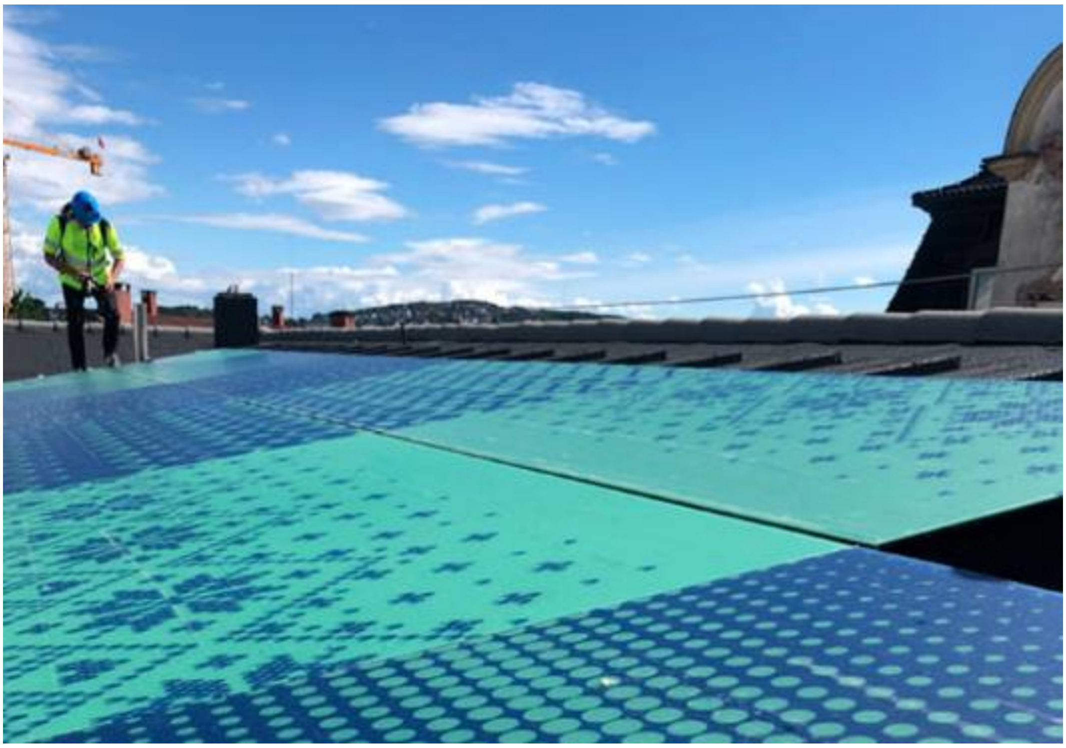

Figure 17. PV as art is successfully demonstrated on the Dronning Ingrids Hage development in Oslo. Source: besmartproject.eu

General information

Dronning Ingrids Hage (Queen Ingrid's Garden) is an innovative mixed-use development whose focus is to enable individuals with cognitive impairment the opportunity to live as normally as possible within a safe framework.

The building is adapted for local energy production, with solar cells on many of the roofs. The project was developed by the municipality of Oslo's development company Oslobygg. Oslobygg has high energy and environmental ambitions and aims to be a leader in the development, construction and management of environmentally friendly and energy efficient buildings.

The project has achieved BREEAM Excellent certification and has been completed as a fossil-free construction site. The building fulfils passive house standards in energy class A.

Intervention Category: Artistic (BIPV)

Although not applied to a historic structure the **artistic** PV panels demonstrate what is currently possible with today's techniques. They can be viewed from an elevated walkway, from which the upper levels of an adjacent historic building form a part of the backdrop. The ceramic printed designs applied to the PV panels merges traditional Norwegian patterns with local quotes and poetry.

Figure 18. Ceramic printed designs applied to the PV panels merges traditional Norwegian patterns with local quotes and poetry. Source: besmartproject.eu

Photovoltaics solutions

The coloured photovoltaic panels are placed on a section of the roof that is accessible to the residents and form part of an elevated walkway offering a magnificent view of the city. The PV panels offer a performance of 160 Wp each and are directly connected to the city's electricity grid.

Figure 19. The ceramic printed designs applied to the PV panels are visible from a high-level walkway. Source: besmartproject.eu

Historical photographs of Norwegian daily life in digital print have also been integrated on photovoltaic panels installed onto the facade in accessible locations. These provide visitors with reminders of past lives and historic scenes from the city’s buildings, nature and streetscapes.

The panels were manufactured by the Belgian company Issol as a part of the EU’s Horizon 2020 Be-Smart project.

Figure 20. Historical photographs of Norwegian daily life are integrated with the PV panels. Source: compaz.art

Figure 21. Examples of some of the street scene images incorporated in the PV panels. Source: compaz.art

Architect: Arkitema Architects

Sources:

(*Queens Ingrid's Garden Oslo, Norway*, n.d.)Useful Links:

(*Queens Ingrid's Garden Oslo, Norway*, n.d.)

(*Dronning Ingrids Hage*, 2021)

(ISSOL, 2025)

The Urban Oasis, UK. (Mobile/Temporary)

Urban Oasis, Chetwoods

Figure 22. The Urban Oasis is a mobile PV-powered installation designed to be used in different settings. Source: Chetwoods.com

General information

The Urban Oasis is an award-winning environmental installation.

The 12-metre-high kinetic structure mimics the design of a growing flower. It is powered by a hydrogen fuel cell, with photovoltaic "petals" which open in response to the sun, utilizing light to generate power.

Supplemented with power from a hydrogen fuel cell and wind turbine, and the use of harvested rainwater for irrigation and cooling, make it self-sufficient. At night the entire structure is transformed into a light sculpture. It has been used in London, Manchester, Birmingham and Cannes.

Designed to demonstrate sustainable energy production within an oasis for city dwellers. It is environmentally sustainable and adaptable for different locations and uses. It has been installed in numerous historic urban settings; including near the historic St James Church on Clerkenwell Close in London, and in Albert Square, Manchester, where it was installed outside the Grade 1 listed Town Hall building. It also formed the central feature of a gold medal-winning show garden at the RHS Chelsea Flower Show.

Intervention Category: Mobile/Temporary

As a **mobile**/**temporary** installation that has high sustainability aspirations as well as architectural and artistic merit the Urban Oasis has been welcomed in numerous historic settings.

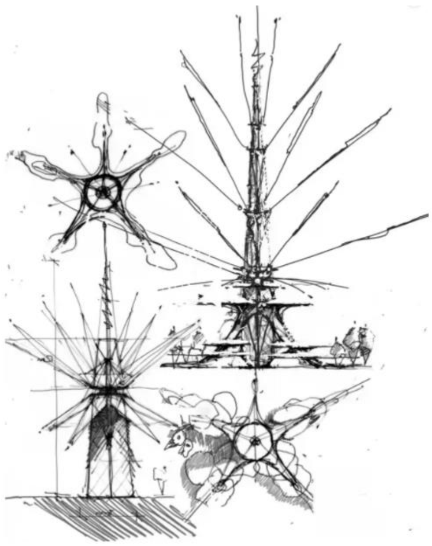

Figure 23. The Urban Oasis is an architect-designed mobile installation designed for temporary use. Source: Chetwoods.com

Figure 24. The Urban Oasis formed the central feature of a gold medal-winning show garden at the RHS Chelsea Flower Show in London, UK. Source: Chetwoods.com

Photovoltaics solutions

The Urban Oasis installation by Chetwoods Architects is a unique example of integrating photovoltaic (PV) technology into a mobile and temporary architectural installation. This 12-meter-tall glass and steel structure is designed to open during the day, revealing photovoltaic panels on its "petals" that capture solar energy. The PV supplied energy is used to power the installation, which is illuminated at night, symbolising the transformation of natural resources into usable energy.

Architect: Chetwoods

Sources:

(Chetwoods, 2025)

Useful Links:

(NLA, n.d.)

5. Conclusions and Outlook

This report, as two sets of guidelines, can be used to enhance the outputs of other FuturHist Work Packages and Tasks. The guidelines were written using state-of-the-art content writing and ideation methods supported by the literature and were subjected to peer review.

5.1. Intra-Project Synergies

The content of this report has significant potential for synergy with the outputs of Work Package 4 and the resulting Toolkit and can also be implemented in the dissemination activities featured in Work Package 7. As stated in the introduction, the guidelines presented were intended as a web article and as a wiki—both of which are well-established modes of communicating information to experts and can be considered in-line with industry standards. In addition, the approaches to both guidelines make them suitable for integration with decision-making support tools that can feed their users specific information based on pre-selected criteria, such as their HBs typology or the desired intervention type.

This synergises particularly well with the wiki format given to the PV guidelines, as sections of a wiki may be pieced together into smaller information packages on a need-to-know basis, thus serving the user the correct amount of informative content without overburdening them with redundant material.

5.2. Future Outlook

If placed before its intended audience, the guidelines can raise awareness about good practices in the implementation of active systems during the energy retrofits of HBs and can inform the approaches of architects regarding the system types featured and can also contribute to a greater uptake of RES-based systems in HB retrofits as a whole.

In the Dissemination and Exploitation WP of the FuturHist project we will be implementing strategies to ensure that the guides are brought to the attention of the architecture and design community in Europe, via publication of articles in respected, and widely read, on-line publications. One avenue of approach that is possible within the framework of the project, especially in terms of publishing the guidelines in the form of a wiki, is to host it on one of the project partners' websites. The ICOMOS-hosted knowledge hub has been identified as the preliminary candidate here due to being an established website operated by a high-profile organisation, which in itself can be leveraged to raise awareness of the guidelines and potentially lead to the establishment of a community around the wiki that could operate it after FuturHist's conclusion. The integration of the wiki with the host website and the potential revision of the HP guidelines into a wiki as well, could take place and be discussed as a part of Work Package 7.

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7. Appendix 1 – Design Sprint Proposals

Proposal 1

Heat pumps in historic buildings – an architect's guide

Introduction: Replacing gas boilers and other fossil based energy sources with heat pumps is a key to the decarbonization of existing buildings. Doing this in buildings of heritage significance requires careful planning. There is no blanket solution that fits every building, but the steps in this guideline will be the same for a 20th century terrace and a 17th century manor. By following the guideline you will understand whether a heat pump solution is feasible for your project, and have drafted an initial concept for a suitable heat pump system.

Step 1: See what you have

The first, and crucial, step is to get a comprehensive understanding of your building. In practice you can carry out step 1,2,3 in parallel, but they should be kept distinct.

- **Technical status of the building and the heating system**: if there is a need of renovation or if there is a potential to improve the energy performance of the building envelope, this should be considered in tandem with an upgrade of the heating system. A technical survey of the existing heating and ventilation system is necessary to understand the potential for accommodating a heat pump.
- **Heritage significance**: What architectural features are worthy of preservation? The installation of an heat pump might have an aesthetic impact, but there might also be a need to alter the historic fabric (e.g. drilling holes). In order to assess such interventions there is a need to understand what is valuable. The level of detail for this investigation depends on the individual project, and there might be a need to consult an heritage expert. See also step 3 if it the building is under statuatory protection.

- **Energy performance and indoor climate**: Determine how much energy that is used for heating, cooling and hot water production in the building. In parallel, survey the use of the building and its current indoor climate. This is important as the energy use is dependent on indoor temperatures and ventilation rates.
- **Available energy sources**. A heat pump transfer energy from the air, the ground, or from nearby water. What are the existing opportunities around your building?
- **Budget and funding opportunities**: The most important constraint for most projects is the budget. To understand what is achievable, also in relation to the balance between short term costs and long term savings there is a need to initially gauge the budgetary constraints and the availability of funding.

Outcome: A comprehensive understanding of the technical status of the building and its heating, cooling and ventilation system. An initial understanding of the heritage significance of the building and what building elements that are worthy of preservation. A baseline assessment of the energy performance and indoor climate. Preliminary budget constraints.

Step 2: Check what you must

When you make a change to your building, there may be laws and regulations that you need to consider. Complying with applicable rules and regulations constitutes the minimum requirements for any project, and it is important to determine what applies in each individual case. You need to consider planning regulations, building codes etc. For a listed building or a building in an conservation area you might need listed building consent. Drilling holes in the ground might require a geotechnical survey or be limited because of the protection of archeological remains.

Outcome: Any formal requirements that might be relevant for the installation of a heat pump system.

Step 3: Decide what you want

What does your client want to achieve by changing the energy source? There might be several objectives and they will vary between projects. Important to consider here is how different alternatives should be assessed later on in the planning.

How important is it in this project to:

- **Be environmentally friendly?** Consider LCA calculations of greenhouse gas emissions.
- **Save money?** Consider the Total cost of ownership, which includes also costs for maintenance.
- **Improve the indoor climate?** An improved indoor climate can also make a change of use possible, increasing the economic revenue of the building.
- **Preserve the character?** How important is this for the client? Are there red lines?
- **Reversibility?** Is it important that the installation is reversible?

The list can be longer or shorter, but it is important to be explicit about the project's objectives and that these are communicated to everyone involved in the planning.

Outcome: An agreement on the purpose of the project and how different alternatives will be evaluated.

Step 4: Identify feasible systems

From a viewpoint of technical and aesthetical compatibility, identify which heat pump systems that can be excluded already from the outset. The main types of heat pumps systems are:

- **Air Source Heat Pumps (ASHP)**
    - **Air-to-Air Heat Pumps**: Extract heat from outdoor air and transfer it directly into indoor air via a fan system. Common in homes without hydronic heating.
    - **Air-to-Water Heat Pumps**: Extract heat from outdoor air and transfer it to a water-based heating system (radiators, underfloor heating, or DHW).
    - The air source heat pump has an outdoor unit that can be difficult to accommodate for aesthetic reasons. There might also be limitations due to the ducting required.
- **Ground Source Heat Pumps (GSHP) (Geothermal)**
    - Use underground pipes to extract heat from the ground.
    - Can be vertical (deep boreholes) or horizontal (shallow loops in a large trench).
    - Provide stable efficiency since underground temperatures are relatively constant year-round.
- **Water Source Heat Pumps (WSHP)**
    - Extract heat from a nearby water body (lake, river, well, or aquifer).

    - Highly efficient but requires access to a suitable water source.
- **Hybrid Heat Pumps**
    - Combine a heat pump with another heating system (e.g., gas boiler or solar thermal) to optimize performance and reduce reliance on electricity during peak demand.
- **Exhaust Air Heat Pumps**
    - Reuse heat from indoor ventilation air, often combined with mechanical ventilation systems.

Outcome: A list of potentially relevant heat pump systems for your building

Step 5: Draft your options

Draft your remaining options and desribe in some detail how they can be implemented. What size of heat pump is needed? How can it be integrated with the existing distribution system? What alternatives are there for locating the units?

Outcome: A description of different alternative solutions, with enough level of detail to make an assessment possible.

Step 6: Assess your options

Assess your options based on the criteria from step 2 and the legal requirements of step 3. The level of detail of the assessment will vary between projects, and there might be a need to consult engineering expertise for this step.

Outcome: A list of pros and cons for each option, quantified where possible (e.g. cost, energy savings)

Step 7: Make your choice

Guided by the purpose of the project, determine if any of the potential solutions are suitable and rank them. If not, go back to step 2 and revise your objectives. Document the planning process so far and share your results with the client and stakeholders.

Outcome: An initial concept for a heat pump system that is in line with the project's objectives, based on a well documented assessment using criteria relevant for the project.

Closing remarks: The choice of technical solution should be the end point and not the starting point for an intervention. By following this guideline you will be assured of that you have identified a good solution that suits your specific building and that is in line with the project's objectives.

Proposal 2

A first general guideline for architects to understand if an HP system is feasible in the considered building

Introduction: This proposed 7-step guideline for Heat Pump (HP) systems in Historic Buildings aims to guide **architects** through the process of identifying if an HP system is a feasible solution for the considered building.

The guideline is intentionally quite generic and covers, not in detail, several aspects related to different fields (from heritage value to specific thermal demand of the considered building) that need to be considered in a first general assessment.

All aspects reported in the following should be assessed more deeply with the help of **experts** (mainly heating engineer designers) and always in contact with the needed **heritage authorities** and the **client**.

Step 1: Assessment of the constraints in the building renovation process:

The first step should focus on understanding the situation of the building in terms of heritage value and other constraints/limits on possible interventions.

This allows to identify:

- the building situation in terms of inclusion in certain buildings' heritage lists;
- the related bodies/agencies to be consulted in case of renovation interventions;
- the documents stating the eventual limits in the renovation interventions.

In particular, it is important to identify and consult the related documents and come up with a clear vision about the general constraints and a more detailed evaluation of:

- Limits in the intervention on the building envelope (what can be done and where according to visual and aesthetic dimensions)
- Limits in the intervention for connecting parts of the system outside with the inside of the building
- Limits in terms of operation of part of the HVAC system put outside (limit on noise level)

If no HVAC system components can be put outside (on the façade, on the roof, or other places like the internal courtyard) and there is no technical room, the only HP solution could be a series of air-air HPs similar to a fan-coil that do not present the outdoor unit. E.g. the model available at the following link:

https://www.olimpiasplendid.com/media/files/5033_EN22_Unico_Air_Inverter_10_SF.pdf

Outcome: After this first step it should be clear:

- Whether the building is included in some historic building stock lists
- which is the bodies/agencies and or the documents to be consulted in case of renovation interventions
- a general overview of the limits in the renovation interventions

Step 2: Assess the actual status in terms of the thermal envelope and HVAC system

Start analyzing the characteristics of the building in terms of at least:

Qualitative:

- Building thermal needs: what are the thermal needs of the building? Space heating, space cooling, Domestic Hot Water?
- Use of the building (is the building used only in some specific periods along the days/weeks? (e.g. Church)
- Check also space available for installing the HP system components (balcony? technical room?)

Quantitative:

- Building envelope thermal characteristics (e.g. U values)
- Existing HVAC system; check at least:

  - generation unit(s): kind (e.g. gas boiler), status (functioning/not functioning), configuration (centralized/decentralized), and, if possible, nominal thermal power
  - distribution system: check at least if a distribution system is present, if it is thermally insulated, if it is outside or inside the building, and which is the fluid circulating
  - emission system: e.g. radiators, fan coils, radiant floor system; check reversibility (able to cover space heating only or space heating and cooling?)
  - Mechanical ventilation system: check at least if this system is present, status (functioning/not functioning), configuration (centralized/decentralized), with or without heat recovery
- Building thermal demand: value in kWh/m2/y that can be obtained from bills plus an estimation of the peak thermal power demand (in W/m2).

Outcome: After this step the actual status of the building, in terms of which are the building thermal needs, the building peak thermal demand(s), the use of the building, the actual HVAC system, and the space available for HP system components should be clear.

Step 3: Identify the new situation after eventual upgrades in the thermal envelope performances

Evaluate a series of interventions that would be beneficial for HP system operation:

- Always start considering energy efficiency first. Before designing the HP system evaluate the possibility of reducing the building's thermal needs by improving thermal envelope efficiency (insulation of opaque envelope elements and replacement/improvement of the windows).
- Estimate the peak thermal load after the planned energy efficiency interventions.
- If the actual emission system uses water at high temperatures (radiators), assess the feasibility of replacing the radiators with a radiant system (floor/ceiling/wall) that operates at lower water temperature.

The new HP system will be designed to cover the updated building’s thermal demand after the thermal envelope improvements and, if possible, using a radiant system operating at low water temperatures.

Outcome: After this step, it should be clear which is the building's thermal demand to be covered by the HP system and which is the emission system considered. In case no energy efficiency interventions are considered (for any reason) the building’s thermal demand to be covered is the one obtained in the previous Step 2.

Step 4: Identify the right HP system for the considered building

Consider the following points:

- Different HP system typologies are available. Ground-water and water-water systems are more efficient but generally more costly and need specific works. For this kind of systems the contribution of an expert is needed starting from the beginning of the planning phase
- On the contrary, a first estimation and analysis of Air-Water and Air-Air HP systems is easier and could be done also by architects in the first conceptual phase. These systems are easier and present limited costs.
- In case the considered building presents a high space heating demand (in the range of 100 W/m2) evaluate, with an expert (a heating engineer designer), the water loop system

https://www.innovaenergie.com/site/assets/files/2790/240212_innova_wlhp_en.pdf

- Identify a series (at least three) of HPs with a nominal thermal power that ensures the covering of the building's thermal needs
- Check the various HP models according to the limits identified in step 1, in particular:
    - Visual aspect (eventually check strategies to mitigate visual impact)
    - Check the noise level for the various HP models identified. Pay attention especially if you adopt units like Olimpia Splendid Unico (see link in step 2) that have everything (compressor included) in the internal unit
- Reversibility: in this context: is it easy to remove and return to the previous configuration?

Outcome: The outcome of this step should be a realistic first concept of the HP system. In particular, regarding the kind of system (Air-Water, Air-Air, etc), the estimated nominal HP thermal power and other aspects (noise level, visual impact, reversibility)

Step 5: Evaluate the possibility of exploiting renewables, storage, flexibility services

Evaluate the possibility of installing a renewable energy system in the building according to the constraint identified for the considered building in step 1. Limit the analysis to PV on the roof and/or on the façade.

This step aims to evaluate eventual synergies between HP and PV systems, allowing for further reducing the running costs of the HP system.

If installing PV is possible evaluate all the steps needed with an **expert** and involve the needed **heritage authorities.**

Optional: assess with an **expert** also the eventual benefit associated with the installation of an electric storage and the eventual presence of different electrical tariffs that could motivate the shifting of electrical consumption to run the HP system in specific periods along the day to answer specific flexibility requests from local Distributor System Operator (DSO) or to benefit from lower el. prices.

Outcome: After this step, it should be clear if PV can be installed and where, plus which documents regulate the PV installation. Moreover, if also the optional point is followed, it should be clear the advantages associated with the use of an electric battery in addition to the PV system and the eventual economic benefit associated with flexibility ensured to the local DSO.

Step 6: First techno-economic assessment using the predefined HP system

Now that you know that an HP system is theoretically feasible (at this conceptual stage) based on the previous steps, check if it is more or less convenient from a techno-economic point of view.

This could be done easily with limited inputs generally available like the Seasonal Coefficient Of Performance (SCOP) of the HP (available from the HP datasheet), the cost of the electricity, and the cost of the gas (if the comparison with a gas boiler system is among the purposes).

Outcome: General first assessment about the techno-economic convenience of using an Air-Water HP system.

Step 7: Control monitoring and maintenance

Although this is not a specific action to be taken in this first conceptual phase, consider that a proper system control is essential to correctly run an HP system.

For this reason, consider involving an **expert** in the following phases to check and adjust HP system operations. There are already different levels of smart/optimized controls that can improve system operation with different purposes (e.g. minimize energy cost).

It is also important to be aware and dedicate the needed resources in the next design phases to install a monitoring system that allows to correctly monitor and detect problems in the system. Moreover, it is also important to prepare in advance a regular maintenance plan.

Outcome: After this step, it should be clear some crucial aspects, needed in the next design phases, to have a properly working HP system.

Closing remarks:

The 7 steps presented above cover several aspects that are all essential when dealing with historic buildings.

After following the previous 7 steps, an architect should have a clearer idea about whether an HP system is a feasible solution for the considered building and what are the main next steps to follow.

As stated in the introduction, all aspects must be analyzed more deeply in the following phases of the process, with the help of **experts** and in contact with **heritage authorities** and the **client.**

Proposal 3

Seven Steps for Determining the Appropriate Heat Pump Solution for Improving Energy Efficiency in Historic Buildings

Introduction: Historic buildings are often challenging when it comes to modernizing systems for energy efficiency. However, integrating heat pump technology can be a sustainable solution for enhancing energy efficiency without compromising the integrity of the building. Heat pumps are efficient and environmentally friendly systems, but careful consideration is required to select the best option for a historic setting.

This report outlines the seven key steps to determine the most suitable heat pump solution for historic buildings, balancing modern energy needs with preservation.

Step 1: Assess the Building's Thermal Characteristics

Understanding the thermal dynamics of a historic building is the first step in selecting an appropriate heat pump system. This includes:

- **Insulation Levels**: Determine the current state of insulation and areas where heat loss may be occurring (e.g., poor windows, uninsulated walls, or attic spaces).
- **Thermal Mass**: Historic buildings often have heavy, solid construction materials (brick, stone) that can store heat and release it slowly. This can influence the type and capacity of the heat pump.
- **Air Tightness**: Older buildings may have gaps and drafts that reduce efficiency. Conduct a blower door test to identify leaks and areas of air infiltration.

  It is always advisable to see if any improvements could be made to the building to reduce heat losses and heat demand. Minimising heat losses will not only reduce the size of the heating plant required, but also the costs of running the heat pump and its carbon impact. Historic England provides guidance on how to improve energy efficiency and insulate historic buildings. Energy Efficiency and Retrofit in Historic Buildings | Historic England

Outcome: A comprehensive understanding of the building's heat retention and loss patterns is important to inform system design.

Step 2: Evaluate the Heating and Cooling Demands

Conduct a detailed analysis of the building's heating and cooling requirements. This step is essential for sizing the heat pump and ensuring it meets the demands without being oversized or undersized.

- **Energy Modelling**: Perform an energy audit and, if necessary, computer simulations to predict heating and cooling loads throughout the year.

- **Zoning**: Historic buildings often have multiple rooms or floors with different temperature requirements, so consider zoning and how the heat pump system can address these differences.

To gain a thorough understanding of the building's environmental performance, it is advisable to carry out monitoring and modelling through on-site investigations. This could include in-situ U-value measurements, hygrothermal and dynamic thermal modelling, air pressure testing, thermal imaging, and on-site weather data collection. For an example see A Retrofit of a Victorian Terrace House in New Bolsover: A Whole House Thermal Performance Assessment | Historic England

Outcome: Accurate sizing of the heat pump system to match the building's needs.

Step 3: Select the Appropriate Type of Heat Pump and emitters

(Step 3 should be considered in parallel with step 4 below)

Heat pumps come in several types, each with advantages and limitations depending on the site and application. The most common options are:

- **Air-source heat pumps (ASHP)**: Suitable for moderate climates. They extract heat from the air outside the building.
- **Ground-source heat pumps (GSHP)**: More efficient but require space for horizontal or vertical ground loops. This can be challenging in dense urban areas but offers significant efficiency gains.
- **Water-source heat pumps (WSHP)**: Ideal for buildings near water bodies, as they draw heat from a water source.

For historic buildings, the type of heat pump should be selected based on space availability, climate, and preservation considerations (e.g., drilling for ground loops may be impractical in some settings).

Selection of heat emitters
The efficiency of most heat pumps increases as the water supply temperature is decreased. Therefore, to maximise efficiency and reduce running costs and carbon emissions, the heating systems are designed to operate at lower flow temperatures. Heat pumps circulate heated water at much lower temperatures than conventional gas and oil boilers, so heat emitters and pipework need to be sized to be large enough to provide adequate heat to rooms. The type of pump, and the size of emitters and

pipework, needs to be assessed by a heating engineer.

Outcome: A heat pump system aligned with the site's specific constraints and opportunities.

Step 4: Consider the Impact on Historic Features

(Step 4 should be considered in parallel with step 3 above)

The primary challenge in retrofitting a historic building is ensuring that any new system does not damage or alter the architectural integrity of the structure. This step involves:

- **Minimizing Disruptions**: Choose heat pump designs that have minimal visual or structural impact (e.g., ductless mini-split systems for air-source pumps).
- **Regulatory Compliance**: In UK consents are likely to be required for installing any type of heat pump in listed buildings or buildings in conservation areas, scheduled monuments, or installations that affect designated wildlife sites. Verify that the installation complies with planning requirements and local historic preservation codes and guidelines, which may restrict modifications to the building's exterior or interior.
- **Aesthetic Integration**: Ensure that outdoor components (such as external units) or visible ductwork blend are carefully sited and where feasible are designed to blend in with the building's historic character.

Outcome: Preservation of the building's aesthetic and historical value while integrating modern energy-saving solutions.

Step 5: Explore the potential for Renewable Energy Integration

For historic buildings aiming to maximize sustainability, integrating renewable energy sources with the heat pump system is a valuable consideration. This might include:

- **Solar Panels**: Supplement the energy demand of the heat pump system with rooftop solar panels to reduce reliance on the grid and lower operational costs.

- **Wind Energy**: If the site is suitable, small wind turbines may help offset electricity consumption.

By considering renewable energy options, the overall environmental impact of the building's energy system can be minimized.

Outcome: A holistic approach to energy efficiency that supports sustainability and reduces long-term operational costs.

Step 6: Evaluate System Cost and Incentives

The upfront cost of heat pump installation in a historic building can vary based on complexity and the type of system chosen. Therefore, consider:

- **Upfront Capital Investment**: Calculate the initial costs for equipment, installation, and any necessary modifications to the building.
- **Energy Cost Savings**: Estimate the reduction in heating and cooling costs over time to determine the return on investment (ROI).
- **Government Incentives**: Explore financial incentives, rebates, or tax credits for retrofitting historic buildings with energy-efficient systems.

Outcome: A cost-benefit analysis to help justify the investment and take advantage of available financial support.

Step 7: Plan for Ongoing Maintenance and Monitoring

Once the heat pump is installed, it is crucial to ensure long-term performance and efficiency. Establish a maintenance and monitoring plan that includes:

- **Regular Inspections**: Schedule annual inspections to check for any mechanical issues or system inefficiencies.
- **Remote Monitoring**: Implement smart thermostats or monitoring systems that allow for remote adjustments and performance tracking.

  .

- **Training**: Ensure building managers, owners or caretakers are trained on proper operation and basic troubleshooting.

Outcome: A reliable, cost-effective, long-term energy solution with minimized downtime and operational issues.

Summary

Following the above steps should help to gain an understanding of the things that need to be considered when proposing heat pumps for use on historic buildings. It is important to explore what can be done to improve the fabric of the building at the same time as exploring the viability of different heat pumps. An improved thermal envelop can mean that a smaller, and potentially less intrusive and costly solution can be chosen. Combining heat pump technologies with on-site renewables can help to further reduce operating costs and the overall environmental impact of energy use.

Proposal 4

Heat Pumps in Historic Settings: Demystified

Introduction: Tackling a historic building as a designer can be challenging, especially when an energy retrofit is part of the project. Heat pumps have been touted as a major contributor to improving energy performance in buildings, including historic ones. However, such buildings, especially when listed, require case-by-case, dedicated approaches. This guide is meant to facilitate this.

Step 1: Define Your project's goals

All projects are meant to achieve something. Clarifying what a project's goal is, what its priorities are, and the hierarchy of those priorities, can go a long way towards ensuring the project is a success. Consider what comes first in Your project and what is Your Client's view on this. Historic buildings have features worth preserving. Determine whether Your project's goals clash with this.

Outcome: You now have a list of priorities against which to weigh Your options.

Step 2: Explore Your options

There are different types of active systems that can be used in a historic building energy retrofit. Investigate them to get a better overview of what is possible. Look for **key support conditions** that make a given system perform at its best. Different types of heat pumps have different key support conditions.

Outcome: You now have a better understanding of active systems and when they work best. You also know more about Your project's key support conditions for these systems.

Step 3: Investigate opportunities

Now that You know the key support conditions, it is time to look for them in Your project. Do this from both ends – that of the active system and that of the building You are retrofitting.

Consider Robert Venturi and Denise Scott-Brown's **Duck–Decorated-Shed dichotomy**. One is meant to be looked at from all sides, whereas the other has a clearly pronounced main feature. Notice how well this corresponds to a freestanding church or a terraced tenement? Perform a viewshed analysis of Your building and of the main heritage features that are of value. Look for areas and spaces that You could use for installing potential active systems units.

From the active systems' end, consider whether Your building or its site has any of the key support conditions that You've identified in the previous step.

Outcome: You now know where You can install any units that come with a heat pump without clashing with heritage values.

Step 4: Consult an energy specialist

Having identified a potential palette of options, it is important to know how what their strengths and weaknesses are. This is best achieved by seeking an informed opinion. Consult Your energy specialist on each option that You think could be used in Your project and the key support conditions Your project has. They may tell You whether a heat pump can be used in Your project.

Your specialist can also tell You what the potential size of the units is going to be, as well as the degree to which the key support conditions favour a particular active system and what the expected cost range is going to be.

Outcome: You now have a specialist's input on Your options.

Step 5: Goals versus options

Remember those project goals we told You to list? It's time to revisit them. Some active systems may be incompatible with Your project's goals, while others may fit one goal perfectly but not another. With properly weighted goals, a shortlist of preferred active systems.

Outcome: You now have a shortlist to present to Your Client.

Step 6: Talk to Your Client, reach a decision

Present Your findings to Your Client to inform them of the results of Your work. Discuss how the Client views the goals You've formulated and how they view the performance of each active system and their price. Obtain Your Client's approval of the proposal.

Outcome: You now have Your Client's approval (or disapproval) to go ahead with the heat pump at hand.

Step 7: Finalise the initial proposal for further development

It is now time to translate the decision You've reached with Your specialist and the Client into an actionable design proposal that can be fed into the design documentation production pipeline.

Outcome: You're all set, it's time to start working on that documentation.

Closing remarks: By keeping the project's goals clearly defined and constantly in view, You can arrive at a solution that best serves the interests of Your Client and of the historic building to be retrofitted. While this approach may appear formulaic, it can aid in informing, clarifying and communicating decisions so that every stakeholder knows why the proposal looks as it does.

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