Deliverable D2.5:
StepUP Plug&Play Protocol

Public Document

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Executive Summary

The present public deliverable **D2.5 StepUP Plug&Play Protocol** is produced in the context of WP2, Task 2.2 - P&P Protocol for inter-compatible and interoperable technologies.

D2.5 is the third of three deliverables of Task 2.2. The main objective of the task is to build a **P&P Protocol** for the integration and interoperability of the StepUP technologies and technology provider's products. The Protocol will be made starting with a set of general specifications for the **P&P Envelope** and the **SmartHeat** system used in WP4 for the first design phase of the technologies. It will include the specifications to integrate the **Technology Provider Cluster** (TPC) products.

The deliverable starts with a brief introduction contextualizing the need for a Plug and Play Protocol and its relation with the StepUP project objectives (**Chapter 1**).

The following chapter, StepUP Technologies (**Chapter 2**), defines the main characteristics and configurations of the Plug and Play solutions: **Plug&Play Envelope** and **SmartHeat** developed by Manni and Suntherm, respectively. It then describes which **Technology Providers Cluster components** can be integrated with these solutions to complement and improve the passive and active systems of the renovation.

Chapter 3 enumerates and describes the **P&P Principles** that should guide the development of the systems and components involved in the renovation process. The principles define a set of requirements that should help the technologies fulfil the goals of the StepUP renovation methodology. Six main principles range from qualitative to technical aspects and are the following: industrialization, customization, compatibility, interoperability circularity, open information exchange, certification, and regulation.

Chapter 4 compiles all the TPC products' **requirements** and defines the technical specifications. The TPC products cover the following systems and components: the external layer, the high-performance windows, the solar protection, the PV | ST panels, the heating, and cooling systems, and the demand-controlled ventilation. Some of these products belong to companies that have already expressed interest in being part of the Third Part Cluster in the workshops organized in November 2020. New workshops have been conducted during May 2022 in order to validate the protocol and the requirements with the TPC.

Chapter 5 includes the results extracted from the events carried out for the validation of the protocol in May 2022. For the validation, an online webinar has been held for the TPC sector in Spain, while in Italy direct contact was organised with the TPC that were interested in the first event organized in November 2020. This chapter also includes a discussion section, where the strengths and weakness of the fulfilment of the protocol are shown, and helps to understand the current state of the TPC.

In **Chapter 6** draws some conclusions from this deliverable and the definition of the following steps. The principles, requirements, and specifications defined in this document are the basis for the Plug&Play Protocol and a set of specifications that should facilitate the connection between P&P technologies and the Technology Provider's Cluster solutions. The P&P Protocol will fulfil the StepUP deep energy renovation process and help bringing innovative solutions to the market.

A final chapter (**Chapter 7**) is presented and includes all the technical sheets that should be fulfilled for the TPC for an accurate energy modelling and to comply with the P&P protocol.

1 Introduction

Deep renovations are critical to drastically reducing the current building energy demand (40% of overall European Union (EU) energy consumption) and moving towards a decarbonized building stock by 2050[1]. **Most of the technology to achieve this reduction is available on the market today**. However, renovation rates are far from the target 3%, and **shallow retrofits has a low energy consumption impact**. Comfort levels are one of the main reasons owners renovate; however, this opportunity is not captured in the motivational framing for energy renovation. Current business models also rely strongly on the public sector as an investment source, which is not a long-term or sustainable solution.

To transform the current scenario, the StepUP project will develop a **new process for deep energy renovation** with fast design to operation feedback loops. The new methodology will integrate all the value chain stakeholders to verify and support its development. The aim is to minimize the performance gap and optimize investments while scaling up promising technologies solutions to **Plug&Play** (P&P) building-level applications.

The StepUP methodology's practical implementation requires **inter-compatible** and **interoperable** deep renovation solutions. In the public deliverable **D1.2: Integrated draft of the methodology,** the methodology is exploded including the description of the StepUP renovation methodology. Also, the upcoming deliverable **D1.3: StepUP renovation Methodology**, will describe a list of key data needed to develop the model. The process should allow a flexible selection of Energy Conservation Methods (ECMs) that answer the needs of the specific building and the possibility to have subsequent installation and verification loops while always delivering a functional renovation solution after each iteration. While a variety of advanced technologies for deep renovation are now available on the market, there is always a need for compromise on the design side to minimise the downsides of their interactions. The StepUP project instead offers a paradigm shift to transform the market of deep renovation technologies, by defining and demonstrating a production process that maximises the efficacy of solutions' interaction, while minimising life cycle cost and installation time.

The reduction of installation errors and onsite work is one of the most important community challenges that need to be achieved in the renovation process. By applying **P&P preassembled solutions** the disruption in residents' life can be reduced significantly. The implemented panels will be defined as a modular system, with standardized pre-designed connections and features and will maximize outside interventions. The developed modules will be adaptable to different building configurations and local scenarios.

A tool that guides the renovation process and the **StepUP** implemented **technologies** is required. This tool is the **P&P Protocol** and the inputs used to build it come from: the StepUP methodology, the companies that provide the active and passive solutions, and the organization of the project. The StepUP methodology defines a new workflow and guides the definition of the P&P Protocol Principles. The companies provide the solutions that can be implemented and help in the validation of the tool functionality. The participant organizations (IES, UNI, MAN, SUN, EUT, ABUD, ENER, ACR, BP18) support the development of the tool and bring information on the necessary parameters and characteristics that components need to provide. The collected data will inform the building analysis, the StepUP integrated technologies and the renovation process.

[1] DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

2 StepUP Technologies

The market of deep renovation technologies today offers a variety of established and innovative solutions. Efforts have mostly focussed on two main components in particular: the building envelope (to minimise demand) and the heating systems (to optimise production). However, while solutions have been advanced in their specific markets, integration of industrialised and prefabricated solutions remain at prototype level with relatively low TRLs. To fast track the application of the StepUP approach to the market, two fundamental Plug&Play technologies for deep renovation are going to be delivered, the **Plug&Play Envelope** and the **SmartHeat System**. This will bring to the market a **fully integrated system** for a building envelope and a heating system capable to be applied in deep renovations. It will also explore the integration of technology providers components to complement and expand the possibilities of the renovation.

Table 1: StepUP Technologies Index

2.1	**P&P Envelope Description**	*2.1.1*	Structure
		2.1.2	Insulation Panels
		2.1.3	Connections
2.2	**SmartHeat Description**	*2.2.1*	Thermal PCM Storage
2.3	**TPC Passive Systems**	*2.3.1*	External Layer
		2.3.2	High Performance Windows
		2.3.3	Solar Protection | Sun Shading
2.4	**TPC Active and Monitoring Systems**	*2.4.1*	PV | ST Panels
		2.4.2	Heating | Cooling Systems
		2.4.3	Demand Controlled Ventilation
		2.4.4	Building Management Systems

2.1 Plug and Play Envelope description

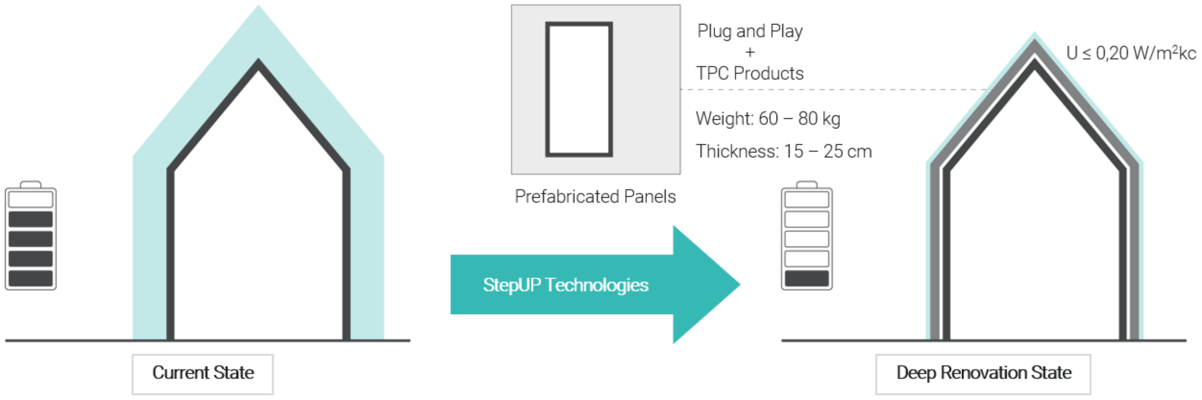

Figure 1: Plug and Play objective

Improving the passive performance of the building envelope is the first and foremost intervention in deep renovation of poorly insulated buildings, as a reduction in energy demand in turn significantly affects the energy production needs. However, this is traditionally one of the most time-consuming interventions with a disruptive impact on the building use and operations. By using preassembled enveloped panels that integrate windows and provision for the technical systems Plug and Play Envelope is capable of greatly reducing time on site. The new envelope uses a system provided by **Manni** that can easily be attached to existing slabs of the building without affecting its structural balance.

2.1.1 Structure

Light cold-formed modular and scalable structures that can be combined with **Isopan** insulating solutions. The prefabrication is based on digital design and production processes and works as a frame for the bespoke designed panels.

2.1.2 Insulation Panels

The insulating panels guarantee thermal and acoustic insulation, strength and air tightness, an excellent reaction to fire, and sound absorption. The **sandwich panels** consist of a layer of polyurethane or mineral wool and two external metal sheets. The panels are light and a versatile and easy to install solution adequate for façade renovation.

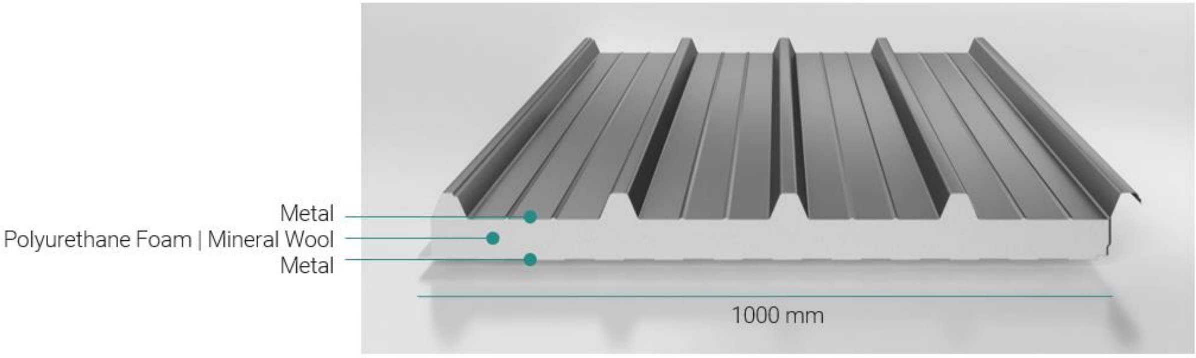

Figure 2: Isopan Sandwich Panel: Iscocop | Isofire-Roof

2.1.3 Connections

A compatible range of fixing components has been designed specifically by Manni for the project. The elements solve the connections between the existing system and the new Plug&Play Envelope. The connections where particular attention must be dedicated are:

a) Between the existing façade and the new envelope.
b) Between panels.
c) Between panels and ventilated façade.

2.2 SmartHeat description

Storage systems have been identified as a key player in enabling the EU to develop a low/zero-carbon energy system. Batteries are main technological drivers as they can store the excess energy generated and deliver it when necessary. **SUNTHERM's** integrated and ground-breaking heating system is composed of an innovative **heat storage battery** connected to established technologies: Photovoltaic collectors, smart grid enabled heat pump (6kW), and cloud-based management.

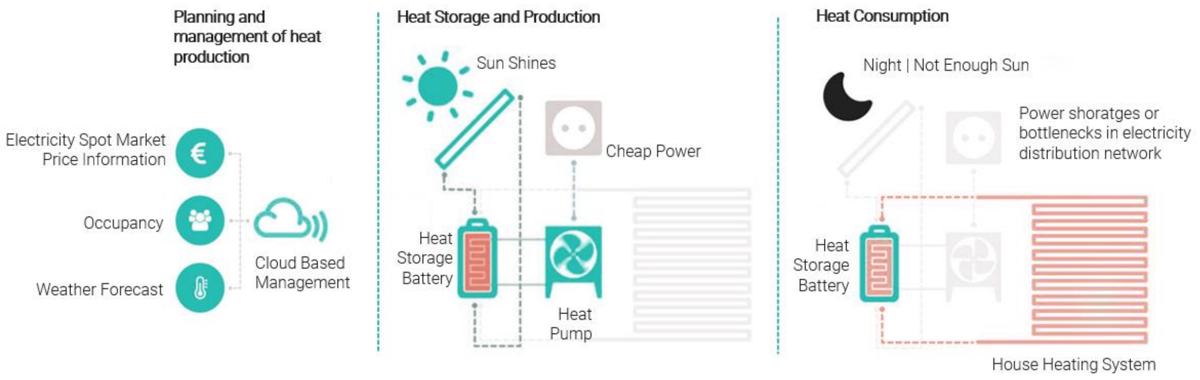

Figure 3: SmartHeat System

2.2.1 Thermal PCM Storage

The SmartHeat battery is Ø60x160cm for single family houses, hasa thermal storage capacity of 15kWh, and uses a salt hydrate solution that allows the storage of **heat equivalent to approximately 1500 litres of hot water storage** and can cover the daily needs of a family for heating.

For retrofitting to existing larger buildings, one solution is to place the storage in the basement, either as multiple smaller tanks or as one large tank. The size of the storage depends on the requirements of the building. Another option that has the PCM storage and the Heat Pumps inside a 20" container is faster to install. The container can be covered by a similar solution to the one applied in the façade for a better integration of the technology.

2.3 TPC Passive Systems

This chapter collects the passive components needed to build and complement the Plug and Play Envelope. It contains the finishing that can be added to the external layer of the facade; it describes the windows systems that can be implemented; and proposes solar protection and sun shading solutions that can help improve the passive performance of the building.

The technologies need to comply with certain requirements to guarantee their compatibility and interoperability with the P&P system. The set of specifications are discussed in **Chapter 4**.

2.3.1 External Layer

The façade modules are a multi-layered prefabricated system where finishing materials on the surfaces can be used both with a technical and an aesthetical purpose. Different options can be taken into consideration when adding additional features to the P&P system:

a) Final aesthetic characteristics and customisation
b) Colour and finishing options.
c) Thermo-insulating and energy performance.
d) Self-cleaning and/or anti-graffiti properties.

The P&P module can be enriched with an additional external layer, which can be a ventilated façade system and/or an adhesive tape.

2.3.1.1 Ventilated Façade

A ventilated façade is a system that consist of a rigid covering, separated from the building wall but anchored to it to transfer loadings. The cavity created between the two elements has openings in some parts, usually in the joints to get air ventilation. This cavity improves building performances avoiding moisture and condensations. The metallic supports are represented by **Isopan,** the outer layer, where TPC products can be applied, can be made with the following solutions:

a) HPL Panels
b) Ceramic Panels
c) Metal Sheet

2.3.1.2 Adhesive Tape

Consists of a pressure-sensitive adhesive coated onto a backing material such as plastic film, cloth, or metal foil. These tapes usually require a release agent on their backing or a release liner to cover the adhesive.

2.3.2 Windows

An aperture especially in the wall or in the roof of a building for light permeability and air admission. It usually consists of outer and sash frames containing a transparent material. The transparent material, usually glass, allows inhabitants to have a visual connection with the outside while providing a separation between the environments. The position and size of opening are also key features in the design of a building both for aesthetic and thermal behaviour.

The windows can be classified by their opening system (casement, hung, sliding), their ubication (roof, facade), and their position within the skin of the building (external position, interior position, centred position).

2.3.3 Solar protection | Sun Shading

Solar radiation can provide light and heat for buildings, reducing the need for artificial lighting or heating. It can be directed and regulated by implementing solar protections and sun shadings. Through its implementation the amount of solar heat gain and visible light that is admitted into a building can be used to optimise thermal performance.

In the market, there is a wide range of solutions solar solutions that can be explored. Their implementation will depend on the design demands and their specific compatibility and interoperability with the P&P Envelope.

Flexible Systems

a) Louvres
b) Roller Shutters
c) Hinged, Folding, Sliding Shutters

Fixed Measures

a) Brie-soleil
b) Canopies
c) Fixed Louvres

2.4 TPC Active and Monitoring System

Active systems are implemented to maintain demanded environmental conditions within a space. It considers all technologies integrated into the building that can use or can produce energy. The technologies considered in this chapter are those that support the implementation of SmartHeat: energy production (PV | ST panels), thermal exchange (heating and cooling systems), comfort, and salubrity (demand-controlled ventilation). The building management system is implemented to monitor and increase the operational performance of the installed solution.

2.4.1 PV and ST Panels

Contribute to SmartHeat with electricity or thermal energy production.

2.4.1.1 Photovoltaic Panels

A photovoltaic panel is an assembly of photovoltaic cells mounted in a framework to facilitate installation. Photovoltaic cells use sunlight as a source of energy to generate direct current electricity.

a) Monocrystalline. Panel made from solar cells, typically 60 cells per panel. Black cells have a best aesthetics and higher cost than polycrystalline. *Performance: 17%-22%.*
b) PolyCrystalline. Solar panel that consists of several crystals of silicon in a single PV cell. Marble blue appearance. *Performance: 15%-17%.*
c) Thin-Film. Thin film solar panels are made by depositing a thin layer of photovoltaic substance onto a solid surface, like glass. They have a lower cost, more flexibility and good aesthetics. *Performance: 10%-13%.*

2.4.1.2 Solar Thermal Panels

Solar thermal panels or solar collectors are devices that are mounted on the roof to absorb the sun's heat and use it to heat up water.

a) Flat-Plate Collectors. They are composed of dark absorbing surface, a transparent cover, a heat insulating backing and, most importantly, a fluid that transports heat from the absorber to a water tank.
b) Evacuated | Vacuum tube collectors. Unlike solar panels, these collectors are made up of several glass tubes though which the transfer fluid flows. These systems are more efficient than flat-plate panels.

2.4.1.3 Hybrid Solution

Hybrid solar panels are capable of simultaneously generating electricity and hot water. *Performance*: 20%

2.4.1.4 Support Structure

Sub-structures and fixing elements that will connect the panels with the existing structure.

2.4.2 Heating and Cooling Systems

The heating and cooling systems presented below refer to available solutions in the market that can work with SmartHeat. The heating systems are responsible to diffuse warm air through a water-air exchange, and cooling systems reduce the room ambient temperature.

2.4.2.1 Heating Systems

a) Fan Coil. Water Temperature (28- 40 ºC)
b) Floor Heating. Water Temperature (30- 35 ºC)
c) High Efficiency Radiators. *Water Temperature* (45-50 ºC)

2.4.2.2 Cooling Systems

a) Fan Coil. Water Temperature (12- 17 ºC)
b) Floor Cooling. Water Temperature (19- 21 ºC)

2.4.3 Demand control ventilation

A smart ventilation system adjusts ventilation rates in a building to be responsive to one or more of the following parameters: occupancy, temperature, and air quality conditions. The main purpose is to ensure efficient air filtration in interior spaces. In StepUP project, demand-controlled ventilation could be integrated within the P&P Envelope as long as a TPC provides an integrable solution. According on the existing building, the demand control ventilation can be solved by placing the air conditioning machines on the roof.

2.4.4 Building Management System

The management system will **collect streaming time series of data** from sensors located at the building and embedded technologies and store them in a cloud platform. The sensors will collect information on primary energy (electricity and gas), thermal comfort, indoor environment quality (IEQ), lighting and occupancy. The information stored in the cloud platform should be sharable via common protocols open systems. More information on the data collection infrastructure can be found in deliverable **D3.2: Data infrastructure requirements for the StepUP Methodology**.

3 Plug and Play Protocol Principles

The P&P Protocol defines a list of principles associated with requirements that the developed **systems [S]** and the integrated **components [C]** need to comply with to meet P&P standards and, consequently, the StepUP goals. The component refers to each of the items that the P&P partners and TPC will supply, and the system is the collection of components organized for a common purpose.

Table 2: Plug and Play Protocol Principles

P1	**Industrialisation**	*P1.1*	Preassembled Offsite
		P1.2	Low Intrusive System
		P1.3	Easy and time-saving on-site installation
P2	**Customisation**	*P2.1*	Adaptable to different architecture geometries
		P2.2	Adaptable to different architectural aesthetics
P3	**Compatibility and Interoperability**	*P3.1*	P&P Envelope and Smart Heat
		P3.2	P&P Envelope and TPC
		P3.3	SmartHeat and TPC
		P3.4	SmartHeat and District Systems
P4	**Circularity**	*P4.1*	Low Embodied Energy
		P4.2	Lean Philosophy
		P4.3	Design for Disassembly
P5	**Open Exchange Information**	*P5.1*	Technical Sheets
		P5.2	2D | 3D Drawing
		P5.3	BIM objects
P6	**Certification and Regulation**	*P6.1*	European Union Regulations
		P6.2	Environmental Certificates

In the following chapter, the principles are described and contextualised. It is also specified if the requirements need to be fulfilled at the component, system, or both levels.

3.1 Industrialisation [P1]

In a P&P scenario the industrialization of the processes is going to be achieved by **maximizing offsite preassembled solutions**. This new workflow will improve **reliability** on the implemented technology and standardize on site work leading to a simplification of construction complexity and a **productivity increase**. The time spent in the construction site will decrease reducing the disruptions caused to the building users. This will be supported by the global strategy of performing outside interventions for the renovation process.

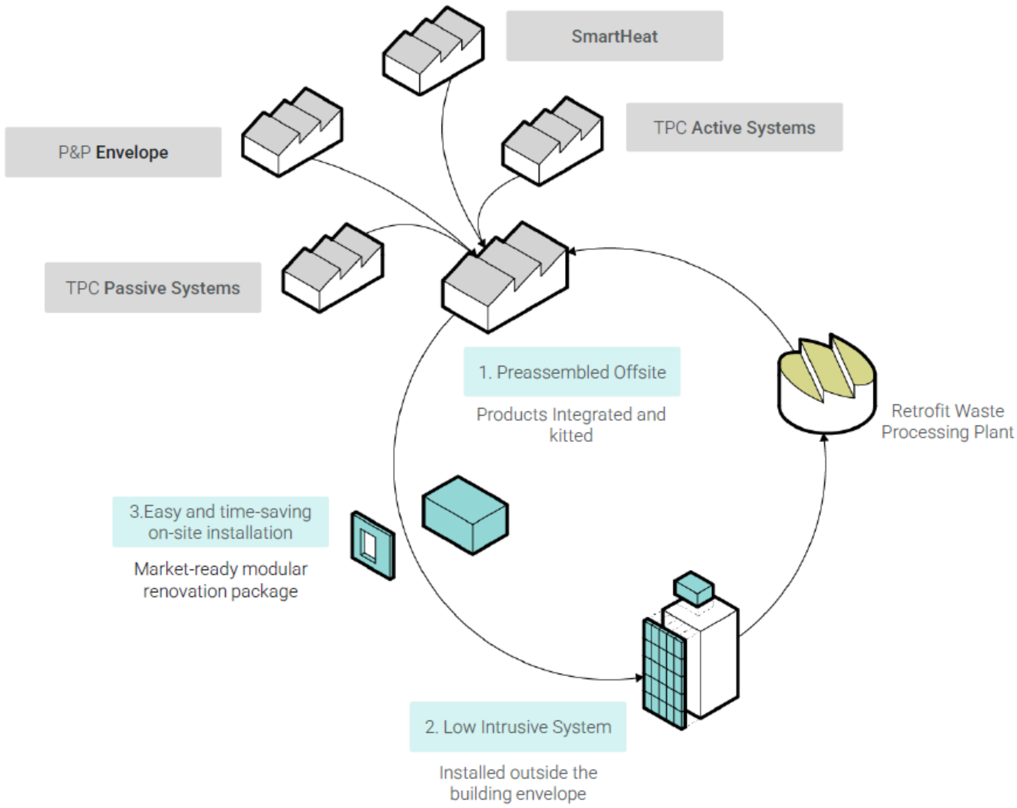

Figure 4: Industrialised Workflow

3.1.1 Preassembled Offsite [P1.1]

Offsite preassembly refers to the manufacturing, planning, design, fabrication, and assembly of building elements at a location other than their final installed location to support the rapid speed of, and efficient construction of a permanent structure. Preassembled systems offer a reduction of construction waste and energy consumption, and less dangerous works on-site than traditional construction practices.

R1.1 Delivery of components in kits **[S] [C]**

3.1.2 Low Intrusive System [P1.2]

There is a need for non-intrusive, quick, and reliable intervention. A significant barrier intrinsic to deep renovation is the need to **maintain buildings in operation**. This is true both for residential buildings, as interventions can often lead to significant disruption of the home life up to requiring temporary relocation, and for non-residential buildings, as interventions can require adjustment to services and activities carried out in the building.

This in turn requires an organisational overhead, which can be a significant cost on top of the renovation itself. To minimise disruption, works can be hurried, which can result in installation errors that have substantial impacts on performance and comfort, and even lead to the need for corrective works in the subsequent years.

R1.2 Installed outside the building envelope **[S]**

3.1.3 Easy and time-saving on-site installation [P1.3]

Minimizing time onsite to 40% of current renovation onsite work duration requires advancing innovative passive and active technologies to a market-ready repetitive and adaptative solution. A multi-disciplinary team with clear instruction for the installation process and the use of dry joints systems can also help reducing the intervention time.

R1.3 Modular renovation package **[S]**

3.2 Customisation [P2]

The aim of the StepUP project is to create a standardized solution that is adaptable to different architectural compositions and that facilitates aesthetical variability.

3.2.1 Adaptable to different architectural geometries [P2.1]

The building stock in the European Union has different formal and structural configurations. Therefore, the proposed systems need to adapt to the different case scenarios (balconies, windows, corners, terraces) while being a standardised solution that can be industrialized.

In the early stage of the P&P Envelope design it is necessary to analyse the building and identify the basic types of modular systems needed to build the envelope.

R2.1 Identification of panel configurations **[S] [C]**

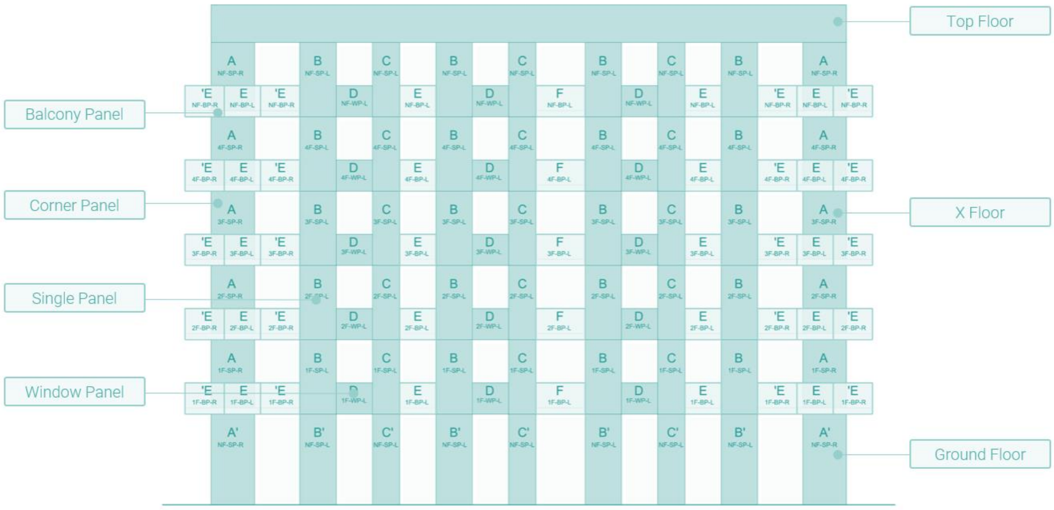

Figure 5: Envelope specifications

Once the basic panel configuration is solved specific details need to be developed of solutions between:

a) Facade – Roof
b) Façade – Foundation – Ground
c) Panel – Window
d) Panel – Balcony

3.2.2 Adaptable to different aesthetical design [P2.2]

One of the purposes of the project is to find a solution that not only improves energy efficiency, but also has an **impact on the quality of life** of the users. Improving the aesthetic appearance of the building is also an important feature to engage users in the desire to perform a renovation. The capability of the system to adapt and support different compositions is crucial for the renovation process.

R2.2 Aesthetical options **[S] [C]**

3.3 Compatibility and Interoperability [P3]

The practical implementation of the StepUP methodology requires intercompatible and interoperable deep renovation solutions that answer the needs of the specific building. This involves the **definition of a matrix** that details how the different systems are connecting. It should consider both passive and active solutions.

3.3.1 P&P envelope and SmartHeat [P3.1]

The P&P envelope will **accommodate the services** needed to connect the SmartHeat with the building. It will consider the electrical connections and the pipes needed to connect the PV/ST with the thermal storage and the home heating/cooling system

R3.1 Integration of services within the passive systems **[S]**

3.3.2 P&P envelope and TPC [P3.2]

The P&P envelope will provide the main features for the new envelope while the TPC components will complement it to increase performance or add aesthetical features. Therefore, the TPC components will have to adjust to the dimensions set by the P&P envelope.

R3.2 Adapt to P&P modularity and characteristics **[C]**

3.3.3 SmartHeat and TPC [P3.3]

To integrate TPC active systems with SmartHeat there are some physical characteristics that need to be considered, for example geometrical constraints (the SmartHeat piping diameter must be smaller than the air gap to include it).

R3.3 Physical requirements active TPC components **[C]**

3.3.4 SmartHeat and District Heating System [P3.4]

SmartHeat will contemplate the district heating systems and develop a heating strategy according to it.

R3.4 Tailored heating system strategies **[S]**

3.4 Circularity [P4]

Material choice has become a greater proportion of overall environmental impact of a building. Modern improvements to heating and cooling technologies and a better control of water and renewable energy has reduced their impact in the building carbon footprint. The concept of circularity in construction rethinks linear building design workflows. It is a holistic approach that examines the sustainable production, assembly, and logistics of materials over their entire lifespan. The key aspects of a circular approach are the planning of material life cycle, the minimisation of its embodied energy and designing for disassembly solutions.

3.4.1 Low Embodied Energy [P4.1]

The **Embodied Energy** focuses on the role of energy, examining the **direct and indirect energy required to produce a product or service**. Energy consumption generates CO_2 emissions which contributes to greenhouse gas emissions. To reduce the environmental impact, the systems and components used in a building should be designed with materials that optimise the use of energy in its manufacturing process or with new low carbon materials. Measuring energy efficiency and operational performance is a growing practice in the architecture field. The method used to analyse the impact of a material from its extraction, manufacture, use, to the end of its life is known as **Life Cycle Analysis.** Evaluating all the potential **environmental effects** at each stage of the product or building allows to balance energy and efficiency. The time factor is an indispensable element to grasp what the embodied energy represents in a building. The past provides data on the energy embedded in the used components; the present the energy consumed during the assembly process; and the future analyses the operational performance that generates energy demand. Balancing these parameters provides the information of the design impact. When using prefabricated solutions, the operation time on-site is reduced thus the construction phase carbon footprint.

When aiming for a circular life cycle is important that the product manufacturer maintains a relationship with its customers to ensure best use of the product, its maintenance, and return at the end-of-life.

R4.1 Life Cycle Assessment **[C] [S]**

3.4.2 Lean Philosophy [P4.2]

The Lean philosophy, traditionally applied to the industrial sector, aims to optimize processes and increase customer satisfaction by:

- Creating value from customer's perspective.
- Encouraging a culture of continuous performance improvement
- Minimizing waste of resources and time
- Developing high quality and stable processes

The implementation of this process in the construction sector supposes a challenge to the current workflows. Unfortunately, the construction sector is characterised by schedule delays, stagnant productivity, budget overruns and dissatisfied clients[2]. The **Lean Construction** moves the traditional management based on planning activities to planning resources in order to reduce efforts, time and unnecessary materials. The document D1.5 and **D1.6 Draft guidelines for Lean Construction** provides more information on the topic and its implementation.

R4.2 Lean Construction **[C] [S]**

3.4.3 Design for Disassembly [P4.3]

Design for disassembly (DFD) is a strategy that facilitates the different components of a building to be **reused**, **reassembled** and **recycled** into new products and minimises waste generation. This method recognises that the building is not a permanent structure but a compilation of building materials with different life cycles. Different layers can be identified:

- Service Systems: 7-15 years
- Internal Distribution: 3-30 years
- Skin: 20 years
- Structure: 30-300 years

Therefore, during the design phase it should be considered how short-lasting elements can **easily** be **accessed** and **replaced**. The chosen connections need to be mechanical joints and contemplate repeated assembly and disassembly without damaging the materials. This approach improves flexibility and optimizes operation and maintenance of the building over its lifetime.

R4.3 Create a deconstruction and maintenance plan **[C] [S]**

[2] Dupagne, A (1991) Computer integrated building. Strategic final report, ESPRIT II.

3.5 Open Exchange Information [P5]

The StepUP Plug and Play Protocol will focus on modular design prefabricated components, as a matrix allowing different material, connectors, and product combination depending on the specific project requirements. This chapter specifies the information that each of the component's manufacturers will deliver.

3.5.1 Technical sheets [P5.1]

Technical sheets are a tool for manufacturers to provide **technical specifications** of their product. It is relevant to facilitate the design team information to make educated decisions. A common specific format will be specified to present the information of the P&P technologies. It will also contain the data needed to perform energy simulations.

R5.1 P&P technical sheet **[C]**

3.5.2 2d | 3d drawings [P5.2]

Graphic representations of the tectonics components. Two-dimension drawings are going to be used to provide **technical representation** of the elements. Three-dimension drawings will be used to verify **overall system compatibility**.

R5.2 Drawing exchange format [.dxf] **[C]**

3.5.3 BIM objects [P5.3]

BIM objects are a useful **source of data**: they are a digital representation of physical and functional characteristics of a building component. They provide detailed information on the design, determine which components are involved in a proposal and help creating bills of quantities, keeping track of natural deterioration and maintenance.

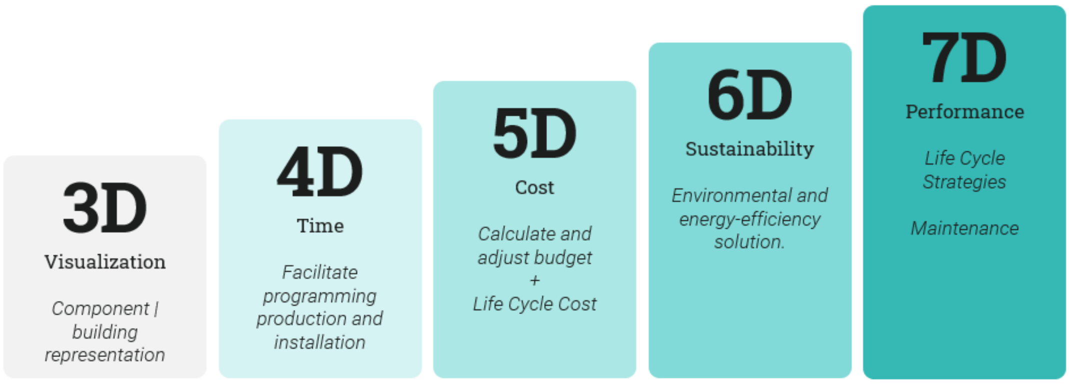

Figure 6: 7D BIM Dimensions

R5.3 7D BIM objects **[C]**

3.6 Certification and Regulation [P6]

This principle brings awareness of the legislations components and systems need to comply with to be implemented within the European Union. It also contextualises the increasing need for environmental product certifications.

3.6.1 European Union Regulations [P6.1]

In order to be implemented, the Plug and Play and TPC technologies need to comply with the European Union standards as well as the local regulations where the project is going to take place. The **CE marking** is the manufacturer's declaration that the technologies delivered in the P&P technologies meet EU standards for health, safety, and environmental protection. This marking provides information that helps validate if the designed solutions comply with the local regulations where the project is developed. To learn more about fire resistance, hygiene, health, and environment requirements and safety measures refer to deliverable D2.3, chapter 7.2.

When local regulations do not provide information on a specific solution the documents shared by the **European Organization for Technical Assessment** (EOTA) can be used as a reference. EOTA produces validation for products within the construction sector. When a new component or system is developed their examples can work as a reference of approved practices. Both European Assessment Documents (EADs) and European Technical Assessments (ETAs) are publicly available facilitating innovation in the construction sector.

R6.1 CE | Local Regulations **[S] [C]**

3.6.2 Environmental Certificates [P6.2]

Aiming to construct more circular, respectful, and sustainable buildings requires a better understanding of the emissions implicated in generating a product. Communicating the information with a standardized method helps guide and validate the life-cycle environmental impact analysis. The **Environmental Product Declaration** (EPD) is an independently verified certificate that communicates this information transparently and comparably.

The information taken from this assessment can be used to evaluate the whole building with **International sustainability certificates** such as LEED, BREEAM and WELL, but also, and more importantly, for the EU Level(s) system, which includes LCA. The Circular Economy Action Plan (November 2020) explicitly mentions that for buildings and civil construction, the European Community (EC) will request to use Level(s) in public procurement. Thus, there is a growing need and relevance for this topic.

The EPD provided by TCP components together with the P&P solution LCA will provide the renovation manager and the end-user a clearer vision of the embodied greenhouse gas (GHG) of the renovation package.

R6.3 Environmental Product Declaration **[C]**

3.7 P&P Protocol Principles and Requirements

In the following table, the **principles** and **requirements** are summarized, and provides an overview of the developed **systems [S]** and the integrated **components [C]** associated to each requirement. For each principle a specific requirement is defined for its component and system.

Table 3: Principles and its requirements at a system and component level

	Principles		Requirements		[S]	[C]
[P1] Industrialised	P1.1	Preassembled Offsite	R1.1	Delivery of components in kits	X	X
	P1.2	Low Intrusive System	R1.2	Installed outside the building envelope	X	X
	P1.3	Easy and time-saving on-site installation	R1.3	Modular renovation package	X	
[P2] Customised	P2.1	Adaptable to different architectural geometries	R2.1	Identification of panel configuration	X	
	P2.2	Adaptable to different aesthetical design	R2.2	Aesthetical options	X	X
[P3] Compatibility and Interoperability	P3.1	P&P envelope and SmartHeat	R3.1	Integration of services and sensors within the passive solution	X	X
	P3.2	P&P envelope and TPC	R3.2	Adapt to P&P modularity and characteristics		X
	P3.3	SmartHeat and TPC	R3.3	Physical requirements active TPC components		X
	P3.4	SmartHeat and District Heating System	R3.4	Tailored heating strategies	X	
[P4] Circularity	P4.1	Low Embodied Energy	R4.1	Life Cycle Assessment	X	
	P4.2	Lean Philosophy	R4.2	Lean Construction	X	X
	P4.3	Design for Disassembly	R4.3	Create deconstruction and maintenance plans	X	X
[P5] Open Exchange Information	P5.1	Technical Sheets	R5.1	P&P Technical Sheets		X
	P5.2	2D | 3D drawings	R5.2	Drawing exchange format .dxf		X
	P5.3	BIM objects	R5.3	5D BIM objects	X	X
[P6] Certification and Regulation	P61	EU Regulations	R6.1	CE | Local Regulations		X
	P6.2	Environmental Certificates	R6.2	EPD		X

4 Step UP Specifications

In this chapter, the specifications of the **requirements** for the TPC products to integrate in the StepUP technologies are described following the StepUP protocol **principles** defined above. The specifications have been validated based on the current capabilities of the Technology Providers Cluster that participated in the first workshops carried on in late 2020. The required data from each technology is also defined in their technical sheets which can be found in the **Chapter 7**, Annexes.

Unismart and Eurecat have organized seminars in Italy and Spain to improve these specifications with companies during May 2022. These workshops from WP2 were planned for 2021, but due to the Covid Pandemic Situation, have been delayed until Spring 2022. The update of the **D2.5** includes all the comments and feedbacks from these new workshops, to improve the StepUP protocol principles.

Table 4: TPC Requirements

4.1 External Layer	4.2 High Performance Windows	4.3 Solar Protection | Sun Shading	4.4 PV | ST Panels	4.5 Heating | Cooling Systems	4.6 Demand Controlled Ventilation		
X	X	X	X	X	X	R1.1	Delivery of components in kits
X	X	X	X		X	R1.2	Installed outside the building envelope
X	X	X	X		X	R2.2	Aesthetical options
	X	X	X	X	X	R3.1	Integration of services and sensors within the passive solution
X	X	X	X	X	X	R3.2	Adapt to P&P modularity and characteristics
			X	X		R3.3	Physical requirements active TPC components
				X		R3.4	Tailored heating strategies
X	X	X	X	X	X	R4.2	Lean Construction
X	X	X	X	X	X	R4.3	Create deconstruction and maintenance plans
X	X	X	X	X	X	R5.1	P&P Technical Sheets
X	X	X	X	X	X	R5.2	Drawing exchange format .dxf
X	X	X	X	X	X	R5.3	5D BIM objects
X	X	X	X	X	X	R6.1	CE | Local Regulations
X	X	X	X	X	X	R6.2	Environmental Product Declaration

It is necessary to mention, that requirements **R2.1** and **R4.1** have been deleted from the table 4 because they are parameters that are imposed by the project or by European regulations. For example, the "R2.1 Identification of panel configuration" is defined and solved by the manufacturer, Manni. And regarding the "R4.1 Life Cycle Assessment", it will be regulated by an international methodology (ISO 14040 ff).

4.1 External Layer

As mentioned above, the requirements for each of the passive components to build the Plug and Play Envelope has been specified. The external layer is made by a multi-layer prefabricated system and different options can be taken. In the following table, the Specifications for External layers and each requirement are described.

Table 5: External Layer Specifications

Requirement			Specification Description
R1.1	Delivery of components in kits	X	The provider delivers the component in a finished kit to facade manufacturing plant. This kit has to be easy to install and regulate Example: having 4 fixing connections to allow regulation in 3 axes.
R1.2	Installed outside the building envelope	X	The external layer will be preassembled offsite. The solutions need to guaranty transportation resistance when being moved to the construction site
R2.2	Aesthetical Options	X	Various materials and finishes should be presented for each of the products provided
R3.1	Integration of services and sensors within the passive systems		
R3.2	Adapt to P&P modularity and characteristics	X	Adaptable to P&P envelope substructure dimensions.
R3.3	Physical requirements active TPC components		
R3.4	Tailored Heating system strategies		
R4.2	Lean Construction	X	The external layer components provider has to be part of the lean construction process.
R4.3	Create deconstruction and maintenance plans	X	Maintenance design is required for external elements. They need to be easy repaired from the outside without disassembling collateral panels.
R5.1	P&P technical sheets	X	Technical sheet required
R5.2	Drawing exchange format .dxf	X	2d drawing required, minimum plant and cross section
R5.3	5D BIM objects .IFC	X	BIM object: minimum BIM3d model, desirable BIM object with 5D content (cost, time)
R6.1	CE | Local Regulations	X	Must comply with CE and Local Regulations
R6.2	EPD	X	Provides a standardized life-cycle assessment of the component

4.2 High Performance Windows

In the following table, the Specifications and requirements for Windows components are described.

Table 6: High Performance Windows Specifications

	Requirement		Specification Description
R1.1	Delivery of components in kits	X	The provider delivers the component in a finished kit to facade manufacturing plant. This kit must be easy to install and regulate Example: having a rigid frame with 4 fixing plates to allow regulate in 3 axes. The kit also needs to be easy to connect to electrical supply
R1.2	Installed outside the building envelope	X	The windows will be preassembled offsite. The solutions need to guaranty transportation resistance when being moved to the construction site
R2.2	Aesthetical Options	X	Various materials and finishes should be presented for each of the products provided
R3.1	Integration of services and sensors within the passive systems	X	Integration of P&P devices that automatically detect the HVAC components with just one unified interface to connect to a BMS
R3.2	Adapt to P&P modularity and characteristics	X	Adaptable to P&P envelope dimensions.
R3.3	Physical requirements active TPC components		
R3.4	Tailored Heating system strategies		
R4.2	Lean Construction	X	The windows provider should be part of the lean construction process.
R4.3	Create deconstruction and maintenance plans	X	Maintenance design is required por sun protection elements, they have to be easy repaired from outside without disassembling more than collateral panels.
R5.1	P&P technical sheets	X	Technical sheet required
R5.2	Drawing exchange format .dxf	X	2d drawing required, minimum plant and cross section
R5.3	5D BIM objects .IFC	X	BIM object: minimum BIM3d model, desirable BIM object with 5D content (cost, time)
R6.1	CE | Local Regulations	X	Must comply with CE and Local Regulations
R6.2	EPD	X	Provides a standardized life-cycle assessment of the component

4.3 Solar Protection | Sun shading

In the following table, the Specifications and requirements for Solar Protections and Sun shading components are described.

Table 7: Solar Protection | Sun shading Specifications

	Requirement		Specification Description
R1.1	Delivery of components in kits	X	The provider delivers the component in a finished kit to facade manufacturing plant. This kit must be easy to install and regulate. Example: having a rigid frame with 4 fixing plates to allow regulate in 3 axes. The kit also needs to be easy to connect to electrical supply
R1.2	Installed outside the building envelope	X	The solar protection element used to be installed outside, however the width of the solution has to be less than the P&P envelops. Therefore, the selected solution must be placed within the width of the system
R2.2	Aesthetical Options	X	Various materials and finishes should be presented for each of the products provided
R3.1	Integration of services and sensors within the passive systems	X	Integration of P&P devices that automatically detect the HVAC components with just one unified interface to connect to a BMS
R3.2	Adapt to P&P modularity and characteristics	X	Adaptable to P&P envelope dimensions.
R3.3	Physical requirements active TPC components		
R3.4	Tailored Heating system strategies		
R4.2	Lean Construction	X	The Solar Protection provider should be part of the lean construction process.
R4.3	Create deconstruction and maintenance plans	X	Maintenance design is required por sun protection elements, they have to be easy repaired from outside without disassembling more than collateral panels.
R5.1	P&P technical sheets	X	Technical sheet required
R5.2	Drawing exchange format .dxf	X	2d drawing required, minimum plant and cross section
R5.3	5D BIM objects .IFC	X	BIM object: minimum BIM3d model, desirable BIM object with 5D content (cost, time)
R6.1	CE | Local Regulations	X	Must comply with CE and Local Regulations
R6.2	EPD	X	Provides a standardized life-cycle assessment of the component

4.4 PV | ST Panels

Active systems can also be implemented to build the Plug and Play Envelope. In the following table, the Specifications for PV | ST Panels and each requirement are described.

Table 8: PV | ST Panels Specifications

	Requirement		Specification Description
R1.1	Delivery of components in kits	X	The provider delivers the component in a finished kit. The kit needs to have a system that can easily be attached to the roof structure or integrated in the façade system. The connection with the thermal | electrical system also needs to be considered.
R1.2	Installed outside the building envelope	X	It will be installed in the facade or on the roof
R2.2	Aesthetical Options	X	Various materials and configurations should be presented for each of the products provided when the system is installed in the façade.
R3.1	Integration of services and sensors within the passive systems	X	Integration of a management system (EMS)
R3.2	Adapt to P&P modularity and characteristics	X	Adaptable to P&P envelope dimensions when installed in the façade
R3.3	Physical requirements active TPC components		Pending to be defined
R3.4	Tailored Heating system strategies		
R4.2	Lean Construction	X	The PV/ST provider should be part of the lean construction process.
R4.3	Create deconstruction and maintenance plans	X	Maintenance design is required por sun protection elements, they have to be easy repaired from outside without disassembling more than collateral panels.
R5.1	P&P technical sheets	X	Technical sheet required. Information specified in the annex.
R5.2	Drawing exchange format .dxf	X	2d drawing required, minimum plant and cross section
R5.3	5D BIM objects .IFC	X	BIM object: minimum BIM3d model, desirable BIM object with 5D content (cost, time)
R6.1	CE | Local Regulations	X	Must comply with CE and Local Regulations
R6.2	EPD	X	Provides a standardized life-cycle assessment of the component

4.5 Heating | Cooling Systems

The heating and cooling systems requirements below refer to available solutions in the market that can work with. In the following table, the Specifications for Heating | Cooling Panels and each requirement are described.

Table 9: Heating and Cooling System Specifications

	Requirement		Specification Description
R1.1	Delivery of components in kits	X	If the solution chosen system can be applied in the façade Kit, the provider has to deliver the component in a finished kit to facade manufacturing plant. This kit must be easy to install and adjust. The kit also needs to be easy to connect to heating | cooling supply

R1.2	Installed outside the building envelope		
R2.2	Aesthetical Options		
R3.1	Integration of services and sensors within the passive systems	X	Integration of P&P devices that automatically detect the HVAC components with just one unified interface to connect to a BMS
R3.2	Adapt to P&P modularity and characteristics	X	It only needs to be adaptable to P&P envelope dimensions when integrated in the facade renovation kit
R3.3	Physical requirements active TPC components	X	Pending to be defined
R3.4	Tailored Heating system strategies	X	Pending to be defined
R4.2	Lean Construction	X	The Solar Protection provider should be part of the lean construction process.
R4.3	Create deconstruction and maintenance plans	X	They have to be easy repaired from the outside without disassembling other components or removing a part that has been design with that purpose in mind
R5.1	P&P technical sheets	X	Technical sheet required
R5.2	Drawing exchange format .dxf	X	2d drawing required, minimum plant and cross section
R5.3	5D BIM objects .IFC	X	BIM object: minimum BIM3d model, desirable BIM object with 5D content (cost, time)
R6.1	CE | Local Regulations	X	Must comply with CE and Local Regulations
R6.2	EPD	X	Provides a standardized life-cycle assessment of the component

4.6 Demand Controlled Ventilation

In the StepUP project, the demand-controlled ventilation will be integrated within the P&P Envelope. In the following table, the Specifications for Demand Controlled Ventilation and each requirement are described.

Table 10: Demand Controlled Ventilation Specifications

Requirement			Specification Description
R1.1	Delivery of components in kits	X	The provider delivers the component in a finished kit to facade manufacturing plant. This kit must be easy to install and regulate Example: having a rigid frame with 4 fixing plates to allow regulate in 3 axes. The kit also needs to be easy to connect to electrical supply
R1.2	Installed outside the building envelope	X	The demand-controlled ventilation system is usually installed inside. However, the solution has to be integrated outside, placed within the width of the P&P Envelope.
R2.2	Aesthetical Options	X	Various materials and finishes should be presented for each of the products provided
R3.1	Integration of services and sensors within the passive systems	X	Integration of demand-controlled ventilation system within P&P envelope. Integration of P&P devices that automatically detect the HVAC components with just one unified interface to connect to a BMS
R3.2	Adapt to P&P modularity and characteristics	X	Adaptable to P&P envelope dimensions.
R3.3	Physical requirements active TPC components		
R3.4	Tailored Heating system strategies		
R4.2	Lean Construction	X	The Demand Controlled Ventilation provider should be part of the lean construction process.
R4.3	Create deconstruction and maintenance plans	X	Maintenance design is required por sun protection elements, they have to be easy repaired from outside without disassembling more than collateral panels.
R5.1	P&P technical sheets	X	Technical sheet required
R5.2	Drawing exchange format .dxf	X	2d drawing required, minimum plant and cross section
R5.3	5D BIM objects .IFC	X	BIM object: minimum BIM3d model, desirable BIM object with 5D content (cost, time)
R6.1	CE | Local Regulations	X	Must comply with CE and Local Regulations
R6.2	EPD	X	Provides a standardized life-cycle assessment of the component

4.7 Plug&Play Protocol Specifications Summary

As discussed above, StepUP is rooted in solutions close to the market and is focused on optimizing these solutions to be integrated and interoperable to achieve quick and affordable deep renovation. The following table summarizes TPC specifications and explains every requirement for each technology.

Table 11: TPC Specifications summary

	Requirements	External Layer	High Performance Windows	Solar Protection | Sun Shading	PV | ST Panels	Heating | Cooling Systems	Demand Controlled Ventilation
R1.1	**Delivery of components in kits**	The provider delivers the component in a finished kit to facade manufacturing plant. This kit has to be easy to install and regulate Example: having 4 fixing connections to allow regulation in 3 axes.	The provider delivers the component in a finished kit to facade manufacturing plant. This kit must be easy to install and regulate Example: having a rigid frame with 4 fixing plates to allow regulate in 3 axes. The kit also needs to be easy to connect to electrical supply	The provider delivers the component in a finished kit to facade manufacturing plant. This kit must be easy to install and regulate Example: having a rigid frame with 4 fixing plates to allow regulate in 3 axes. The kit also needs to be easy to connect to electrical supply	The provider delivers the component in a finished kit. The kit needs to have a system that can easily be attached to the roof structure or integrated in the façade system. The connection with the thermal | electrical system also needs to be considered.	If the solution chosen system can be applied in the façade Kit, the provider has to deliver the component in a finished kit to facade manufacturing plant. This kit must be easy to install and adjust. The kit also needs to be easy to connect to heating | cooling supply	The provider delivers the component in a finished kit to facade manufacturing plant. This kit must be easy to install and regulate Example: having a rigid frame with 4 fixing plates to allow regulate in 3 axes. The kit also needs to be easy to connect to electrical supply
R1.2	**Installed outside the building envelope**	The external layer will be preassembled offsite. The solutions need to guaranty transportation resistance when being moved to the construction site	The windows will be preassembled offsite. The solutions need to guaranty transportation resistance when being moved to the construction site	The solar protection element used to be installed outside, however the width of the solution has to be less than the P&P envelops. Therefore, the selected solution must be placed within the width of the system	It will be installed in the facade or on the roof		The demand-controlled ventilation system is usually installed inside. However, the solution has to be integrated outside, placed within the width of the P&P Envelope.
R2.2	**Aesthetical Options**	Various materials and colours should be presented for each of the products provided	Various materials and finishes should be presented for each of the products provided	Various materials and finishes should be presented for each of the products provided	Various materials and configurations should be presented for each of the products provided when the system is installed in the façade.		Various materials and finishes should be presented for each of the products provided
R3.1	**Integration of services and sensors within the tectonic solution**		Integration of P&P devices that automatically detect the HVAC components with just one unified interface to connect to a BMS	Integration of P&P devices that automatically detect the HVAC components with just one unified interface to connect to a BMS	Integration of a management system (EMS)	Integration of P&P devices that automatically detect the HVAC components with just one unified interface to connect to a BMS	Integration of demand-controlled ventilation system within P&P envelope
R3.2	**Adapt to P&P modularity and characteristics**	Adaptable to P&P envelope substructure dimensions.	Adaptable to P&P envelope dimensions.	Adaptable to P&P envelope dimensions.	Adaptable to P&P envelope dimensions when installed in the façade	It only needs to be adaptable to P&P envelope dimensions when integrated in the facade renovation kit	Adaptable to P&P envelope dimensions.
R3.3	**Physical requirements active TPC**				Pending to be defined	Pending to be defined	
R3.4	**Tailored Heating Strategies**					Pending to be defined	
R4.2	**Lean Construction**	The external layer components provider has to be part of the lean construction process.	The windows provider should be part of the lean construction process.	The Solar Protection provider should be part of the lean construction process.	The PV/ST provider should be part of the lean construction process.	The Heating/Cooling System provider should be part of the lean construction process.	The Demand Controlled Ventilation provider should be part of the lean construction process.
R4.3	**Create deconstruction plans**	Maintenance design is required for external elements. They need to be easy repaired from the outside without disassembling collateral panels.	Maintenance design is required for window elements, they have to be easy repaired from outside without disassembling more than collateral panels.	Maintenance design is required por sun protection elements, they have to be easy repaired from outside without disassembling more than collateral panels.	Maintenance design is required for PV/ST elements, they have to be easily repaired from outside without disassembling more than collateral panels.	They have to be easy repaired from the outside without disassembling other components or removing a part that has been design with that purpose in mind	Maintenance design is required for window elements, they have to be easy repaired from outside without disassembling more than collateral panels.
R5.1	**P&P technical sheets**	Technical sheet required. Information specified in the annex.	Technical sheet required. Information specified in the annex.	Technical sheet required. Information specified in the annex.	Technical sheet required. Information specified in the annex.	Technical sheet required. Information specified in the annex.	Technical sheet required. Information specified in the annex.
R5.2	**Drawing exchange format .dxf**	2d drawing required, minimum plant and cross section	2d drawing required, minimum plant and cross section	2d drawing required, minimum plant and cross section	2d drawing required, minimum plant and cross section	2d drawing required, minimum plant and cross section	2d drawing required, minimum plant and cross section

R5.3	**5D BIM objects**	BIM object: minimum BIM3d model, desirable BIM object with 5D content (energy consumption, cost, maintenance)	BIM object: minimum BIM3d model, desirable BIM object with 5D content (energy consumption, cost, maintenance)	BIM object: minimum BIM3d model, desirable BIM object with 5D content (energy consumption, cost, maintenance)	BIM object: minimum BIM3d model, desirable BIM object with 5D content (energy consumption, cost, maintenance)	BIM object: minimum BIM3d model, desirable BIM object with 5D content (energy consumption, cost, maintenance)	BIM object: minimum BIM3d model, desirable BIM object with 5D content (energy consumption, cost, maintenance)
R6.1	**CE | Local Regulations**	Must comply with CE and Local Regulations	Must comply with CE and Local Regulations	Must comply with CE and Local Regulations	Must comply with CE and Local Regulations	Must comply with CE and Local Regulations	Must comply with CE and Local Regulations
R6.2	**Environmental Product Declaration**	Provides a standardized life-cycle assessment of the component.	Provides a standardized life-cycle assessment of the component.	Defined at the beginning of each project.	Provides a standardized life-cycle assessment of the component.	Provides a standardized life-cycle assessment of the component.	Provides a standardized life-cycle assessment of the component.

5 StepUP protocol validation with the TPC

This chapter attempts to synthesize the results obtained from the TPC responses, with the aim of the validation of the StepUP protocol and retrofit from the data obtained to see if improvements can be implemented.

During the past months, Eurecat has organized a webinar in Spain to improve and contrast the StepUP protocol and their specifications with TPC companies. Meanwhile, Unismart has contacted directly with the TPC, as many companies showed interest in the first event organized in November 2020.

These workshops from WP2 were delayed due to Covid Pandemic Situation until Spring 2022. They help to understand the readiness of the **Plug&Play Protocol** and its capability to be implemented in the StepUP renovation process, following the specifications and requirements detailed in this document. The objectives of these workshops were:

1) Validate the requirements conceived for systems and components to meet P&P standards.
2) Ensure that each TPC and each technology can fulfil the specifications.
3) Validate the technical sheets with the TPC to ensure that TPC can provide this information.
4) Understand which phase of the construction (offsite, onsite, etc.) is more convenient to integrate each technology.
5) Collect the missing information from the P&P Technologies and the StepUP partners.

In May 2022, Eurecat organised an online webinar in Spain under the title "Decarbonization of buildings through Plug&Play solutions for deep renovation" with about 25 participants. The event had the participation of different speakers, where they offered their experience based on similar research projects related with the Plug&Play technologies, such as the façade system Plug&Harvest developed by the R&D department of Pich Architects. This type of webinar offered the opportunity to the TPC to understand the objectives of the StepUp project and related research projects form the EU.

The objectives were validated through the explanation of the protocol, its principles, its requirements, and the role of the TPC in the project. Then, a round of questions was developed that referred to the requirements that the TPC should meet to be integrated into the StepUP methodology.

In the following table, the questions prepared for the event are presented. To simplify the data collection, the questions were raised for yes or no answer. The protocol for the integration and interoperability of the StepUP technologies was validated by 14 companies.

Table 12: Questions for the StepUp protocol validation

	Requirement	Questions	
R1.1	Delivery of components in kits	Does your technology provide an anchoring system in 3 axee? // Is your technology providing a sub-frame to adapt it to the system?	▢ Yes ▢ No
R1.2	Installed outside the building envelope	The external layer will be preassembled offsite. Is your solution able to guarantee transportation resistance when being moved to Manni manufactures or from the manufactures to the construction site?	▢ Yes ▢ No
		During the transportation, could be possible to not have control over the outside condition. Your technology has some component to be protected from the outside environment?	▢ Yes ▢ No
R2.2	Aesthetical Options	Are your products allowing different finishes, shapes and colours?	▢ Yes ▢ No
R3.1	Integration of services and sensors within the passive systems		-
R3.2	Adapt to P&P modularity and characteristics	Do your products allow to be adapted to dimensions around 2,5m x 3m?	▢ Yes ▢ No
R3.3	Physical requirements active TPC components		-
R3.4	Tailored Heating system strategies		-
R4.2	Lean Construction	Is your company willing to participate in the LEAN methodology with other companies?	▢ Yes ▢ No
R4.3	Create deconstruction and maintenance plans	Is your System designed to be reused, reassembled and recycled?	▢ Yes ▢ No
R5.1	P&P technical sheets	Is your company providing the technical sheets of your products?	▢ Yes ▢ No
R5.2	Drawing exchange format .dxf	Is your company providing information in 2D format such as .dxf?	▢ Yes ▢ No
R5.3	5D BIM objects .IFC	Is your company providing information in .IFC for BIM models?	▢ Yes ▢ No
R6.1	CE | Local Regulations	Are your technologies/products providing an CE making or Local Regulations certificate?	▢ Yes ▢ No
R6.2	Environmental Product Declaration	Are your products providing an EPD of the component? (CO_2 or J/kg)	▢ Yes ▢ No

5.1 Results and discussion

The following table summarizes the results of the two events developed in Spain and Italy. However, the table shows with an **X** the requirements in which the TPC's cannot be met today. It can be drawn as a preliminary conclusion, that there is a pattern that is repeated among the **requirements** that cannot be met, emphasizing **R1.1, R4.3, R5.3,** and **R6.2.**

Table 13: Results summary of the workshops held in May 2022

External Layer	High Performance Windows	Solar Protection | Sun Shading	PV | ST Panels	Heating | Cooling Systems	Demand Controlled Ventilation		
4.1	4.2	4.3	4.4	4.5	4.6		
X	X	X	X			R1.1	Delivery of components in kits
						R1.2	Installed outside the building envelope
						R2.2	Aesthetical options
						R3.1	Integration of services and sensors within the passive solution
						R3.2	Adapt to P&P modularity and characteristics
						R3.3	Physical requirements active TPC components
						R3.4	Tailored heating strategies
						R4.2	Lean Construction
X	X		X	X	X	R4.3	Create deconstruction and maintenance plans
						R5.1	P&P Technical Sheets
				X		R5.2	Drawing exchange format .dxf
X	X	X	X	X	X	R5.3	5D BIM objects
						R6.1	CE | Local Regulations
X	X	X	X	X	X	R6.2	Environmental Product Declaration

5.1.1 R1.1 Delivery components in kits

For the fulfilment of this requirement, two questions were asked in the workshops:

1) 1.- Does your technology provide an anchoring system in 3 axes?
2) 2.- Is your technology providing a sub-frame to adapt it to the system?

These questions refer to the integration of the TPC products on the **P&P façade module**, which is the most restrictive system. In other words, in the Smartheat system, the integration can be supplied by components that are joined together by Plug&Play technologies and does not depend on the dimensions of the existing building.

Thus, the results of the quests show that today the TPC does not provide a system that is easy to adapt to the P&P envelope. This topic was foreseen in the StepUP project and is explained in detail in the deliverable **D4.4 :Integrating P&P technologies with TPC**, where the Third-Party Products (TPP) integration is addressed.

5.1.2 R4.3 Create deconstruction and maintenance plans

As a result of the questions raised, it can be said that currently TPC products do not have their products designed to be disassembled and recycled.

The cradle-to-cradle concept has been introduced in the construction sector for a few years. The results show a **lack of sustainability** awareness of their products and that the companies should start developing R&D&I to meet the environmental needs of the sector.

Sooner or later, this requirement will be meet. The European commission is working on new rules to make almost all physical goods on the EU market more friendly to the environment, circular, and energy efficient throughout their whole lifecycle from the design phase through to daily use, repurposing and end-of-life. On the 30th of March 2022 a package of European Green Deal proposal to make sustainable products the EU. This means that all regulated products will have a **Digital Product Passport,** and will make it easier to repair or recycle once its life cycle ends.[3]

5.1.3 R5.3 5D BIM objects

BIM objects provide detailed design information, which is a good solution for building maintenance, thanks to the amount of information that this type of data source can store.

The results of the workshops show **the lack of information** on this requirement. According to data consulted in the *European Architectural Barometer Q2 2021*. The trend with construction and architecture companies shows that more and more companies will offer this service.

In addition, some countries are legislating on BIM, such as UK, Spain and Norway. Thus, that manufacturers capable to offer their products in BIM will gain a huge competitive advantage.

5.1.4 R6.2 Environmental Product Declaration

As mentioned in R4.3, there is a **lack of environmental commitment** on the part of the companies. This missing information regarding this requirement can be solved through new European directives that obligate companies to provide their products' environmental data.

[3] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2013

5.1.5 Others

It has been considered relevant to add a new chapter in the discussion and refer companies that have participated in the workshops but did not fit with any classification.

During the workshops developed, some companies that were not part of any of the TPCs identified to include in the SteUP project. Thus, this is because some of them are companies that supply small construction components, such as silicones, screws, or anchoring elements. These companies are part of the value chain, but they provide constructive elements that would be used during their installations or are included in the TPP itself.

These ''other'' companies have a common pattern and are ready to comply with the P&P protocol, but they are not a prototype itself.

6 Conclusions

The development of the deliverable **D2.5 Plug&Play Protocol** has led to the definition of the **Plug&Play Principles and requirements** that should facilitate the connection between P&P technologies (P&P Envelope and SmartHeat) and Technology Providers Cluster solutions.

A protocol has been defined based on the interoperability of technologies and the open data exchange to evaluate the energy performance of the building's deep renovation. The principles are the basis of the protocol, and the specification and the technical sheets give the concretion.

The **requirements** of the protocol have been validated through the TPC in order to understand the current market state and see if companies can meet the protocol goals. In summary, a lack of compliance with the requirements in four field has been detected, and are included in the following list:

a) **R1.2** Delivery components in kits
b) **R4.3** Create deconstruction and maintenance plans
c) **R5.3** 5D BIM objects
d) **R6.2** Environmental Product Declaration

It can be concluded that nowadays, a deep change of the construction sector is needed in order to transform the sector into a real industry. However, no TPC has been found that meets all the requirements. The TPC companies are not far to comply the requirements of the StepUP project. Despite this, the requirements **R4.3, R5.3** and **R6.2** can be solved easily, either through the environmental commitment of companies or through new European directives. In other words, these requirements are beginning to be regulated through European directives and companies will have to adapt the sustainability requirements demanded by the sector.

While for the compliance of the requirement **R1.2,** it is part of the development of the project and can be found in the **D4.4: Integrating P&P technologies with TPC.** The integration with Technology Provider Cluster is something that needs to be studied in detail, and the validation of its implementation requires some tests to validate the P&P protocol. However, integration with TPC is a process that involves different companies, validation, and tests.

Despite this, it is clear that the Third-Party Companies show a clear interest in industrial processes and offsite construction. Furthermore, the protocol will be presented in some conferences and will be validated by TPC's that show interest in the implementation of their products in-to the StepUP technologies.

The deliverable D2.5.v5 is an update of the deliverable D2.5.v4 delivered in February. This new deliverable includes all the information collected in the workshops with the objective to validate the protocol and receive feedback from TPC.

7 Annex. Technical Sheets

In this chapter, the technical sheets are presented for accurate energy modelling for each TPC technology. However, to have digital models and energy simulations it is necessary to be accurate with material information, to be as faithful as possible to reality. The purpose of presenting this information is to ensure that technology providers can collect this information and be ready to provide it, e.g. by including it in a technical product sheet compliant with the P&P Protocol.

7.1 External Layer

Table 14: Technical Sheet-External Layer

Material	material description
Thickness	[mm]
Conductivity	[W/m*K]
Density	[kg/m^3]
Specific heat capacity	[J/(kg*K)]
Resistance	[m^{2}K/W]
Vapour resistivity	[GN*s/(kg*K)]
Category	Select from the following categories
Asphalts & Others Roofing	
Boards, Sheets & Decking	
Brick & Blockwork	
Carpets	
Concretes	
Gravels, Beddings, etc	
Insulating Materials	
Metals	
Plaster	
Screeds & Renders	
Sands, Stones and Soils	
Tiles	
Timber	
Glass	
Floor finishes	
Suspended ceilings	
Include drawing of the product	Perspective | Plan | Cross-section

7.2 High Performance Windows

Table 15: Technical Sheet - High Performance Windows

Place Opening	
Base height	[m]
Width	[m]
Height	[m]
Project Constructions	
Tvis	
Glazed frame	[%]
Glazed frame resistance	[m^2K/W]
Glazed frame material	select
Aluminium	
Hardwood	
Metal	
Metal with Thermal Break	
PVC	
Softwood	
Steel	
Surface Tab	Outside surface and inside surface
Emissivity	
Resistance	[m^2K/W]
Frame Tab	
Percentage	
Absorptance	
Resistance	
Outside surface area ratio	
Inside surface area ratio	
Type	select
Aluminium	
Hardwood	
Metal	
Metal with Thermal Break	
PVC	
Softwood	
Steel	
Shading Device Tap	
Local Shade	
External Shade	
Internal Shade	
Construction Layers Tab	outside to inside grid
Material	ID and description of the material composing the layer, or alternatively 'Cavity'
Thickness	

Conductivity	
Angular dependence	
Fresnel	
Explicit	
Constant	
LBNL	
Gas	(Optional)
Convection coefficient	[W/m²k] (optional)
Resistance	[m²K/W] (optional-Air Gap Only)
Transmittance	
Outside Reflectance	
Refractive index	

7.3 Solar Protection | Sun shading

Table 16: Technical Sheet - Solar Protection | Sun shading

Material	material description
Thickness	[mm]
Conductivity	[W/m*K]
Density	[kg/m^3]
Specific heat capacity	[J/(kg*K)]
Resistance	[m^{2}K/W]
Vapour resistivity	[GN*s/(kg*K)]
Category	Select from the following categories
Asphalts & Others Roofing	
Boards, Sheets & Decking	
Brick & Blockwork	
Carpets	
Concretes	
Gravels, Beddings, etc	
Insulating Materials	
Metals	
Plaster	
Screeds & Renders	
Sands, Stones and Soils	
Tiles	
Timber	
Glass	
Floor finishes	
Suspended ceilings	

7.4 PV | ST Panels

Table 17: Technical Sheet - PV| ST Panels

Parametric Panels	
PV Type	
Amarphous Silicon	
Monocrystalline Silicon	
Other Thin Films	
Polycrystalline Silicon	
Other Thin Films	
Thin Film Cadmium-Telluride	
Thin Film Copper-Indium-Gallium-Diselenide	
Custom	
Module Nominal Efficiency	
Nominal Cell Temperature	[NOCT] [ºC]
Reference Irradiance for NOCT	[W/m2]
Temperature Coefficient for Module Efficiency Pmax	[%/ºC]
Degradation Factor	
Electrical Conversion Efficiency	
Area	[m^2]
Azimuth	[°clockwise from north]
Inclination	[°from horizontal]
Shading Factor	
Free Standing Panels	
PV Type	
Amarphous Silicon	
Monocrystalline Silicon	
Other Thin Films	
Polycrystalline Silicon	
Other Thin Films	
Thin Film Cadmium-Telluride	
Thin Film Copper-Indium-Gallium-Diselenide	
Custom:	
Module Nominal Efficiency	
Nominal Cell Temperature	[NOCT] [ºC]
Reference Irradiance for NOCT	[W/m2]
Temperature Coefficient for Module Efficiency Pmax	[%/ºC]
Degradation Factor	
Electrical Conversion Efficiency	
Area	[m^2]
Azimuth	[°clockwise from north]
Inclination	[°from horizontal]
Shading Factor	
High Concentration PV	

Cell Surface	[cm^2]
Number of Cells	
Geometric Concentration	
Power Temperature Coefficient	[1/k]
Optical Efficiency	
Cell Efficiency	
Spectral Factor	
Tacking Device Power	[%]
Linear Temperature Factor	[m^{2}k/W]
Tracking Error	

7.5 Heating | Cooling Systems

Table 18: Technical Sheet - Heating System Specifications

Hot Water Loop tab	
Distribution Losses	[%]
Oversizing Factor	
Use this heat source for DHW	[box to check]
Design Hot Water Supply Temperatures	Tlbtdes [°C]
Hot Water Supply Temperature Set Point Type	[°C]
Constant	
Timed	
Reset	
Constant Hot Water Supply Temperature Set Point	[°C]
Timed Hot Water Supply Temperature Set Point Profile	[°C]
Hot Water Supply Temperature Reset Type	[°C]
Outdor air temperature reset	
Outdoor dry-bulb temperature low limit	
Outdoor dry-bulb temperature high limit	
Hot water supply temperature at or above high limit	
Outdoor Dry-bulb Temperature Low Limit	[°C]
Hot Water Supply Temperature at or above High Limit	[°C]
Outdoor Dry-Bulb Temperature High Limit	[°C]
Hot Water Supply Temperature at or above High Limit	[°C]
Design Hot Water Loop Temperature Difference	[°C]
Loop Configuration	
Primary-only	
Primary-Secondary	
Primary Circuit Hot Water Specific Pump Power at Rated Speed	[W/gpm] or [W/(l/s)]
Primary Circuit Hot Water Pump Heat Gain to Hot Water Loop	[fraction]
Primary Circuit Hot Water Pump Power Curve	fPv[v]
Secondary Circuit Hot Water Specific Pump Power at Rated Speed	[W/gpm] or [W/(l/s)]
Secondary Circuit Hot Water Pump Heat Gain to Hot Water Loop	[fraction]
Secondary Circuit Hot Water Pump Power Curve	fPv[v]
Pre-heating tab	
Location of Pre-heating component	
Solar water heater checkbox	
Heat recovery checkbox	
Air to water heat pump checkbox	
Combined heat and power checkbox	
Solar water heater tab	
Reference	
Area	[m²]
Azimuth	[° clockwise from north]
Tilt	[° from horizontal]
Shading factor	
Degradation factor	
Conversion efficiency at ambient temperature	

First order heat loss coefficient	[W/m²K]
Second order heat loss coefficient	[W/m²K]2
Flow rate	[l/(h.m²)] or [US gal/(hr·ft²)]
Pump power	[kW]
Heat exchanger effectiveness	
Storage tank volume [USgal]	
Storage tank loss factor	[kWh/l/day or Btu/(USgal·day)]
Heat recovery tab	
Heat recovery Model	
Percentage of heat rejection heat-exchanger model	
Source type	
Source	
Max heat recovery with HX	[%]
Heat pump capacity	[%]
Heat pump COP	
Heat pump fuel	
Fixed-COP water-source heat pump modell	
Explicit heat transfer	
Model	
Water to water heat pump checkbox	
Source type	
Source	
Heat exchanger design effectiveness	
Heat pump capacity as percentage of source loop capacity	[%]
Heat pump thermal lift	[two delta T point] [ºF]
Heat pump COP at two operating points	
Heat pump fuel	
Variable-COP water-source heat pump model	
Air to water heat pump	
Reference	
Reference	
Reference	
Combined heat and power	
CHP sequence ranking	
High equipment	
Heating Equipment Model Type to Add	
Hot water boiler	
Par load curve heating plant	
Heating Equipment List	[1/k]
Heating equipment type	
PLE = Part-load equipment	
HWB = Hot-water boiler	
Part Load Range	[up to %]
Heating Equipment Auto sizing Capacity Weighting	[%]
Hot Water Radiators	
Reference	
Orientation	

Horizontal	
Vertical	
Radiant Fraction	
Reference temperature difference	[k]
Heating Output at Reference Temperature	[kW]
Maximum Input from Heat Source	[kW]
Distribution pump consumption	[kW]
Material	
Steel	
Aluminium	
Radiator Weight	[kg][excluding weight of water]
Water capacity	[l]

Table 19: Technical Sheet - Cooling System Specifications

Chill Water Loop tab - Manages parameters relating to chilled water loop setup of system	
Chilled water loop capacity	[kW]
Distribution losses	
Loop configuration	[box to check]
Primary only	
Primary/secondary	
Primary (/ Secondary if specified) circuit	[°C]
Chilled water supply reset type:	
No reset	
Outdoor dry-bulb temperature	
CWP loop load	
Outdoor dew-point temperature	
Cooling coil max flow	
Outdoor dry-bulb temperature high threshold*	[°C]
Supply temperature at/above high threshold*	[°C]
Outdoor dry-bulb temperature low threshold*	[°C]
Supply temperature at/below low threshold*	[°C]
Design Temperature Difference, DeltaTcdes	[k]
Primary circuit pump configuration	
Single pump	
Dedicated chiller pumps	
Specific pump power at design flow	[W/(l/s)]
Pre-Cooling	
Design Outdoor Dry-bulb Temperature	[°C]
Design Outdoor Wet-bulb Temperature	[°C]
Location of pre-cooling loop:	
Secondary load return	
Primary loop downstream of bypass	
Pre-cooling capacity:	
% of CHWL capacity	
Capacity	[kW]

Heat rejection devices:	[º clockwise from north]
Water source heat exchanger:	[º from horizontal]
Cooling capacity:	
% of CHWL capacity	
Capacity	[kW]
Source water temperature	[ºC]
Source water specific pump power	[W/(l/s)]
Approach	[k]
Source-side delta T	[k]
Source-side flow rate	[l/s]
Cooling tower with heat exchanger:	
Energy end use:	
Cooling	
Heat rejection	
Cooling capacity, Qhrdes	[kW]
Approach	[k]
Range	[k]
Flow rate	[l/s]
Fan power	[kW]
Fan control:	
One speed	
Two speed	
VSD	
Low speed fan fractions:	
Flow	
Power	
Heat exchanger approach	[k]
Specific pump power at design flow rate	[W/(l/s)]
Pump heat gain to cooling tower loop	[fraction]
Fluid Cooler:	
Energy end use:	
Cooling	
Heat rejection	
Fluid cooler type:	
Wet/dry	
Dry	
Cooling capacity, Qhrdes	[kW]
Outdoor dry-bulb temp. for wet/dry mode switch	[ºC]
Approach	[k]
Wet-bulb delta T	[k]
Fan power, Wfan	[kW]
Low speed fan fractions:	
Flow	
Power	
CHP sequence ranking	[kW]
Chiller Set	

Chiller Type	
Part load curve chiller	
Absortion chiller	[true/false]
Energy end use:	
Cooling	
Heat rejection	
Heat source (Absorption chiller only)	
Minimum chilled-water flow fraction	
Chiller pumps	[kW]
Condernser pumps	[kW]
Heat rejection fans	[kW]
Outside temperature for COP data:	
No temperature dependence	
Dry bulb	
Wet bulb	
Previous night min wet bulb	
Temperature 1	[ºC]
Part Load Performance:	
Output	[kW]
Chiller pump power	[%]
Condenser pump power	[%]
Fan power	[%]
COP @T1	
Electric air-cooled chiller:	
Performance curve set:	
Centrifugal	
Screw	
Screw/1Compressor	
Screw/2Compressor	
HermReciprocating/1Compressor	
HermReciprocating/2Compressor	
HermReciprocating/3Compressor	
HermReciprocating/4Compressor	
Cooling capacity curve	
EIR (temp dependence) curve	
EIR (part-load dependence) curve	
Min chilled water flow fraction	
Min part-load ratio for continuous operation	
Condenser fan power, Wfan	[kW]
Cooling capacity, Qrat	[kW]
COPrat	
Outfoor air dry-bulb temperature, Todbrat	[ºC]
Supply temp, Tletrat	[ºC]
Verat/Qrat	[l/s/kW]
Electric water-cooled chiller:	
Performance curve set:	

Generic HermCentrifugal	
Generic HermCentrifugal VSD	
Generic HermCentrifugal2Comp	
Generic HermCentrifugal1Comp	
Generic Screw2Compressor	
Generic Screw1Compressor	
Generic OpenCentrifugal	
Generic OpenReciprocatg	
Generic Virtual DES Cooling	
Min chilled water flow fraction	
Min condenser water flow fraction	
Min part-load ratio for continuous operation	
Compressor heat gain to condenser water loop fraction	
Cooling capacity, Qref	[kW]
COPref	
Entering temp, Tectref	[ºC]
Vcref/Qref	[l/s/kW]
Supply temp, Tletref	[ºC]
Vereft/Qref	[l/s/kW]
Part load range (up to %) and chiller/ cooling device	
Heat Rejection	
Design Outdoor Dry-bulb Temperature	[ºC]
Design Outdoor Wet-bulb Temperature	[ºC]
Condenser water loop heat rejection device:	
Cooling tower	
Fluid tower	
Waterside economizer (true/ false)	
Condenser Water Loop:	
Design Condenser Water Loop Supply Temperature	[ºC]
Design Temperature Difference, DeltaTcdes	[k]
Condenser Water Loop Supply Temperature Set Point	[ºC]
Condenser Loop Flow Rate	[l/s]
Condenser Water Specific Pump Power	[W/(l/s)]
Condenser Water Pump Heat Gain to Condenser Water Loop (fraction)	
Pump configuration:	
Single pump	
Dedicated condenser pumps	
Max pump flow fraction	
Min pump flow fraction	
Cooling tower	
Cell Control	
Maximize Cell operation	
Interlocked with chillers	
N+1 cooling towers per chiller	
Number of cells	
Cell Capacity	

% of CWL capacity	
Capacity	[kW]
Cooling Tower Design Leaving Temperature	[ºC]
Cooling Tower Design Heat Rejection, Qhrdes	[kW]
Cooling Tower Design Approach	[k]
Cooling Tower Design Range	[k]
Cooling Tower Fan Power, Wfan	[kW]
Cooling Tower Fan Electric Input Ratio, Wfan/Qhrdes	
Cooling Tower Fan control	
One-speed fan	
Two-speed fan	
VSD fan	
Cooling Tower Low-speed Fan Flow Fraction	
Cooling Tower Low-speed Fan Power Fraction	
Fluid Cooler	
Cell control	
Maximize Cell operation	
Interlocked with chillers	
N+1 fluid coolers per chiller	
Number of cells	
Cell capacity:	
% of CWL capacity	
Capacity	[kW]
Fluid cooler type:	
Wet/dry	
Dry	
Fluid Cooler Outdoor Temperature Wet/Dry Mode Switch	
Fluid Cooler Design Approach	[k]
Fluid Cooler Design Range	[k]
Fluid Cooler ΔT	[k]
Fluid Cooler Fan Power, Wfan	[kW]
Fluid Cooler Fan Electric Input Ratio, Wfan/Qhrdes	
Fluid Cooler Fan control	
One-speed fan	
Two-speed fan	
VSD fan	
Fluid Cooler Low-speed Fan Flow Fraction	
Fluid Cooler Low-speed Fan Power Fraction	
Fluid Cooler Spray Power, Wpump	[kW]
Fluid Cooler Spray Pump Electric Input Ratio, Wpump/Qhrdes	
Waterside Economizer	
Location of waterside economizer:	
Secondary load return	
Primary loop downstream of bypass	
Use WSE only when it can meet load in full	[True/false]
Heat exchanger approach	[k]

Dedicated Waterside Economizers	
Backup chilled water loop:	
None	
One EWC chiller with VSD pump on secondary CHW loop	
Cooling Tower Design Approach	[k]
Cooling Tower Design Range	[k]
Design Outdoor Wet-bulb Temperature	[ºC]
Design Cooling tower load	[kW]
Cooling Coil design water delta T	[k]
Cooling tower design fan power	[kW]
Fan control:	
One-speed fan	
Two-speed fan	
VSD fan	
Low speed fan flow fraction	
Low speed fan power fraction	
Heat exchanger effectiveness	
DX Cooling	
Condenser Type	
Air cooled	
Evaporative cooled	
Cooling capacity curve	
EIR (temp dependence) curve	
EIR (part-load dependence) curve	
Minimum part-load ratio for continuous operation	
Condenser fan EIR, EIRfan/pump	
Coefficient of performance, COPrat	
Outdoor air dry0bulb temperature, Todbrat	[ºC]
Entering coil wet-bulb temperature, Tewbrat	[ºC]
Chilled Ceiling	
Orientation	
Horizontal	
Vertical	
Radiant fraction	
Reference Temperature difference	[k]
Cooling output at ref. temp difference	[kW]
Maximum cooling from chiller	[kW]
Distribution Pump power	[kW]
Material:	
Steel	
Aluminium	
Weight chilled panel, excl. water	[kg]
Water capacity	[l]