Heat4Cool – Task 8.3 Education and training.

TRAINING MATERIAL

In the framework of T8.3 of the Heat4Cool project, we are presenting you the training material dedicated to each of the four demo sites involved in the project, and the different technologies tested and installed in these facilities.

This training material aims to present to external stakeholders the functioning of the Heat4Cool technologies installed in each demo, and present the systems developed within the project; thus, to allow a better comprehension, increase the interest of the audience and promote the use of the project solutions in the market.

The training material is divided into **four dossiers,** each one dedicated to one demo site.

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Demo site in Sofia (Bulgaria)

Demo manager: BALKANIKA

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1 HEAT4COOL PROJECT INTRODUCTION AND OBJECTIVES

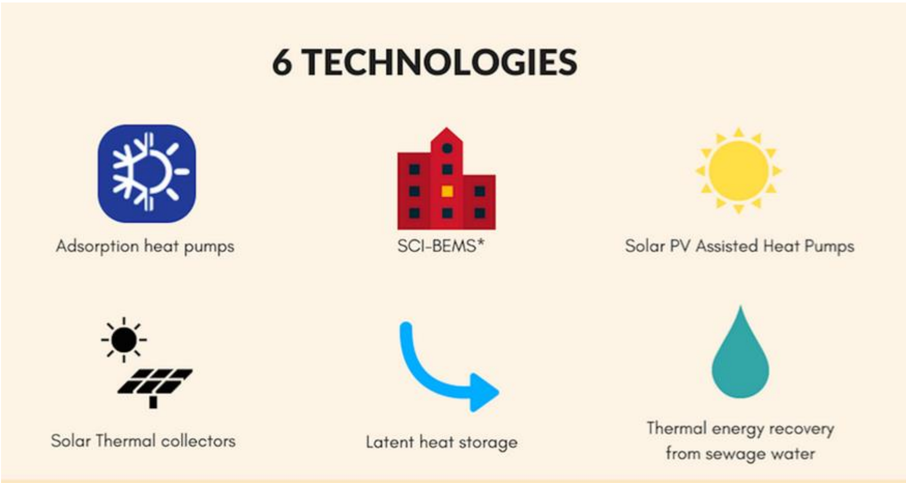
1.1. Introduction

The Heat4Cool project is an EU funded project, started in October 2016 and will run for four years.

The project proposes innovative, efficient and cost-effective heating and cooling solutions to optimize the integration of six technologies:

- Adsorption heat pump,
- PCM storage batteries,
- SCI-BEMS, Solar PV,
- Solar thermal,
- Heat recovery from sewage water

at building and district level, to meet net-zero energy standards.



The project will showcase four different retrofitting solutions, three of them will be focusing on residential buildings where the new innovative systems will be monitored and controlled through the SCI-BEMS (self-correcting intelligent building energy management system).

1.2 Testing technologies

The technologies based on solar energy and heat pumps developed within the Heat4Cool project are being implemented in Tecnalia's Kubik® facility, located in Bilbao (Spain).

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In the facility, Tecnalia tested the thermal storage system coupled with a reversible heat pump and the solar driven adsorption cooling system.

The main aim of these tests is to carry out a proof of concept for two complete systems in order to assess the thermal performance of Heat4Cool solutions under realistic boundary conditions. These two systems are already connected to the centralized HVAC system to test the effective integration of the heating and cooling technologies.

The thermal storage system coupled by a reversible heat pump is the concept solution developed by Sunamp. A total of 7 PCM (Phase change material) heat storages connected to an air to water electric heat pump have been installed. This is the first version of the system that will later evolve to a DC driven heat pump connected to a PV panel field, a solution that will be implemented in the pilot buildings of Sofia and Chorzow. The system to be tested in Kubik will allow improving the interaction between the heat pump and the heat storages while the contribution of the solar field will be post-processed.

The solar-driven adsorption cooling system has Fahrenheit's Zeolite prototype chiller as the main innovative component. Combined together with a solar thermal field composed of flat plate collectors, the heat pump will produce cold water that will be stored into an 800L tank connected to the cooling circuit. As a result of the adsorption process, waste heat will be produced at medium temperature (35-40 °C), which will be used for preheating of domestic hot water or dissipated to the atmosphere by means of a dry cooler unit.

Preliminary tests have been performed for both sets and performance data of the components are being collected to evaluate the contribution and benefits of implementing both concepts.

1.3 Project Outcomes

The integrated solutions developed and tested in Heat4Cool project will provide:

- **Space heating, cooling and domestic hot water** in one case by integrating the Adsorption heat pump to the natural gas boilers, and in the other case by coupling the DC heat pump powered by photovoltaic panels and PCM storage.
- **Renewable energy solutions**
- **Smart control system** which the "brain" of the heating and cooling energy system and will constantly monitor the environment conditions and the performances in order to identify the optimal option in terms of comfort and energy efficiency.

Heat4cool project aims to achieve:

- a **reduction of 30% in energy consumption** in a technically, socially, and financially feasible manner,
- a demonstrate a **return on investment** lower than ten years,
- and provide **best practices examples** for the construction sector.

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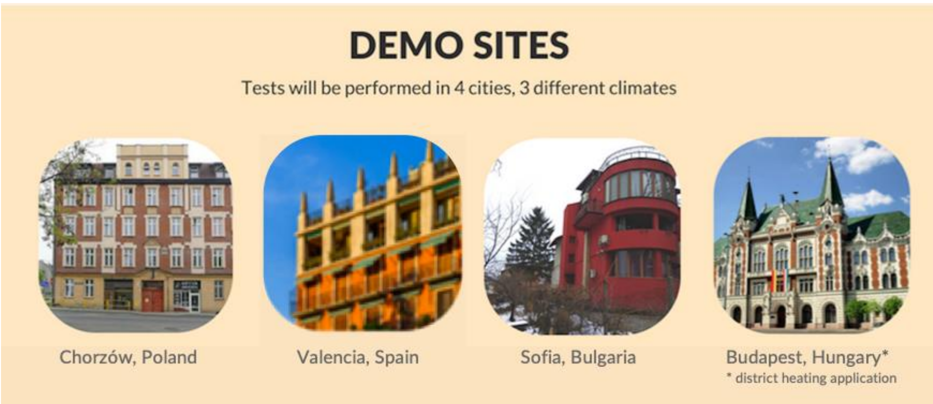
1.4 Demo sites introduction

The Heat4Cool technologies has been installed and tested in four demo sites located in three different climate areas in Europe.

1. **Chorzow, Poland**
    - The building is a multi-story house with three commercial premises and one residential apartment on the ground floor and 11 apartments on the other floors (12 residential apartments in total) with a total floors area of 998 m^2. Only 11 apartments have been retrofitted within the project.
2. **Valencia, Spain**
    - Apartment housing composed by composed by 12 flats, 610m^2 of total floor area.
3. **Sofia, Bulgaria**
    - Residential building, 3 apartments, total floor area of 564m^2.
4. **Budapest, Hungary**
    - District H&C system supply three different buildings: two public buildings (a recently retrofitted over 100-year-old and a ~2-decade-old building) and one newly constructed mixed-purpose building (commercial and cultural institution).



1.5 Consortium

The Heat4Cool project is composed by 13 partners from 7 associated European countries, more into details:

- 3 research organisations
- 9 SMEs
- 1 non- profit organisation

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2 TECHNOLOGIES INTRODUCTION

In this section all the technologies installed in the demo site in **Sofia (Bulgaria)** will be presented.

2.1 PCM STORAGE BATTERIES (SUNAMP)

2.1.1 Blueprint

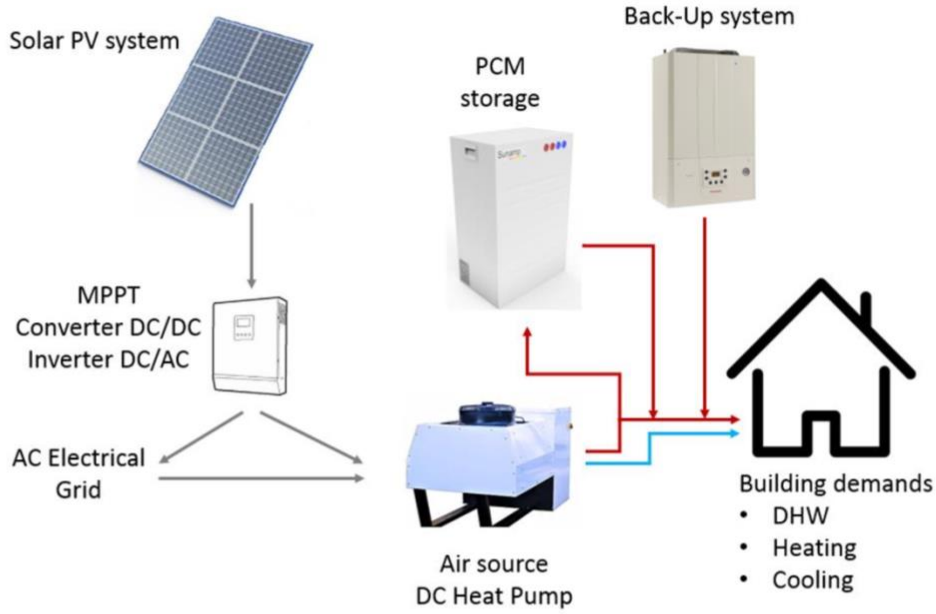

Figure 1 Scheme of the system Solar PV +DC Heat Pump + PCM storage

2.1.2 Component Description

The system provided by Sunamp is composed by:

1) A DC air-to-water heat pump: this heat pump is able to provide thermal energy by efficiently upgrading the ambient heat to hot water and space heating or downgrading the ambient heat to space cooling. This heat pump can be run directly from DC electricity generated by the solar panels as well as from the AC electricity from the grid. In this project, two heat pumps are used with thermal loads of 10kW and 30kW, respectively;

2) PCM storage units: they are compact, high-power thermal storage based on phase change materials (PCMs). They are recharged directly from the heat pump when required and provide

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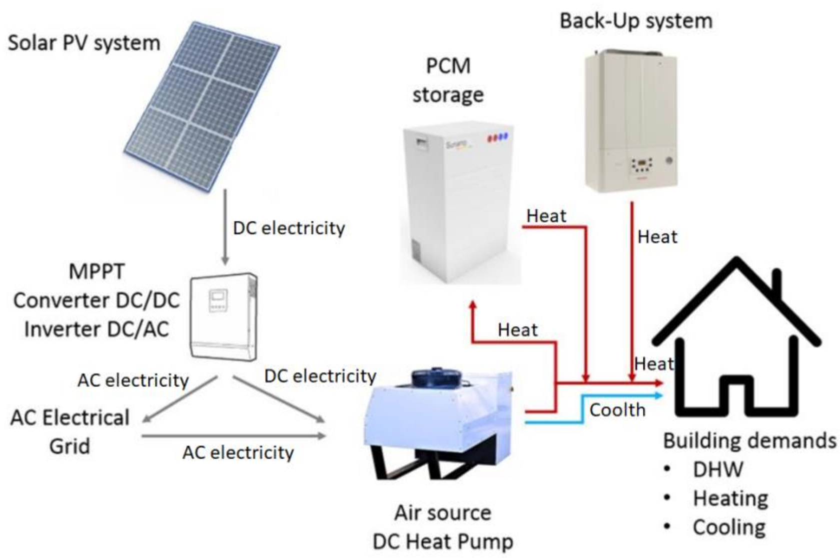
thermal energy to the building. The storage used in this project includes different PCMs with different operating temperatures.

2.1.3 How it works:

Following multiple input from the building and environment and following a decision process in the controller developed by the partners in the project, the heat pump will operate to (i) recharge the PCM storage; (ii) provide space heating / cooling to the building or (iii) both. The PCM storage is then used to provide high flow rates of hot water on-demand. When the storage is not able to provide the hot water directly, it is used as a pre-heater to the backup system in the building e.g. a gas boiler.
The capability to use DC or AC electricity and the usage maximise the flexibility of the system, allowing the building controller to optimize its operation for e.g. maximum amount of renewables or minimum cost or minimum CO2 emissions, while ensuring maximum comfort for the tenants.

2.1.4 Energy and material flow:



2.1.5 Performances:

Performances are highly variables depending on:
1) Operating conditions;
2) Sizing of the components in this subsystem;
3) Integration into the buildings.

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A full description of real-operating conditions performance can be provided with the results collected on trial sites in the next months.

2.2 SOLAR PV (AES SOLAR)

2.2.1 Blueprint

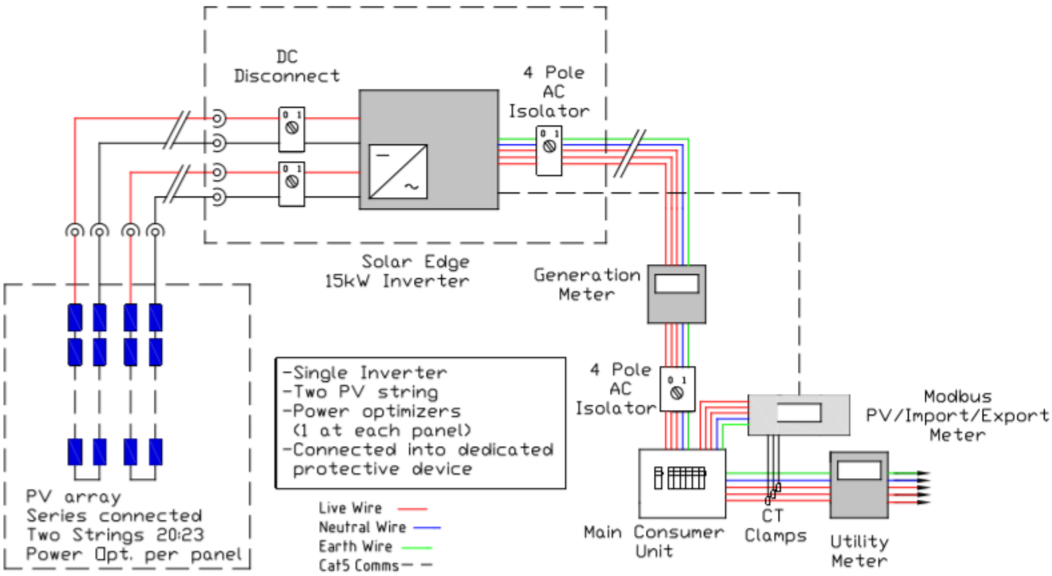

Figure 2 Schematic Heat4Cool solar PV AC connected system

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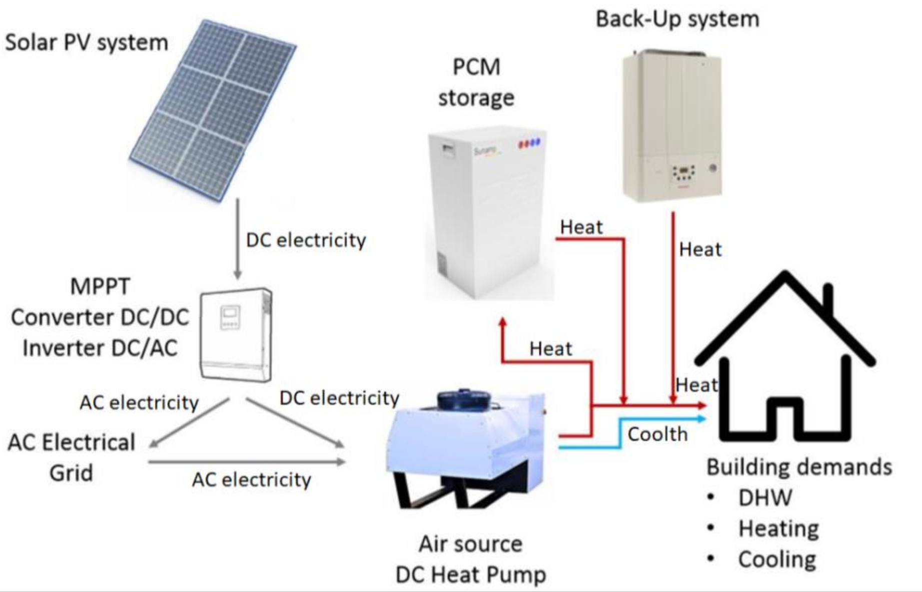

Figure 3 schematic for Heat4Cool solution

2.2.2 Component Description:

Solar PV generates DC (direct current) electricity from sunlight. Most loads in buildings use alternating current (AC). It is standard for Solar PV system on buildings to include an inverter to convert the DC electricity to usable AC electricity that can be used on site or exported to the grid. The inverter usually includes hardware and software to facilitate remote monitoring and other functionality.

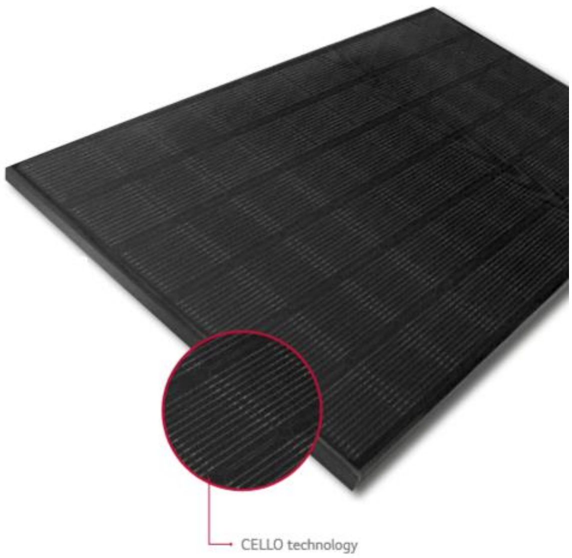

Figure 4 Solar PV Module (LG Chem)

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HEAT4COOL aims to maximize the amount of electricity used by an air source heat pump that is supplied by on-site solar PV. Most air source heat pumps have an inverter built-in which converts AC electricity from the grid to DC electricity to run the internal systems. The HEAT4COOL solution utilizes a heat pump which ca be driven partly by DC electricity when available but also receive an AC input.

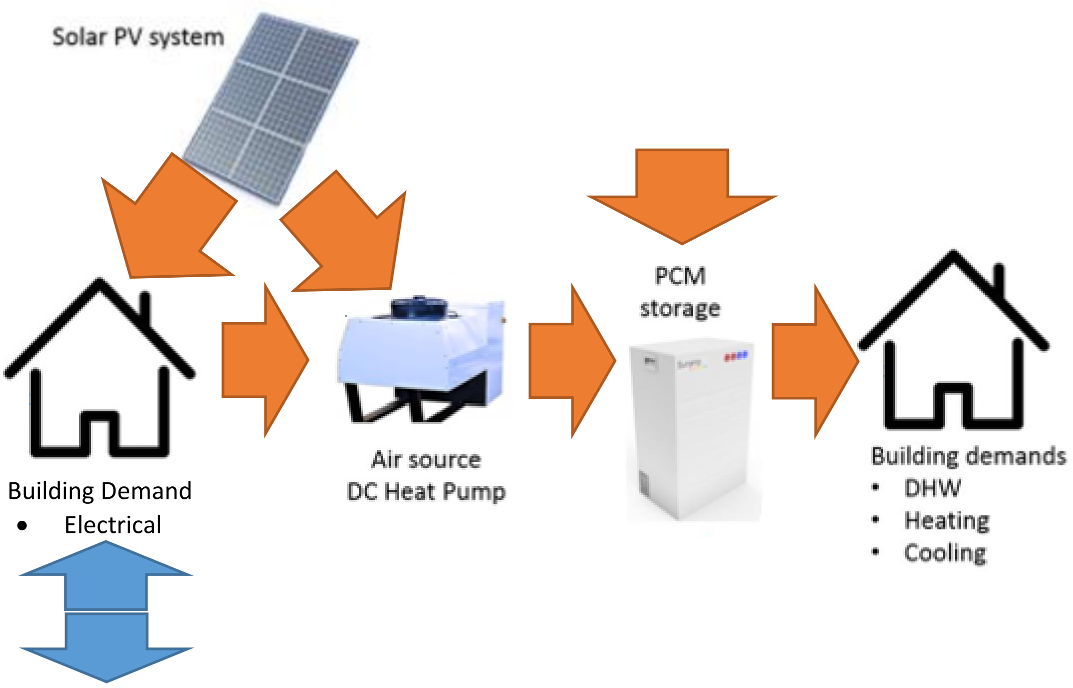
2.2.3 How It Works:

The Solar PV system is configured based on available space, possible orientation, inclination, geographic location and normal heat loads of the heat pump to maximize the solar electricity provided in relation to the heat pump load.

Whenever electricity is generated by the solar PV system it will flow first to any loads on site (including the heat pump when calling for power) and then will export to grid to benefit from an export tariff or other mechanism of reward.

The heat pump used by HEAT4COOL is equipped with both AC and DC inputs because the DC input would not be able to provide the required start-up power alone. The Solar PV system includes an inverter because otherwise there would be times when potential PV production would be curtailed if the heat pump requirement was lower.

2.2.4 Energy and Material Flow:



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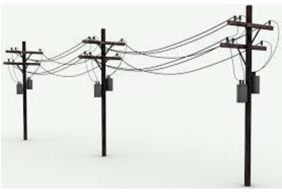

2.3 SCI-BEMS (HYPERTECH and WATT & VOLT)

2.3.1 Blueprint:

The SCI-BEMS system concentrates on the monitoring and control, from one side of the centralized heating/cooling energy generation system, and on the other side on the comfort-based energy efficient automation of the end-user demand.

The monitoring and principles of optimal use for the central system were defined and setup through rigorous testing and simulations by the technical partners, taking into account the different conditions and setups of the various pilot sites.

On the demand side, the system consists of a smart home installation that allows real-time recording and control of the emission system. The basic workflow for the optimization is shown in the figure below.

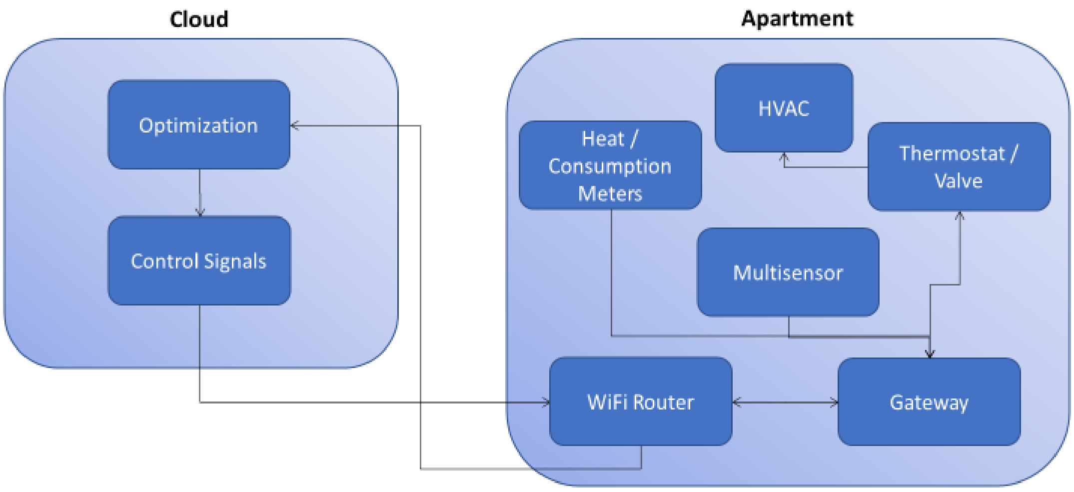

Figure 5 Graphical representation of the demand side SCI-BEMS system.

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2.3.2 Component Description:

The main objective when designing the system is to enable the detailed monitoring of the heating/cooling system in its entirety, as well as its constituent components, as well as the ability to apply certain control strategies in a remote and automated manner. To that extent, a plethora of metering and monitoring devices, along with communication servers are deployed in the pilot sites. Due to the specificities of each one, the solution was tailored according to each pilot site's needs. More details on this are reported in the installation section below.

When it comes to the in-apartment infrastructure, a common approach was adopted, based on a solution comprising a gateway device and various z-wave enables sensors and thermostats. The figure below depicts the main components of such an installation. What is now shown in the figure is the non-hardware part of the installation, which comprises of cloud-based services for the recording and processing of the data.

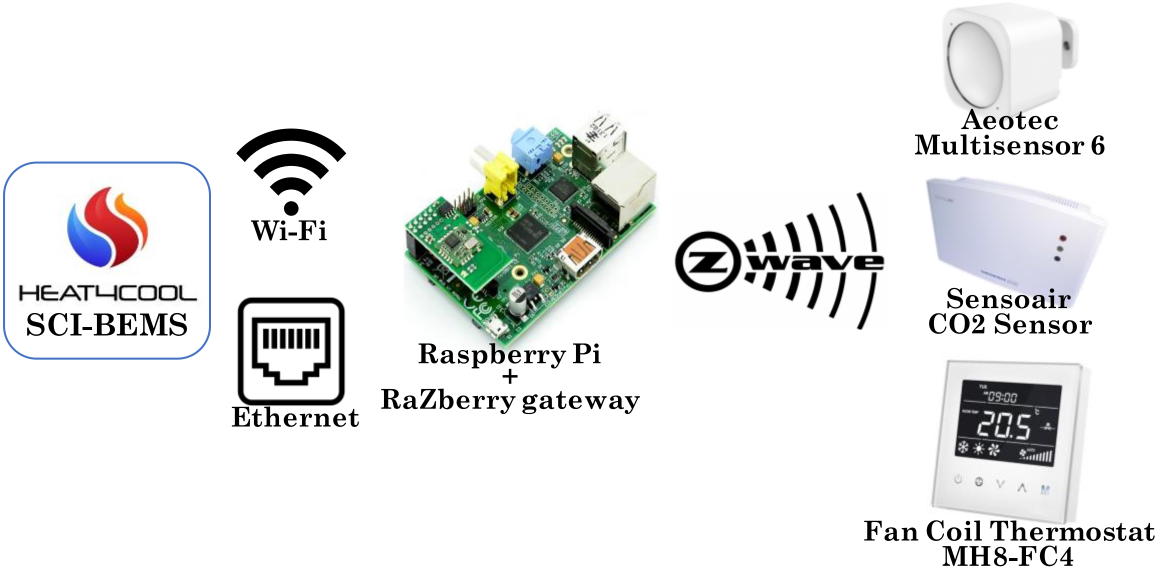

Figure 6 SCI-BEMS components.

2.3.3 How It Works:

The critical part of the SCI-BEMS automation algorithm focuses on the efficient management of the apartments' demand for heating and cooling. The approach consists of a number of steps, which can be seen in the following figure.

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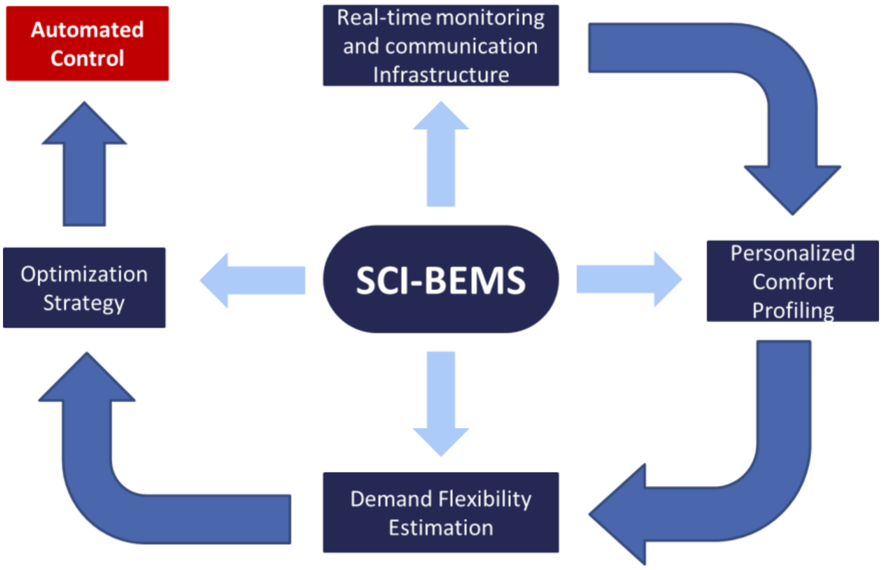

Figure 7 SCI-BEMS automation workflow.

In essence, through the real-time monitoring of environmental conditions and HVAC data, we are able to extract in an automated and consistent manner the comfort preferences of the occupants. These are used as constraints in a model predictive optimization of the system's emission setpoints. The optimal control signals are then applied to the fan coil or radiator units remotely.

3 TECHNOLOGY SOLUTION ON SITE

3.1 Sofia demo site Presentation:

The Bulgarian demo site is located in the Boyana Neighbourhood in Sofia. Sofia has a continental climate that with an average annual temperature of +10°C, the temperatures can range from temperatures as low as -11°C during winter times to +31°C during summer times.

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Figure 8 Sofia demo site façade

The demo site is a two floor multifamily apartment building that was completed in 1974. In 2004 a renovation was conducted, and a new part was added to the building. The building had been designed to have a total of 6 apartments on 4 levels, 2 in each floor, with a total surface of 560 m^2. Additionally, there is a basement and open terrace on the last floor.

The building has a refurbished envelope, and its facades are oriented towards South-East and South west. The building is equipped with a gas boiler for space heating as well as for domestic hot water.

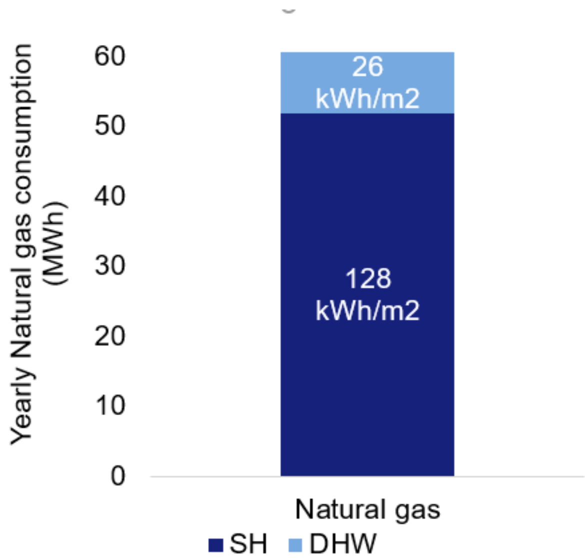

Figure 9 Schematic natural gas consumption/year

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The works performed in the building within the **Heat4Cool** project are:

- Modernization of the space heating system in 1 apartment;
- Added new piping infrastructure to accommodate the new equipment and the more complex heating/cooling system;
- Installation of the photovoltaic system on the roof of the building;
- Starting the implementation of the SCI-BEMS.

Implemented technologies are:

- 10 kW air to water heat pump;
- Heat batteries based on phase change materials for hot water preparation – 3 heat batteries, each of 12 kWh capacity, 36 kWh in total;
- PV system on the roof of the building – 42 LG 340N1K-V5 modules with total generation of 14.28 kWp.

3.2 Installation

The building is divided in three thermal zones.

Space heating system:

The main source of the heating power are two gas boilers for the whole building as well as two heat pumps. The heat is distributed through the apartments thanks to radiators with thermostats.

The hot water preheating system:

- heat batteries connected in four couples,
- heat pumps and domestic hot water circuits connected in *Tichelmann System.*

The charging of the heat batteries is controlled by Siemens PLC, that manages the circulation pump based on data from the temperature sensors in the heat batteries.

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Figure 10 PLC Managing system

Heat Pump Installation:

The 10kW heat pump installed is one unit device for indoor use that it's connected through the building with pre-insulated PEX pipes.

Figure 11 Heat Batteries

Solar Photovoltaic System:

The solar photovoltaic system is composed by:

- 42 LG modules have been installed on the roof, which have a total generation power of 14.28 kWp. Meanwhile 33 of the modules have been installed on the south-east façade, the other 9 are positioned on the flat roof areas;
- Two 3 x 6 kW SolarEdge inverters have been installed to convert direct current to alternative current to allow maximum generation from the system and enable all power to be used for

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either the heat pump and the rest of the building or to be exported, depending on the present. demand. These are to be connected to the Internet and the monitoring platform;

- 2-way electricity meter will be installed by the energy supplier;
- Lightning protection on the roof.

Figure 12 View of the demo's rooftop

Figure 13 Solar edge inverters

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Self-correcting energy management system (SCI-BEMS):

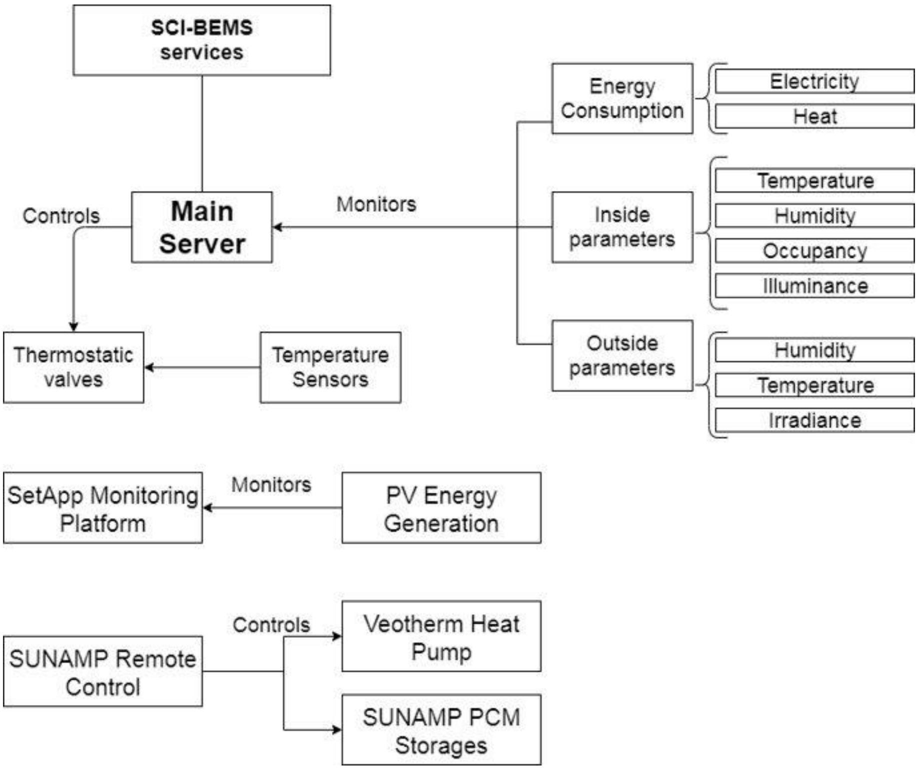

Figure 14 SCI-BEMS schematic

The SCI-BEMS has a main server through which can monitor:

- Energy consumption (including electricity and heat)
- Inside parameters such as temperature, humidity, occupancy, illuminance
- Outside parameters such as humidity, temperature and irradiance

The main server is in charge of controlling the thermostatic valves, which receive data from the respective temperature sensors.

This intelligent system also includes a SetApp Monitoring Platform which monitors the Photovoltaic Energy Generation as well as the SUNAMP remote control that controls the Heat Pump Unit and the PCM storage.

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Monitored data in apartments:

- **Indoor temperatures** in each thermal zone –
- **Humidity** and **movement** –
- **Heat** and **temperatures** provide d from the heat pump and from the gas boiler to the space heating system, and from the gas boiler to DHW system

Monitored data in the building:

- **Heat** and **temperatures** provided from the heat pump to central the heating system, to the heat batteries, and from the heat batteries to the DHW
- **Electricity consumption** by the heat pump and circulation pumps –
- **Electricity generation** from the PV system – SolarEdge inverter
- **Electricity export** and **import** – SolarEdge energy meter
- **Solar radiation** – external radiation sensor
- **External temperature** – the heat pump's temperature sensor
- system, and from the gas boiler to DHW system

3.3 Demonstration of the benefits in the real case and how the different technologies are integrated

The simulations of this retrofit project show that it is possible to achieve a 30% reduction of electricity consumption as well as reduce carbon emissions by 30%.
Planning a sell of some part of the electricity generated, it is possible to recuperate the investment on the project in about circa. 10 years.

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