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# Renewable Heating and Cooling Solutions for Buildings and Industry †

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**Abstract:** This workshop brought together a selection of H2020 EU-funded projects involving experts from the biomass, geothermal, solar thermal, and heat pump sectors to discuss a common strategy for increasing the use of renewable energy technologies for heating and cooling for buildings and industry.

**Keywords:** building; renewable; heating; cooling; industry; biomass; geothermal; heat pump; solar thermal

## 1. Introduction

Renewable energy technologies for heating and cooling are safe, clean, efficient, and increasingly cost-competitive. In its vision 2050 prospective document, the European Technology and Innovation Platform on Renewable Heating and Cooling—RHC ETIP—envisions that 100% renewable energy-based heating and cooling (100% RHC) in Europe is possible by 2050.

This workshop brought together fifteen H2020 EU-funded projects involving experts from the biomass, geothermal, solar thermal, and heat pump sectors to discuss a common strategy for increasing the use of renewable energy technologies for heating and cooling for buildings and industry.

These projects were clustered into four categories during the workshop according to their focus: (1) RHC for industrial applications; (2) storage solutions for RHC support in buildings; (3) innovative solutions for RHC deployment in buildings; (4) demonstration actions for RHC in buildings.

## 2. RHC for Industrial Applications

### *2.1. HyCool*

The HyCool [1] project proposes a major technological breakthrough to increase the current use of solar heat in industry processes (SHIP) by coupling a new Fresnel Concentrating Solar Power thermal collector (FCSP) with an innovative hybrid heat pump (HHP)—a "two-in-one" combination of adsorption- and compressor-based heat pumps. This project has very clear key objectives to showcase two demonstration plants—one for the food industry and one for the chemical industry, with the key equipment to improve industrial integration as a cost-effective TOTEX solution and trust in the HyCool technology. Component tests of the HHP shows increased Energy Efficiency Ratio (between +15% and +25%) compared to standard compression chillers. With the HyCool Pre-Feasibility Simulator tool, interested stakeholders can easily investigate the potential use of the HyCool Solar Cooling technology for their own projects in different industrial sectors (such as chemical and food industry).

### *2.2. SHIP2FAIR*

SHIP2FAIR [2] (Solar Heat for Industrial Process towards Food and Agro Industries commitment in Renewables) aims to foster the integration of solar heat in industrial processes of the agro–food industry. With this purpose, SHIP2FAIR will develop and demonstrate a set of tools and methods for the development of industrial solar heat projects during their whole lifecycle.

Demonstration and validation will take place at four real industrial sites representative of the agro–food sector: spirits distillation (Italy), fresh duck products manufacturing (France), sugar boiling (Portugal), and wine fermentation and stabilization (Spain). SHIP2FAIR is a project developed by 15 partners from all over Europe and with the support of the European Commission.

The main aspects in which the innovation takes places within SHIP2FAIR are: (1) design and development of the Replication Tool, (2) the solar technologies involved, (3) solar heat integration in the industrial processes, (4) control strategies and systems for operating the complete industry, and (5) the capacity-building program linked to the project.

### *2.3. FRIENDSHIP*

Solar heat can already be used in the low-temperature range (T < 150 °C) covering a number of processes in the agro–food industry. The FRIENDSHIP [3] project aims to demonstrate that solar heat can also be a reliable, user-friendly, high-quality, and cost-effective resource in the mid-temperature range (150 °C < T < 300 °C) to meet the heat needs of other industrial sectors such as textile, plastics, wood, metal, and chemistry. The two developed systems consisting of different aggregation of solar fields, a very high-temperature heat pump, combined heat storage and chillers will together be able to supply heat at temperatures up to 300 °C and negative cold at temperatures down to −40 °C with the objective of reducing CO2 and air pollutant emissions by 30%.

## 3. Storage Solutions for RHC Support in Buildings

### *3.1. HYBUILD*

HYBUILD [4] develops two innovative hybrid storage concepts: (1) for the Mediterranean climate, primarily meant for cooling energy provision; (2) for the Continental climate, primarily meant for heating and Domestic Hot Water production.

The hybrid storage concepts are based on innovative components such as a compact sorption module, high-density latent storage, reversible vapor compression heat pumps, and DC bus interconnection. The whole systems will be properly managed by advanced controls and building energy management systems (BEMS). The developed solutions will be validated in three different demo-sites located in Austria, Spain, and Cyprus.

### *3.2. SWS-Heating*

The SWS-Heating [5] project aims at developing an innovative seasonal thermal energy storage (STES) unit with a novel storage material and a creative configuration, i.e., a low-temperature charging sorbent material embedded in a compact multimodular sorption unit. This will allow storing and shifting a part of the harvested solar energy available in summer to the less sunny and colder winter period thus covering a large fraction of heating and domestic hot water demand in new and existing buildings. This next-generation high-performing solar heating technology will guarantee a solar fraction of at least 60% in Central/Northern Europe, reaching 80% in the sunnier Southern Europe, boosting low-cost solar-active houses development throughout the EU.

### *3.3. CREATE*

The CREATE [6] system is an advanced thermal storage system based on thermochemical materials (TCMs) that enable economically affordable, compact, and loss-free storage of heat in existing buildings. The system consists of several storage modules containing salt which is hydrated (charged) in summer and dehydrated (discharged) in winter. To demonstrate applicability of the thermochemical storage solution and its operation in real-life conditions, a full-scale solar thermochemical storage system delivered by the CREATE project was installed at a single-family house in Warsaw, Poland, where the local climate delivers both cold winters and warm summers. The CREATE project ran from 2015 until 2020 and was coordinated by AEE (Institut für Nachhaltige Technologien) from Austria.

### *3.4. SCORES*

The main aim of the SCORES [7] project is to develop and demonstrate a building energy system—including new compact hybrid storage technologies—that optimizes supply, storage, and demand of electricity and heat in residential buildings. The system will increase self-consumption of local renewable energy at the lowest cost and defer investments in the energy grid. The combination and optimization of multigeneration, storage, and consumption of local renewable energy (electricity and heat) brings new sources of flexibility to the grid. The impact of the SCORES system will be a broad assessment covering stakeholders at various economic levels, e.g., individual homeowners, housing companies, grid owners, and energy companies. Within the impact assessment, evaluation of the integrated hybrid energy system is performed on two demonstrations—real buildings representing different climate and energy system configurations for three cases—in Central Europe (Austria) with and without the heat grid and in the Middle/Southern Europe (France) without the heat grid. The SCORES project started in November 2017 and will end in November 2021.

## 4. Innovative Solutions for RHC Deployment in Buildings

### 4.1. Innova-MicroSolar

Innova-MicroSolar [8] develops a small solar thermal power plant with funding from the EU Horizon 2020 program. The plant is configured around a 2 kWel Organic Rankine Cycle (ORC) turbine and a solar field made of Fresnel mirrors. The solar field is used to heat thermal oil to the temperature of about 240 °C to expand the ORC turbine and/or charge the thermal storage. This thermal energy is used to run the ORC turbine and the heat rejected in its condenser (about 18 kWth) is utilized for hot water production and living space heating. The plant is equipped with a latent heat thermal storage to extend operation of the ORC unit by about 4 h during the evening occupancy period. The phase change material used is the solar salt with enhanced thermal conductivity and the melting/solidification point at about 220 °C. The total mass of the Phase-Change-Material is about 3800 kg and the thermal storage capacity is about 100 kWh. The Thermal Energy Storage system is charged and discharged by using heat pipes. The operation of the plant is monitored by a central controller unit. The main components of the plant were manufactured and laboratory-tested. The plant was assembled at the demonstration site located in Catalonia, Spain. At the first stage of investigations, the ORC turbine was directly integrated with the solar field to evaluate their joint performance. During the second stage of tests, the latent heat thermal storage will be incorporated into the plant and its performance during the charging and discharging processes will be investigated. It is planned that continuous field tests of the whole plant and the final rationalization of its design will be performed during the spring–summer period in 2021.

### 4.2. SolBio-Rev

The SolBio-Rev [9] project will develop a flexible energy system suitable for building integration based on renewables for covering a large share of energy demand (heating/cooling/electricity). Its flexibility is derived from the long-term collaboration of key industrial partners with research organizations, having in mind the large variety of EU buildings, especially non-residential ones (types, uses, and sizes). The overall objective is to develop a configuration based on renewables that allows covering all heating and cooling demands and a variable electricity demand (from zero up to even 100%) in a cost-effective manner. The SolBio-Rev concept is based on solar thermal collectors with vacuum tubes combined with thermoelectrics, a cascade thermal chiller with electrically driven heat pump for very high performance under the cooling operation even at extremely hot conditions, a reversible heat pump/ORC for enhancing flexibility and switching operating modes between summer and winter exploiting all available solar heat, and an advanced biomass boiler coupled with the above ORC for Combined Heat and Power operation. A smart control is finally envisaged to manage and optimize system operation with user-friendly features.

### 4.3. TRI-HP

Within TRI-HP [10], flexible energy-efficient and affordable tri-generation systems are developed and tested in a laboratory using the hardware-in-the-loop approach. The systems are based on electrically driven natural refrigerant heat pumps coupled with PV to provide heating, cooling, and electricity to new and refurbished multi-family residential buildings with an on-site renewable share of 80%. The flexibility is achieved by allowing the use of three heat renewable sources: solar (with ice/water as the storage medium), ground, and ambient air. TRI-HP systems include advanced controls managing electricity, heat, and cold in a way that optimizes performance of the system and increases its reliability via failure self-detection. Moreover, TRI-HP will provide the most appropriate knowledge and technical solutions in order to cope with stakeholder's needs, building demand characteristics, local regulations, and social barriers. The innovations proposed will reduce the system cost by at least 10–15% compared to the current heat pump technologies with equivalent energy performance reducing Greenhouse Gases emissions by 75% compared to gas boilers and air chillers.

### 4.4. RES4BUILD

RES4BUILD [11] develops integrated renewable energy-based solutions (IES) for heating and cooling. The consortium is working to improve photovoltaic thermal collectors, magnetocaloric and multi-source heat pumps and optimize their integrated performance through advanced control systems. A good practice assessment report found that a robust IES should, (a) be an integrated turnkey technology package with guaranteed energy performance, (b) provide innovative financial solutions (e.g., building-linked, rent, lease, subscription fees), and (c) ensure early involvement of building end users to improve acceptance and faster implementation of the IES by establishing collaborations with end user groups like homeowner associations and energy cooperatives.

## 5. Demonstration Actions for RHC in Buildings

### 5.1. GEOFIT

GEOFIT [12] is an integrated industrially-driven action aimed at deployment of cost-effective enhanced geothermal systems (EGS) in energy-efficient building retrofitting. This entails technical development of innovative EGS and their components, namely, non-standard heat exchanger configurations, a novel hybrid heat pump and electrically-driven compression heat pump systems, and a suite of heating and cooling components to be integrated with the novel ground-source heat pump concepts. To make viable the novel EGS in energy-efficient building retrofitting, a suite of tools and technologies is developed. By using the five demonstration sites as open-case studies in four countries and climates, GEOFIT will leverage its key exploitable results.

### 5.2. Heat4Cool

The Heat4Cool [13] project develops, integrates, and demonstrates energy-efficient solutions for the retrofitting of heating/cooling and domestic hot water systems, including at the district level. The building retrofitting begins with a decision-making tool and leads to an optimal solution combining solar thermally-driven adsorption heat pumps (HP), solar PV-assisted HP connected to a compact and modular thermal energy storage using a phase change material, a self-correcting intelligent building energy management system, and energy recovery from sewage water.

In this framework, four pilots have been realized in four European countries. Now, the pilots are under continuous monitoring, evaluation, and optimization. Modeling and simulation have been key in identifying the best configuration and control strategy in each pilot.

### 5.3. Hybrid-BioVGE

The Hybrid-BioVGE [14] project has the primary objective of developing and demonstrating an integrated solar/biomass hybrid air conditioning system for space cooling and heating of residential and commercial buildings that is affordable, operating with improved efficiency and reduced need for maintenance. The Hybrid-BioVGE project contributes to overcoming the existing technological barriers of solar/biomass small-scale space heating and cooling systems, such as high system complexity, lack of demonstration plants, and lack of experience to improve their performance. The project focuses on the development of three highly integrated prototypes adequate for residential and small commercial buildings under different European climatic conditions.

### 5.4. SunHorizon

SunHorizon [15] aims to demonstrate innovative solutions for providing heating and cooling thanks to heat pump technologies coupled with advanced solar panels and thermal energy storage. Five different integrated solutions will be demonstrated in eight residential and tertiary buildings to evaluate different climate and market conditions and facilitate future replication. The reduction of energy bills (up to 60%) and emissions (up to 80%) will be achieved thanks to an improved design of the enabling technologies as well as with integrated monitoring and control systems aiming at a comfort-driven optimized solution. SunHorizon will bring competitive products for attracting new investments in the H&C industry and building/ESCO (Energy Service Companies) industry.

## 6. Key Findings and Conclusions

Development and validation of RHC solutions are of primary importance to further support the increase of the renewable energy share across the EU. The relevance of this topic is demonstrated by the different fields of application in which innovative RHC technologies are proposed and currently investigated. Concerning applications of solar thermal technologies in the industrial sector, they can directly support both provision of heating for industrial processes as well as for cooling and refrigeration (through solar cooling technologies). To achieve wide deployment, not only their efficiency, but also their reliability must be demonstrated, since one of the main barriers is represented by the reluctance of industrial companies towards innovative technologies, which may create issues in production processes. Still, the main area of low Technology Readiness Level (TRL) investigation is represented by the application of RHC in buildings. A lot of efforts are put on innovative solutions for thermal energy storage to enhance their energy storage density and reduce heat losses, thus supporting the RHC penetration at the building scale. What looks extremely important is to enhance the collaboration among EU partners to profit from the obtained experience and to investigate the social barriers towards the adoption of these solutions. Regarding RHC generation in buildings, innovative approaches are proposed exploiting biomass, solar, and heat pumps. Digitalization of these technologies may become critical to speed up their future market uptake. The final step is represented by the validation of innovative RHC solutions in buildings. This represents a major issue to make these technologies attractive, demonstrating their positive impact on the environment as well as their economic feasibility. This must come hand-in-hand with proper financing instruments as well as dedicated design tools.

**Supplementary Materials:** The recording of the workshop is available online at: https://www.sustainableplaces.eu/home/sp20-workshops-events/sp20-renewable-hc-solutions-for-buildings-and-industry-workshop/.

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