L'Europe en Méditerranée
Europe in the Mediterranean

Projet cofinancé par le Fonds Européen de Développement Régional (FEDER)
Project cofinanced by the European Regional Development Fund (ERDF)

Identified technologies for the InfraSUN pilot plant

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Executive summary

Jožef Stefan Institute (JSI) is one of 6 partners in the EMILIE project, which is aiming to raise awareness on latest energy efficient (EE) technologies related to buildings and thus support the growth potential and capacity for innovation of small and medium enterprises (SMEs). One of the core actions and aims of the project is to build-up pilot plants (one per each project partner) and to demonstrate selected technologies. IJS pilot plant, named InfraSUN, is focusing on demonstration and testing of emerging or advanced solar thermal technologies which are being new to the Slovenian market of solar cooling and heating, particularly innovative (heat pipe) vacuum tube collectors and adsorption chiller. The pilot action, which will be built at JSI campus in Ljubljana, will offer practical demonstration of the concept on smaller areas (business or trade zones, settlements) in the region. Multiple benefits are expected and described in a document.

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"Jožef Stefan" Institute
Ljubljana, Slovenia

1. Introduction

This report is the Slovenian (IJS) fold of Deliverable D4.1.1., which aims at detailing the technologies that will be implemented within the pilot actions of the EMILIE project. Overall, 6 pilot plants will be installed: one per participating region. The 6 pilot plants are:

- SunLab in Italy, Venezia region, under the lead of AREA
- HVACLab in Spain, Andalusia region, under the lead of IAT
- SmartEE in France, PACA (Provence-Alpes-Côte d'Azur) region, under the lead of Capenergies
- InfraSun in Slovenia, Ljubljana region, under the lead of IJS
- Glassolating in Spain, Aragon region, under the lead of CIRCE
- SunCool in Croatia, Kvarner region, under the lead of REA

The aim of the IJS pilot plant it to build-up and demonstrate the model of solar thermal installations in terms of public infrastructure which could be defined as 'the basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise', see *http://www.oxforddictionaries.com/definition/english/infrastructure*. In the presented case, solar thermal will 'replace' regional infrastructural pipelines for fossil fuel (gas or other fossil fuels). The recognition of solar thermal installations as an important public infrastructure will enhance the use of solar energy and dissemination of solar heating (and cooling – SHC) facilities, particularly in Mediterranean regions. This will help to meet the objectives of EU regarding renewable energy production and achieving significant energy savings throughout the region. The use of huge solar potential for the development of renewable energy of the Mediterranean is addressed also by other initiatives, e.g. the Mediterranean Solar Plan (MSP) which is supported by the EU Commission.

This document provides information on:

- the demonstration site, chosen for the InfraSUN pilot action,
- presentation of the main pilot action technologies and
- what are the energy saving challenges of the pilot plant, as well as expected benefits.

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2. Presentation of the demonstration site

An IJS pilot project, named InfraSUN, will be based on the implementation of solar heating and cooling using adsorption chiller as a refrigeration unit and vacuum tube solar thermal collectors (panels) with the innovative heat pipe technology as a heat source. These technologies will be integrated into existing installations.

The pilot plant will be installed in the building C, which is located on the northern part of Jožef Stefan Institute campus in Ljubljana. The facility related to the plant is used for administrative, research and laboratory activities and is placed in the top floor of the building, covering 438 m2 of inner surface. Rooms are occupied year round on weekdays from 8 am to 18 pm. Constant high-rate (2.000 m3/h) ventilation is required due to laboratory activities and safety reasons. Central ventilation system operates 24/7. Space heating is provided by natural gas powered boiler via panel radiators and via existing ventilation system in case of laboratories' area. Existing air handling unit has no heat recovery, consequently ventilation heat losses are quite high. The cooling system (split) is installed solely in a room where sensitive measuring equipment is located (18 m^2), laboratories are not cooled yet.

Figure 1: Location and building where InfraSUN pilot plant will be installed

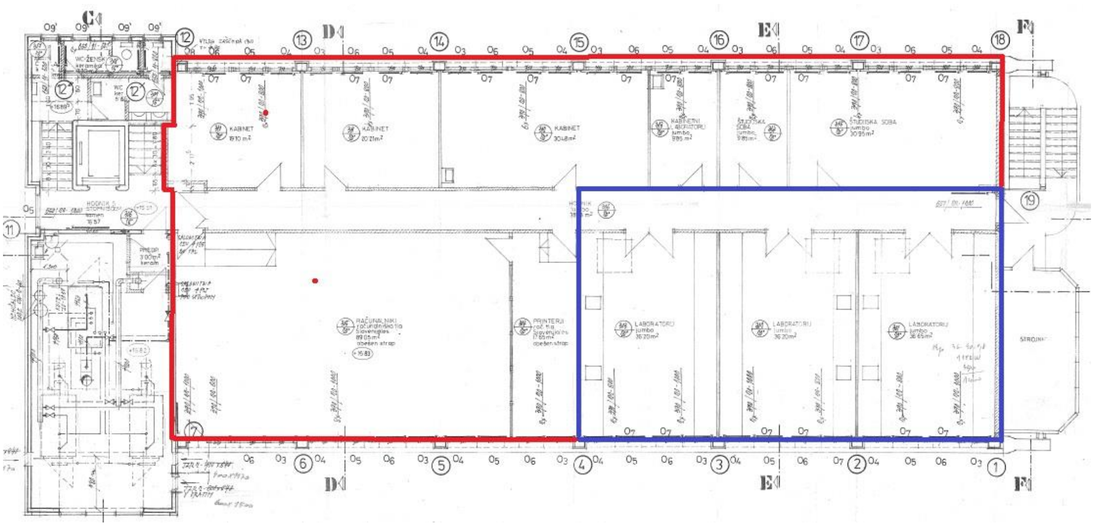

Figure 2: Area related to the pilot plant (blue: laboratories / high flow rate ventilation)

Energy accounting is based on monthly evidence of energy consumption and is implemented on the level of the institute. At present there is no system of energy use targeting, the energy management is in the implementation process. Measurements on HVAC systems (T, Rh, Q) in the area related to the pilot has been implemented.

The location has annually approximately 3300 average heating/cooling degree days. An average annual air temperature is about 10^{o}C.

Technical state of the building (area related to the pilot plant):

- Outer wall: 395.72 m2, thermal insulation: concrete 35 cm, 10 cm kombifas façade, U=0.52 W/m2
- Floor: 438 m2, thermal insulation: concrete 48 cm, polyfoam 1 cm, flooring 2 cm, U=0.7 W/m2
- Roof: 613 m2, thermal insulation: concrete 10 cm, polyfoam 11 cm, U=0.32 W/m2
- Windows: 58.18 m2; Aluminium frame with thermopane glass surface, U = 2.0 W/m2K;
- Windows with a dome for flat roofs: 10 m2, U = 1.3 – 1.8 W/m2K

Break down of annual energy consumption (estimated for the area related to the pilot plant):

- Heating: 178 MWh/a
- Cooling (VAC): 9 MWh/a
- Hot water: 8 MWh/a
- Lighting: 19 MWh/a

Currently the following measurements of the conditions take place: inlet air flow, ambient temperature and humidity on 3 different representative locations within the air-conditioned area and outside temperature and humidity.

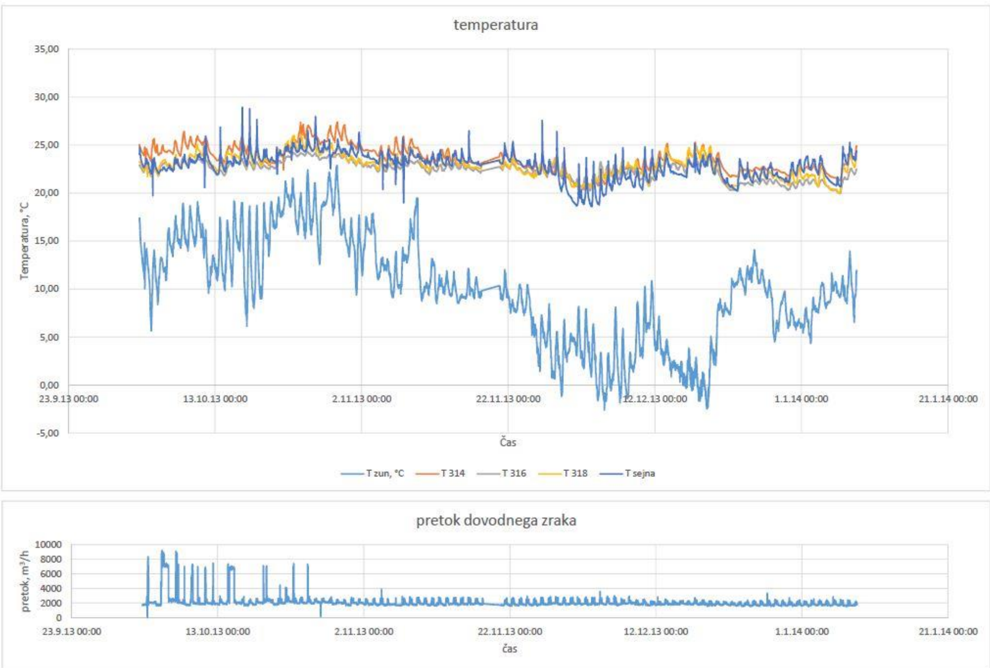

Figure 3: Environmental conditions – temperature and inlet air flow

3. Description of the pilot plant

Solar heating and cooling (SHC) technologies collect the thermal energy from the sun and use this heat to provide space heating and cooling, hot water and pool heating for residential, commercial and industrial applications. These technologies displace the need to use natural gas or electricity. Solar heating and cooling systems could also significantly reduce the dependence on imported, mainly fossil fuels. Solar heating and cooling technologies could play an important role particularly as they are compatible with majority of conventional heat sources and offer high efficiency when combined into district heating systems. They have large potential to reduce exposure and sensitivity to energy price fluctuations, as most costs occur at the initial investment stage and operating costs are minimal. Standard systems for easy installation and operation are under development, thus reducing cost for chiller and other components.

Solar cooling is a highly promising renewable solution for the world's strongly and large growing air conditioning needs. It benefits from the correlation between energy supply and cooling demand - when the solar resource is at its strongest the demand for cooling is highest. Great opportunities for new application of thermal cooling chillers offer a variety of possible heat sources, besides solar heat also waste heat, district heat or especially the combination of cogeneration units. One of the main barriers for market development has been the lack of compact, high performing and cost effective chillers. Additionally, planning and installation costs are still high compared to standard solar thermal systems, mainly due to lack of standardized systems. The small scale adsorption chillers, where easy install systems packages contain a power scalable cascading solution, offer opportunities for a market breakthrough of solar cooling.

System design

The following main subsystems and components will be installed:
- vacuum tube solar thermal collectors (heat source),
- adsorption chiller (refrigeration/cooling),
- flat panel heat exchanger (heat recovery),
- piping and hydraulic components,
- regulation and control system.

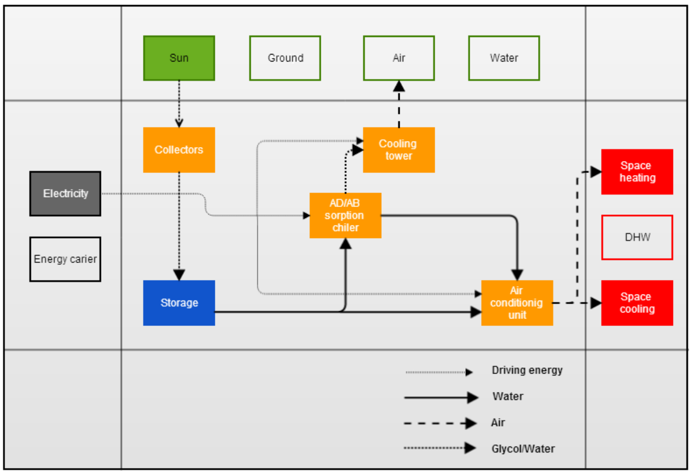

Figure 4: The square view shows all main energy related components and fluxes in the system

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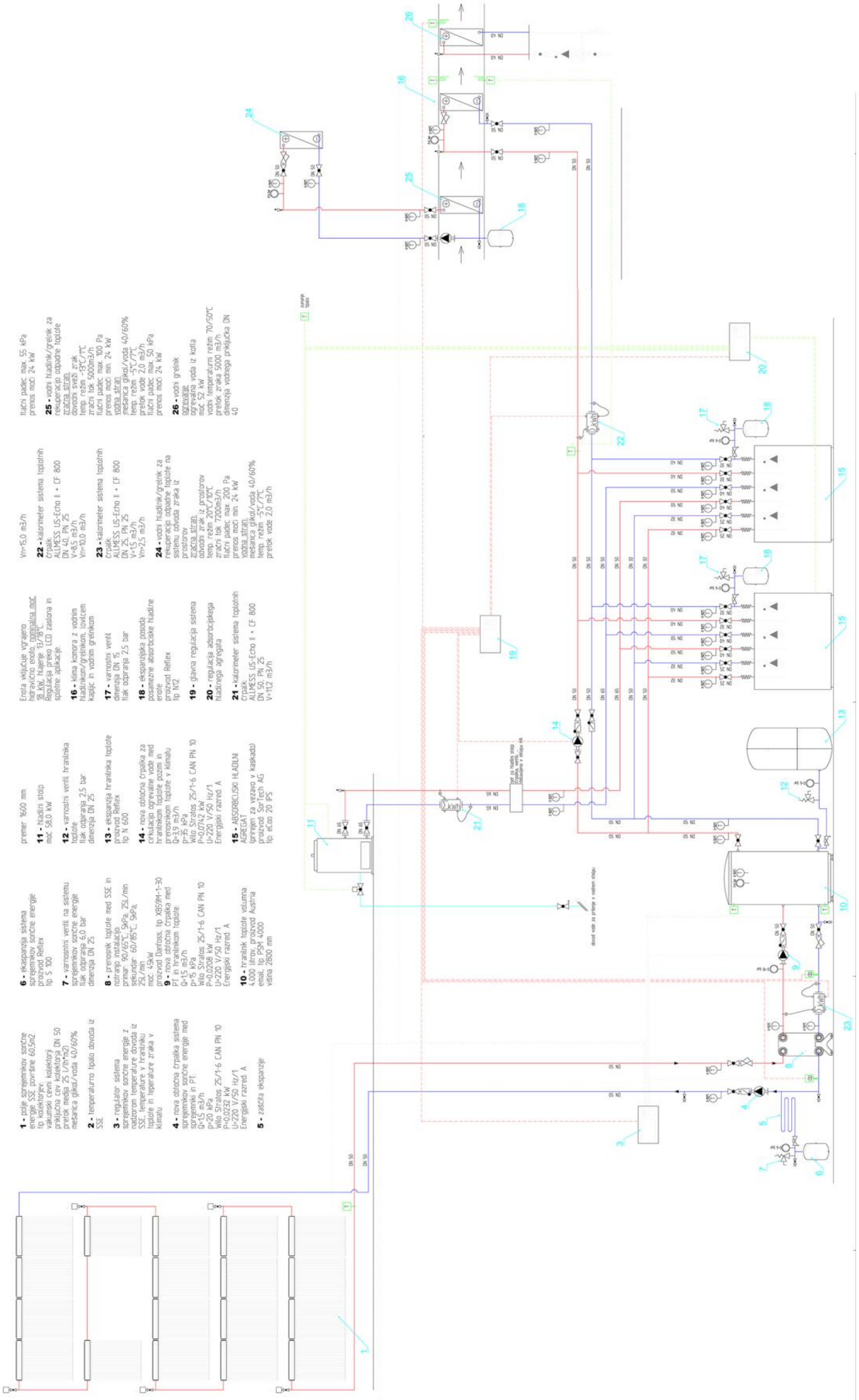

Figure 5: System design – hydraulic scheme

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Solar thermal collectors

The selected technology is developed primarily as solar heat supply for industrial applications (60°C - 130°C) in large scale systems (0,5 to 50 MW thermal) and district heating, as well as district cooling and desalination, all at a competitive price compared to fossil fuels. The main competitive advantages of the selected collector's technology are:

- low operational cost (low pressure drop which requires smaller pumps),
- not complicated and low cost maintenance (no moving parts, no leak),
- robustness (simplicity of operations, originally designed for wide power ranges),
- technology of installation is adapted to all markets (local skills and local jobs can be applied),
- temperature range (60°C - 130°C) useful for numerous purposes.

Two operating modes have been considered:

1. Summer mode: provision of heat for the needs of an absorption refrigeration unit
2. Winter mode: preheating of air in an air-conditioning unit (space heating) and water heating in the storage tank for heating support.

The hydraulic part is based on a DN50 steel pipe collector to which condensers (heat pipes) are attached by means of a rolled dry connection joint. Such construction of the collector field allows serial binding of a large number of collectors (without having excessive pressure drop and problem with hydraulic balancing), thereby achieving high temperatures. Panels are to be mounted on a support construction at an angle of 35°. Heated water will be stored in a storage water tank of a 4 m^3 volume.

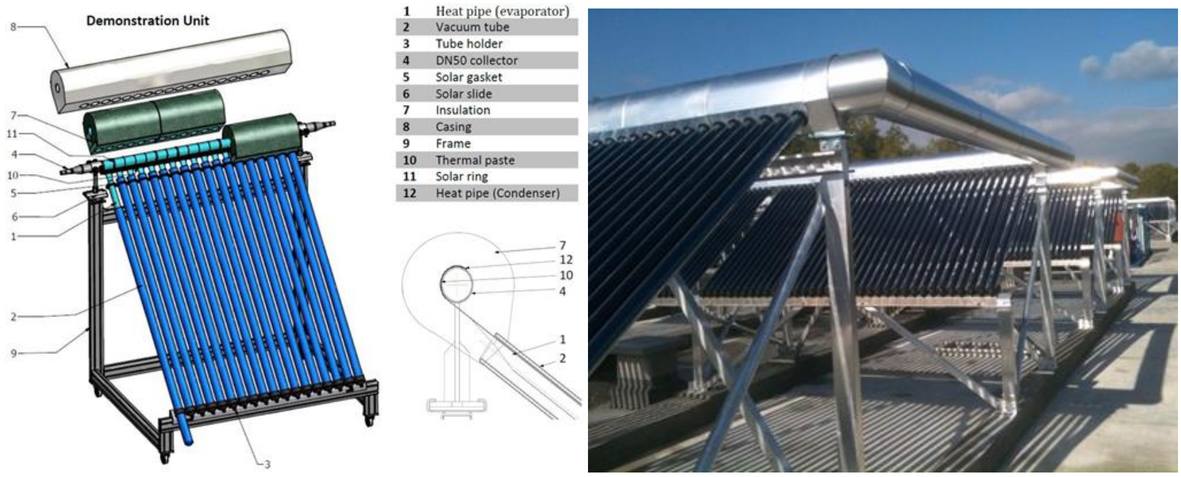

Figure 6: Solar thermal collectors – installation setup

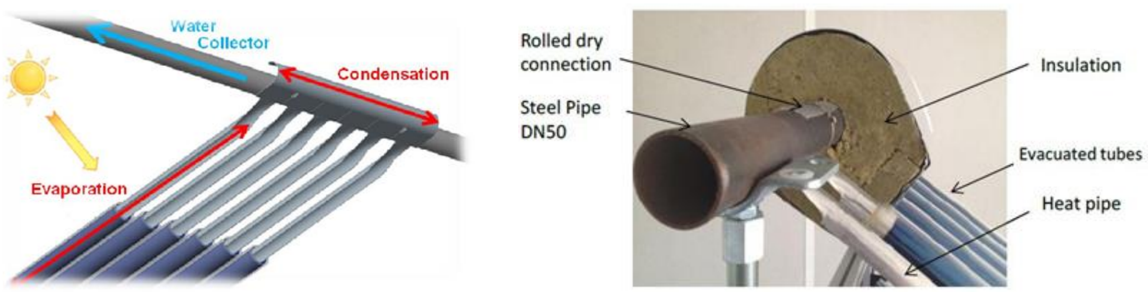

Figure 7: Principle of operation and clamping detail

A simulation of cooling needs has lead up to the solar field of 648 tubes, equivalent to an aperture area of 60 m² and the thermal power of about 41 kWth. The simulation of the plant has shown a maximum daily production of 343 kWh (calculated on a nominal adsorption chiller temperature range of 85°C). The solar thermal system will be installed on the flat roof directly above the cooled premises.

Simulated installation			
Strategy			
Configuration	**Buffer tank**		
Solar collector's field		**Buffer tank**	
Inclination	**35 °**	Volume	**4 m3**
Orientation	**164 °**	Energy	**46 kWh**
Number of tubes	**648**		
Aperture area	**60 m²**	**Pressure drop**	
Collector area (bulk)	**93 m²**	Collector field	**0.2 m H2O**
Occupied area	**201 m²**	Exchanger	**3.00 m H2O**
Min flowrate	**0.3 kg/s**		
Max. flowrate	**1.00 kg/s**		
Heat exchanger			
Nomimal conditions			
Mass flowrate	**1.00 kg/s**		
Inlet (from solar) temperature	**90 °C**		
Delta T°	**10 °C**		
Therm. power	**41 kW**		

	Horizontal irradiation (kWh/m²)	Tilted irradiation (kWh/m²)	Gross thermal production (kWh)
January	40	76	2 126
February	56	93	2 805
March	90	127	3 912
April	132	165	5 442
May	160	179	5 878
June	180	193	6 512
July	190	209	7 182
August	167	200	6 986
September	117	157	5 269
October	78	121	3 831
November	47	84	2 489
December	30	58	1 543
TOTAL	**1 287**	**1 662**	**53 975**

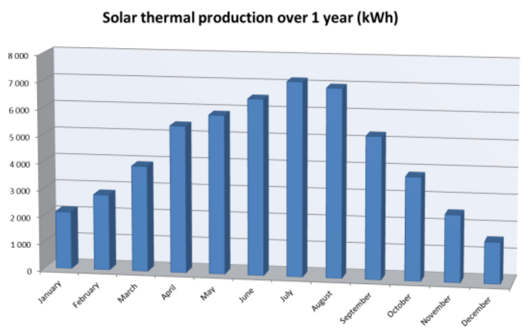

Figure 8: The simulated annual solar thermal production (Solar data source: SAED, Soda-is.com)

Adsorption chiller and recooling unit

The cooling system is composed of the adsorption refrigeration unit, which is installed in an existing engine room and an external hybrid type re-cooler, which serves for the discharge of (waste) process heat and is installed on the roof of the building. The energy source used for the operation of the refrigeration unit is powered by solar heat, harvested through the field of vacuum solar collectors that are installed on the roof. The entire system is controlled by a main control unit, which ensures appropriate inter-operability between solar, ventilation and cooling systems. This control unit will regulate operation of the unit at partial load, operation of circulation pumps, fan speed and water spraying of the recooler, and temperature of the cooled air.

The consumption of electricity as an auxiliary energy source (e.g. for the operation of pumps and regulation) is very low (EER > 10 – approx. 1 kW electricity for 10 kW thermal). Compared to conventional cooling systems up to 70% reduction of electricity consumption is expected.

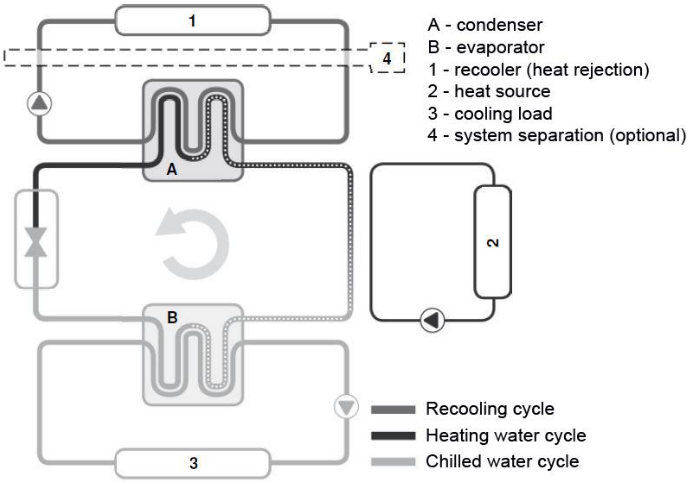

Figure 9: Functional scheme of an adsorption refrigeration unit (Source: Sortech)

In principle there are three circuits in the chiller:

- Hot water circuit (drive cycle) - the thermal energy is supplied to operate the chiller (adsorption);
- Recooling circuit - the heat supplied (from the object to be cooled, heat for drying of the working medium) is removed by being discharged to the environment on the mean temperature level;
- Chilled water circuit – the heat is extracted from the object to be cooled.

The selected refrigeration unit can be used to cool or heat single- and multi-family dwellings, offices and commercial properties, technical facilities as well as technical processes with chilled water in a temperature range between 6° C and 20°C. Input (driving) temperatures are low and variable (55° C to 95°C), which is ideal for use in combination with selected heat source (solar panel field) as well as CHPs, local and district heating and industrial waste heat. The device is almost free of noise and vibrations, it requires minimal installation area. The dry recooling is possible under extreme ambient temperatures for the selected region of up to 40°C.

To achieve higher cooling capacities it is possible to connect several chillers in parallel, or a redundancy supply for critical applications. An adsorption chiller (or set of two) with nominal capacity of 18 - 20 kWth is estimated to be sufficient to lower the inside air temperature for approx. 7°C in summer peaks.

Hybrid cooling tower will be installed on the roof for heat rejection from the chiller recooling circuit. The chiller and the heat storage tanks are foreseen to be installed in existing technical premises.

Upgrade of the existing HVAC installations

On the existing ventilation system the following modifications will be performed:

- Installation of a heat recovery unit;
- Installation of heat exchanger into an inlet air channel (in the winter it will serve as the air preheater);
- Relocation of the air heater from the existing air conditioning into the channel;
- Insulation of existing ventilation channels;
- Integration into the common control system.

4. Expected impacts

4.1. Energy savings

The cooling system will be added, hence electricity consumption will rise. Compared the installed technology to conventional cooling systems, up to 70% lower electricity consumption is expected for the same cooling power. Most energy savings, amounting to about 35% (for heating), are expected due to installation of heat recovery system and upgrade of a roof thermal insulation.

4.2. Other environmental benefits

The improvement on HVAC equipment, including heat recovery unit, shall result in reduction of use of fossil fuels (natural gas), consequently CO_2 emissions will be reduced.

4.3. Social impact

Awareness level of solar cooling technology, other EE technologies and renewable energy use will be enhanced by promotional activities and visits to the pilot plant.
The living comfort in premises will be obviously improved - temperature and humidity in laboratories and offices will be controlled and adjustable.

4.4. Financial advantages

The cost of the installation (investment) is currently rather high, but operational costs and particularly expected maintenance costs (almost no maintenance needed) are considerably lower. Thus the system will be much less sensitive to the energy price or any other service price fluctuation.

4.5. Other impacts

The setup will serve as an object of demonstration and testing of emerging or advanced solar thermal technologies which are entering the Slovenian market – innovative (heat pipe) vacuum tube STC (ideal for DHC - infrastructural approach) and adsorption chiller (latest technology, extensible cooling power and variable driving T, applicable in various combinations of heat sources). It will offer practical demonstration of the concept on smaller areas (business or trade zones, settlements) in the region.
The extent of improvement of indoor thermal environment using renewable energy source for cooling and use of solar thermal system also as a supplementary heating source in heating period will be evaluated.
Based on a real experience, a model of infrastructural solar heating and cooling could be elaborated and practical guidelines for policy makers on using sun as infrastructure will be provided.