	Project Acronym: S3UNICA ***Project Title:*** Smart SpecialiSation UNIvercity Campus ***Program:*** **Interreg Europe** **Topic**: Low carbon economy **Specific Objective:** 3.1. Improving low-carbon economy policies ***Subsidy contract no.:*** PGI06201 ***Starting date:*** 1st August 2019 ***Ending date:*** 31st July 2023

S3UNICA
Interreg Europe

European Union
European Regional
Development Fund

CAMPUS TECHNICAL SOLUTION PUBLICATION
Universities of Udine and Trieste

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1. Introduction

1.1. The University of Udine

The University of Udine is a young university that was founded in **1978** as part of the reconstruction plan of Friuli **after the earthquake of 1976** whose third mission, in addition to **education and research missions**, is to **provide assistance to the community by transferring its innovative technologies, new methods, and skills to the territory**.

It is a small university but has a network of expertise covering all research areas (Figure 1). It is a university with about **15.500 students**, **240 PhD students**, **160 research fellows** and **650 professors and researchers**, **540 laboratory technicians**, and **administrative staff**. It provides **77-degree courses** and **15 PhD courses**. It is actively involved in **student and school exchange projects** with **universities** within the **EU**, and it is currently working closely with **several universities in Eastern Europe and other non-EU countries**.

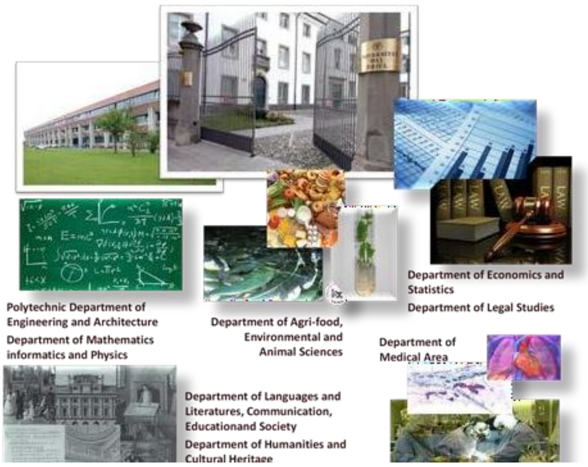


Figure 1: Departments of University of Udine

1.2. The University of Trieste

The community of Trieste's wish to establish a university is first documented in the 1800s when the city's port was built. Since then, the University changed a lot: from a secondary school specialised in **Commerce to University of Economics** and **Business and the Faculty of Law and Political Science** up to the structural re-organization of 2012, when the faculties were abolished, favouring a department-based system instead **of with specific mandates for both teaching and research**. The University of Trieste aims to be an active player on the European stage through an excellent educational system to contribute to making **society more educated, innovative, cohesive, and sustainable**. Indeed, the academic activity must be oriented to transfer

a significant contribution of knowledge endowments to **provide young generations with the appropriate skills for broad overviews and real innovation through a cultural knowledge integration process.**

Referring to 2019/2020 academic year, the University of Trieste count **30 Bachelor's Degrees**, **28 Masters' Degree**, **11 PhD Programmes**, **16.013 students enrolled at bachelor's and master's Degrees** (**7,1% International).**

Figure 2: University Central Building.
Source: https://www.units.it/en/about/history

2. Campus activities

2.1. Energy saving activities

Udine Campus is composed of a **variety of buildings**, some ancient and others rather recent ('90) that allow you to **experiment with many solutions in different conditions** (151.340 m2 as usable area, 591.400 m^3 as gross volume) The "**Rizzi" building** (scientific pole – 90.415 m^2, 346.940m^3 - green are in figure 2) is the one which hosts the **largest number of students** and the one **which accounts for half of the consumption of** the **entire university**. The others university buildings (60.930m^2, 244.450m^3) are spread on the city area between other private and public buildings.

Site	energy consumption [KWh]	[%]
Scientific Area	5,747,464	66,30
Medical Area	713,531	8,23
Humanistic /Teacher training Area	1,559,039	17,98
Economic and Law Area	528,259	6,09
Main buildings amount	**8,548,293**	**98,61**
Other sites	120,769	1,39
Total amount	**8,669,062**	

Figure 3: *Location of University of Udine buildings*

From the energy point of view, the University of Udine has two missions: the first one is to **support institutions in identifying actions from the urban-industrial symbiosis perspective**, and the second one is to **develop innovative products and supply chains**. The university is working with public bodies to develop **DSS models to draw up sustainable energy and environmental planning**. On the other hand, the university is working on innovative products. For example, to reduce energy consumption in data centres with Google, it is developing **technologies for shopping malls and energy recovery from waste heat**, particularly from steel industry.

As mentioned before, University of Udine has about 15.500 students spread over more or less 40 buildings all around the city, but as you can see from the table in figure 3, the **75% of the energy consumption comes from the medical-scientific pole** (green area in figure 3). For this reason, we chose **two different energy saving strategies for the orange area and the green one**. In the green area we planned only good housekeeping measures and we signed an EPC contract including investments in efficiency. **A half million euros has been invested, saving 6% of energy consumption**.

Figure 4: Performances of the energy performance contract (EPC) in the green area

Instead in the **orange area** we planned **innovative projects for energy efficiency**: on the one hand we operate as a **living lab**, and, on the other hand we develop **urban symbiosis projects**. "**Aton**" project (paragraph 3.1.1) is an example of our living lab: University of Udine decided to shut down our boilers to help waste heat recovery from the hospital trigeneration plant planned itself by the University of Udine; the project is now completed, and it is a good example of an industrial urban symbiosis.

Figure 5: Performance of the multi energy system (ATON project)

2.2. Presentation of the University of Trieste

The University of Trieste electrical distribution grid will be monitored by a **dedicated HW-SW platform**, where the **acquisition of voltages and currents must be done in real-time**. In such a regard, the designed platform has the main goal to **reduce the time/cost when new applications are integrated**. To this aim, **x86 personal computers with the real-time operating system RTAI have been adopted**. The RTAI is a **Linux extension to ensure real-time characteristics**. It consists in a patch for the standard Linux kernel, where a hardware abstraction layer gives a deterministic response to interrupts. By adopting the RTAI, **the 50 Hz sinusoidal signals** (**voltages and currents**) are sampled at a **frequency around 1 kHz**, while the error is about few tens of microseconds. The RTAI can develop **block diagrams in Matlab/Simulink**, later **translated in C language**. Then, the last C program is compiled and **executed on the RTAI operating system**. For the considered real-time monitoring platform (Fig. 6), **a sample time of 1.6 ms is sufficient for sinusoidal waveforms at 50 Hz**. Therefore, 12 samples for the corresponding period of 20 ms are adequate to measure the real-time electrical quantities like the voltage in **Fig. 7**. Finally, to identify the final measurements on each station, **Simulink block diagrams** (Fig. 7) are designed to **calculate the Park transformation of voltages-currents**. The power flows in each transformation substation (both active and reactive) are then defined from voltages and currents. To perform the monitoring activity, a general-purpose operating system with real-time characteristics is adopted: this means that a **standard hardware is sufficient** (i.e., conventional/industrial PCs), while **TCP/IP stack and network functionalities are present by default in the system**.

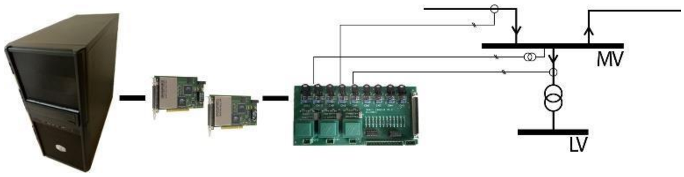


Figure 6: Entire system setup for the single substation[1]

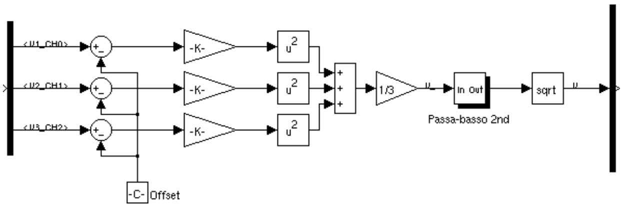


Figure 7: 60 ms raw data samples of two phases voltage sinusoids[1]

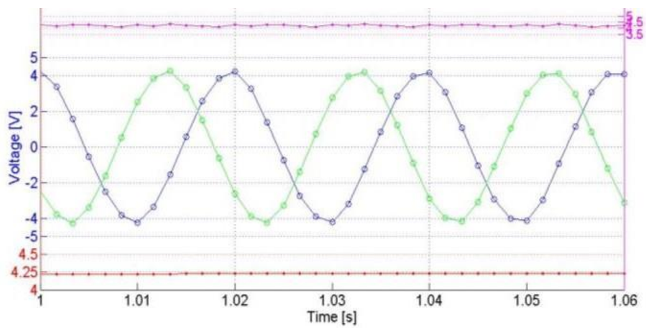


Figure 8: Simulink block diagram to calculate the voltage-current Park Transform[1]

3. Innovative technical solutions

3.1. University of Udine

To summarize, the actions to improve the energy efficiency of the University Campuses mainly concern two types of activities (figure 9): system innovation in symbiosis with the territory or development of product innovation, and energy-saving related to classic actions aimed to improve the efficiency of buildings.

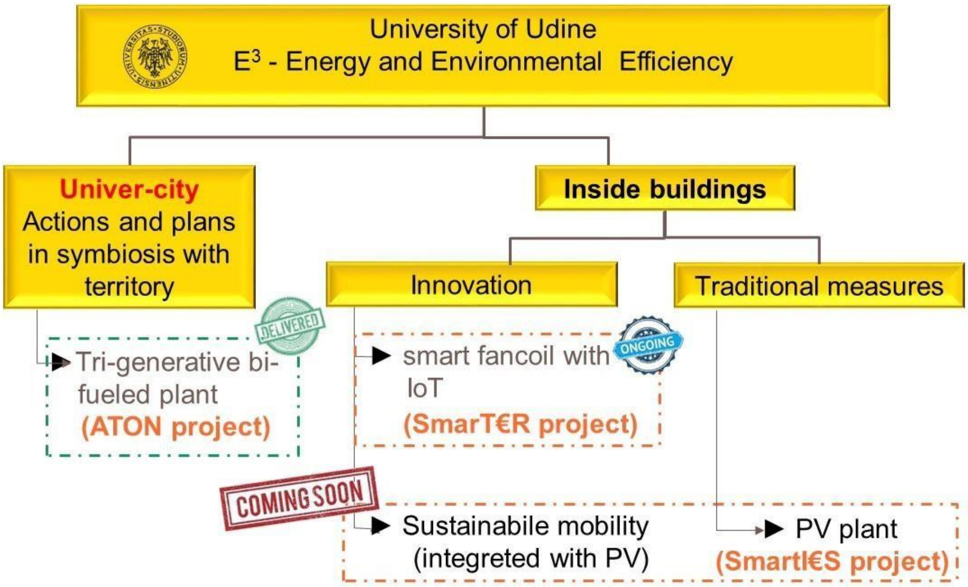


Figure 9: Action for energy and environmental efficiency in university buildings

Regarding the living lab, we have two ongoing projects that will be applied in the green area, in the scientific pole.

In "**SmarT€R project**" we developed a **simple electronic device** designed for the a**dvanced management of heating and cooling fancoils** (in buildings where the conditioning systems are centralized and the presence of people inside the rooms is not continuous). Its simplest version (for energy-saving education purposes) allows the fancoil to be switched on by means of a proximity sensor that the user must consciously and deliberately activate. A new activation is required after a reasonable time. So, **the heating or cooling service becomes "on-demand" and user-controlled**. In the most advanced version, it includes several additional functions allowing the device to be connected to environmental sensors and to the Internet, to improve the **energy management capabilities of the device**, even remotely, and to **enable advanced diagnostic**

functions, e.g., predictive maintenance of the conditioning system and of the device itself. Some prototypes have been produced for preliminary testing and validation.

Within "SmarT€S project", our university laboratory, the **Power Electronic Converters**, Electric **Machines** and **Drives Laboratory** (**PEMD**), and our spin-off **Koala Electronics s.r.l**. are dealing the **advanced conversion systems technologies for renewable energy applications and sustainable mobility**, focusing on light-weight electric vehicle traction, high-efficiency charging, and auxiliary systems. The project concerns a **new electric grid powered by a PV plant with energy storage in batteries used for electric mobility**. A small part of the **PV plant** has been **implemented**, and we are now waiting to have more funds.

3.1.1. Aton project

The initiative for the construction of the new power plant was part of a complex general redevelopment project of the "*Santa Maria della Misericordia*" hospital complex, which began in 2002. The idea of the project was to **create a district multi energy system based on the use of cascading energy in the territory** that would encourage **cooperation and synergies between different public and private stakeholders** towards common energy saving objectives starting from the valorisation and specificity of the territories. **In Italy, it is the firstproject in which a hospital's trigenerative power plant feeds a city network**.

The energy system consists of a **tri-generation plant** and a **district heating network of 13 km connecting both subscribers of the Community Planning Agreement in the first construction stage** (red buildings in Figure 10) and **other public and private end consumers in the second stage** (blue buildings in Figure 10).

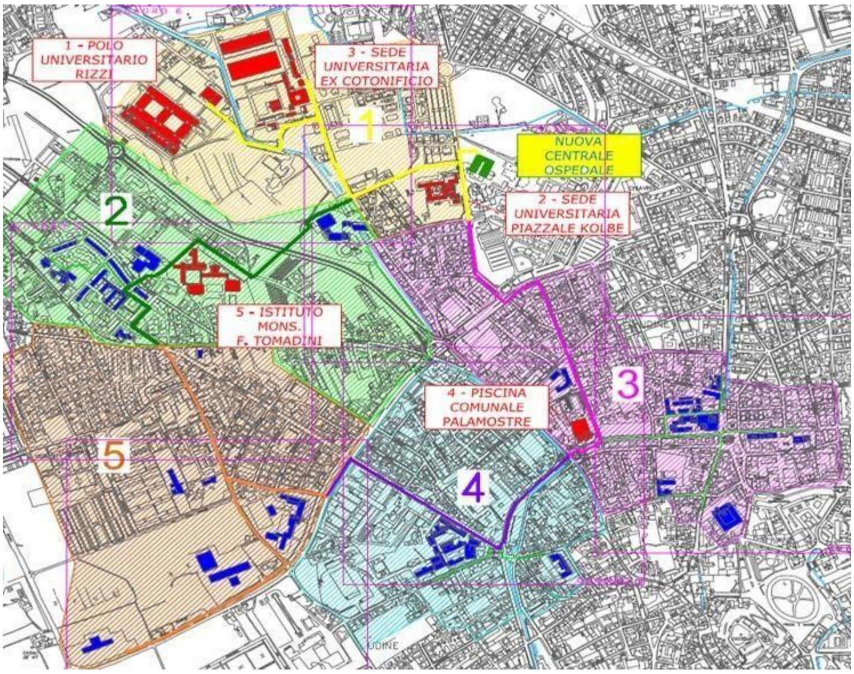


Figure 10: The district heating network: red areas mark the early subscribers, while the green ones clients to be connected in the second project stage

The energy system configuration (see Figure 11) includes:

- the **CHP station**, fed by **natural gas and renewable sources** (bio-oil), which **supplies heat** (**9.9 MWt**) for **hospital** uses and **the district heating system,** and **power** (**10.3 MWe**) for **hospital requirements**, with the excess to be sold to the national grid. The **cogeneration system involves three natural gas engines of 2.6 MWe** each, and **2 bio-oil engines of 1.25 MWe each**.
- The **heat generation system**, with installed power of **75 MWt** to **supply hot water for heating** and **steam for technological uses** (sterilization and humidification). Hot water production for heating uses includes **4 units of 13 MWt**, while steam production is provided by **3 units operating at 11 bar**: one **unit of 12 t/h and 8 MWt and one of 20 t/h and 12.5 MWt are reused from the previous hospital heat production plant**, with the **addition of a new unit of 4 t/h and 2.5 MWt**. The **new unit** has been sized to **cover the lower steam demand by the hospital in the summer season**, to **improve seasonal efficiency** by minimising part load operation. **Sterilized steam production** is obtained by **6 evaporators** (1 for back up) **of 3 t/h at 7 bar each**.

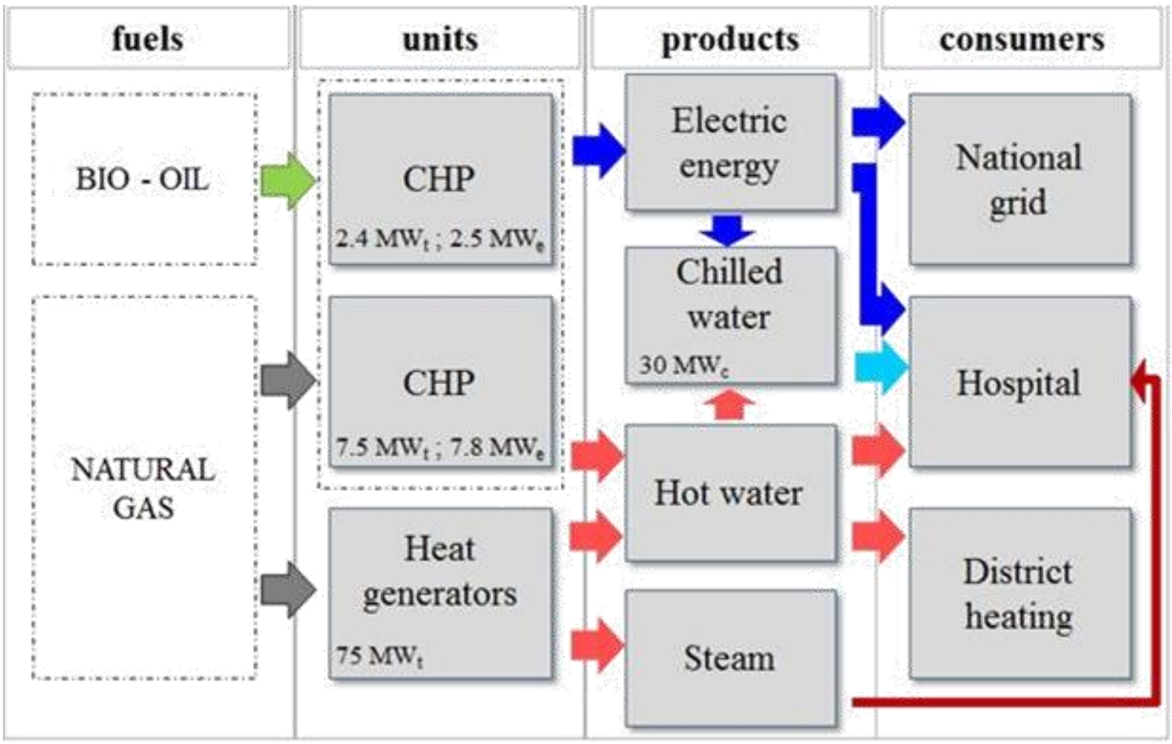


Figure 11: Energy system configuration

- The **cooling system to supply cool water for the hospital air conditioning system**. It includes an **absorption chiller of 2 MWc**, fed by **recovered heat from the CHP unit**, **2 centrifugal compressor chillers of 7 MWc**, and **3 centrifugal compressor chillers of 3.5 MWc adopting R134a as working fluid**, since no use restriction nor limits are set for this fluid on the base of Montreal Protocol and CE 2037/2000 about ozone depletion. All the compression-based chillers use electric power generated by the CHP unit. Further increase of energy efficiency is obtained with a chilled water tank of 2,500 m3 storing 14 MWhc and covering 4 hours demand. **Thanks to this solution the installation of a new fossil fuelled unit of 3.5 MWc is avoided, and available cooling power is increased from 26 MWc to 30 MWc**.
- The **district heating network**. The distribution system is divided into two main parts by a set of reservoirs tanks. The former serves the hospital (14 buildings) with a total volume of 300,000 m^3. The **latter feeds the district heating network for the city with a heating power of about 48 MWt and an extension of 13 km**, serving early subscribers (see red marks in Figure 10), that sum up to about **14 MWt**, and the **second stage** connections for a **total thermal power of 33.6 MWt**. This leaves also 3 MWt of additional power available for future developments. The use of district heating system allows to dismantle the obsolete heating units of 17 school and residential buildings (see Figure 12), reducing the number of points of emission and related control issues. **Improved air quality is assured by increased height of the chimneys of the new power station**, which enforces the capability of pollution dispersion in the atmosphere. Further benefits for urban clients' regard **safety** and **maintenance**, since, by **replacing single boilers with heat exchangers of the district heating network**, **a strong reduction of risks for blasts and bad combustions with potential poisonings and lower maintenance costs are achieved**.

Year	Network	Users	Power[MWt]
2014	3,5 km	24	20.47 MW
2015	5,2 km	36	25.91 MW
2016	8,7 km	39	27.17 MW
2017	9,8 km	42	41.15 MW
2018	10,2 km	58	47.59 MW

Configu-ration	Primary demand [MWh/yr]	Emissions [tCO_2/yr]
New system	221,014	34,452
Savings	30,974	16,920
Reduction [%]	12,29	32.94

Buildings	Power [MWt]
University (research buildings, labs, conference hall, students' house)	10.80
Municipality of Udine (wimming pool, art gallery , theatre and 5 schools)	3,18
Udine Local Housing Authority (8 residential buildings)	5,03
Region FVG (School centre)	14,27
Privats (37 customers)	14,31

Figure 12: District heating power, Energy saving and emissions

The system had three innovations:

- ***Design innovation***. Generally, a design starts from the needs and then reaches to the plant that allows a lower payback or the best economic performances. Instead, in this case, the **plant has been designed principles of the 2050 roadm**ap, i.e., the whole system has been optimized to minimize natural gas consumption for the surrounding and the hospital at the same time.
- ***Technical innovation***. The "***Cold Switch concept***" has been introduced, with the possibility to cover the **refrigeration thermal need of the hospital with two different chillers**, one **heat-powered absorption chiller and one electric chiller** which is the classic refrigeration unit. In this way, we can choose the form of energy input of this system. In this way the congenators can work at the maximum efficiency. Another innovation is **the use of large cold storage tanks in the foundations of the power plant**. There are two large tanks that allow to be loaded at night and discharged during the day, so we are able to cover the peaks in cooling needs

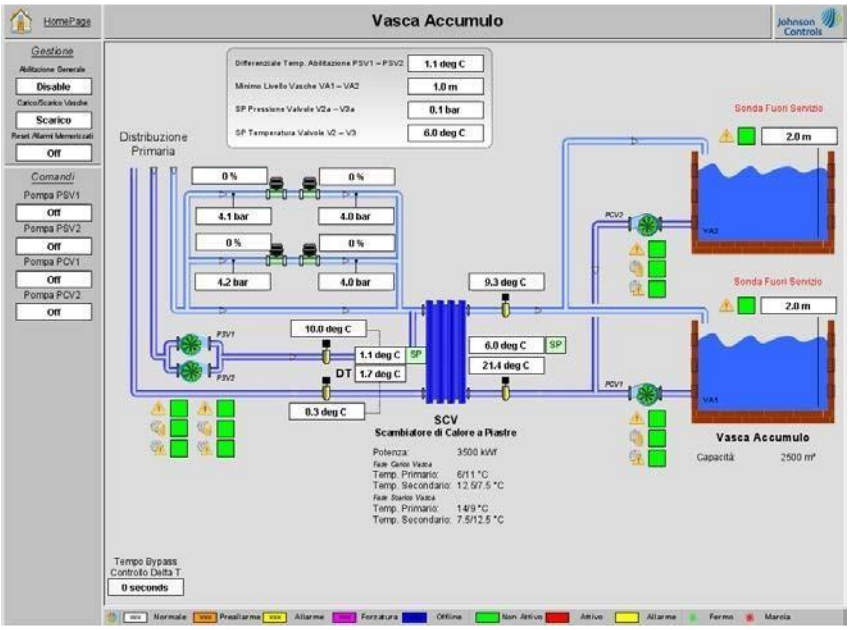


Figure 13: Cooling energy storage system

- ***Management innovation***. The experience of the trigenerative plant and district heating network of Udine is also of great importance from the legal point of view, regarding the instruments that are best suitable to develop innovative solutions for the implementation of the energy transition at city level. The design, construction, and implementation of the plant at the local hospital, with the development of a city district heating network which ensures electricity, hot water, heating and cooling not only to the entire hospital, but also to the campus of the University of Udine as well as to other public buildings (such as the municipal swimming pool) and numerous private homes represents one of the most remarkable examples of the innovative potential deriving from the use of new, more modern public-private contractual schemes. **The solution came from one of the first examples in Italy of cooperation among institutions** (University of Udine, Municipality of Udine, Friuli-Venezia Giulia Region and "S. Maria della Misericordia" Hospital of Udine) **based on a PPP and on the integration of the skills of each party**.

The construction of the plant was envisaged as part of a tender procedure for a construction and management concession in the form of a project financing operation, at that time already provided by the Italian regulatory framework. It was based on a previous and preliminary consultation of all public bodies concerned and gave a decisive role to the university for the development of the project idea. It was indeed thanks to the applied energy research teams of the university of Udine that the innovative solution was identified and outlined. It was in particular in 2004 that a consultancy and preliminary design assignment was given by the Municipality to the University, which studied such an innovative urban symbiotic system.

Once the idea was concretely conceived and approved also by Friuli Venezia Giulia Autonomous Region, in 2006 the **Municipality of Udine**, the **University of Udine** and the **Hospital** concluded a **public partners program agreement** that defined **aims and objectives of the operation**, indicated **methods** and **timeline** of the operation, provided basic regulation for **financial and economic aspects** of the operation, identified in the **Hospital the contracting authority for the awarding procedure** of the contract and created a steering committee for the development of the whole operation. Also, the Region in 2006, after having approved the operation, identified the project financing scheme as the public-private partnership tool to be used for the development of such an innovative idea, which was as well provided at that point by the Municipal energy plan. In compliance with those provisions, the program agreement foresaw as well to award a concession, in the form of a project financing operation, as the legal procedure most suitable to foster innovation also by the private partner of the project.

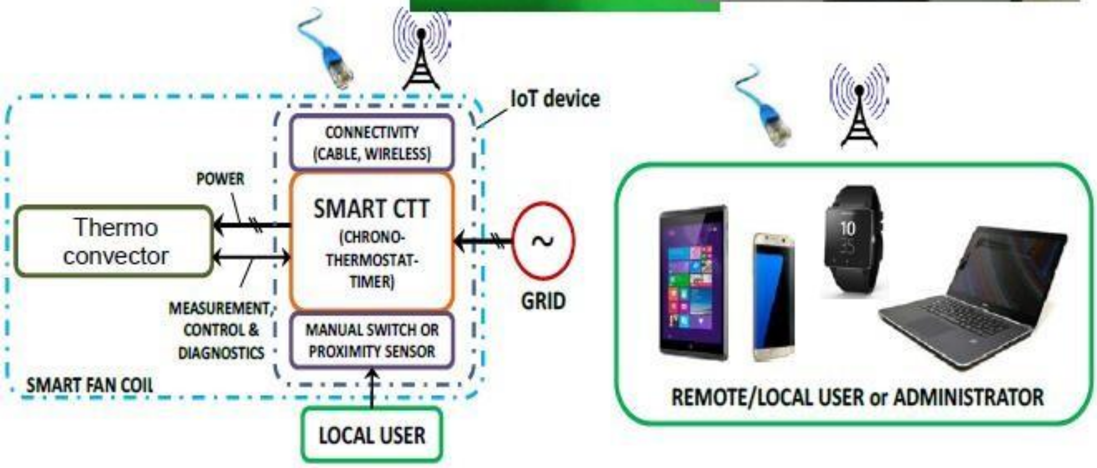
Indeed, the concession notice was published in December 2007, and it provided, among the awarding criteria, the awarding of more points (9/100) for those tenders proposing an improvement and enlargement of the city district network. Thanks to this provision, the concession was awarded in April 2009, after the evaluation phase, to a temporary association of undertakings that proposed a district heating network of three times the length and power compared to the one provided by the original project.

The concession contract was therefore signed on 6 October 2009, with a total duration of nearly 30 years, for the service provision and management and a company was created to deal with the project's development. In the light of the complexity of the project, the need to specify the project and adjust the economic balance, over the following years (and up to now) five additional acts were signed, in 2011, 2014, 2015, 2016 and 2019. The Plant was inaugurated in December 2012 and the city district network subsequently implemented, being today able to supply more than 40 private homes, other than the Campus of the University and other public budlings, like the local swimming pool.

As it emerges also from the procedural aspect of the project, **the trigeneration power plant of Udine represents an important good practice not only from a technical point of view**, of solutions that can be implemented for the achievement of energy sustainability at local level, **but also from a legal perspective**. Indeed, it is a fundamental example that reminds public administrations not to underestimate underlying legal profiles connected to innovative projects. It constitutes a **central aspect for the development of truly innovative solutions capable of achieving energy efficiency goals on university campuses**, but also with regard to **all other public buildings**.

3.1.2. SmarT€R project

In existing or historical buildings, the collection of the data required both to build systems to achieve energy efficiency and environmental sustainability and to manage and monitor their performance (for maintenance, safety, etc.), is often not financially or technically convenient with current techniques. This is the reason why the University of Udine is developing and implementing new systems. The solution improves climatic conditions while providing useful guidance for monitoring system efficiency and maintenance (for reduced operating costs). The systems do not require maintenance once installed and do not require any special training. The University of Udine is working to install this **low-cost electronic management devices designed to be used in existing buildings with simple, fast, and economical installation to implement the IOT**.



In this device foresees to make "smart" fancoils and environments through the concept of IOT by inserting the electronic system designed with the aim of optimizing (reduce) energy consumption (electric and thermal) of the fancoil heating rooms (offices, laboratories, meeting rooms, warehouses, etc.) and monitoring the environment in buildings where the presence of people is occasional, and the plants are centralised. The existing environments and fancoils with this system become a component connected to the Internet, visible and accessible on "cloud" space. This allows for advanced fancoiler management to implement innovative features such as:

- **timed and/or scheduled local and/or remote timing and/or timer shutdown** (via a specific "app" to be used on a common smartphone) or automatically when the user (and his /her smartphone) enters a space well-defined near the system.
- **Centralized management of the entire network for monitoring, diagnostics, optimization.**
- **Replacement of the mechanical thermostat and the "electromechanical" management system of the seasonality.**
- **Short term monitoring and data logging of machinery and environments**

Monitoring temperatures, humidity and other environmental variables can be processed. The system will be instrumented also to allow you to:

- verify the operating state of the system in order to verify its efficiency.
- Verify the state of health (state-of-health, SOH).

The application is a good example of **feasibility of low cost IoT solutions**, immediately usable for monitoring in existing and historical buildings where it is not possible (technically and economically) tobuild plants in the structures. It allows a quick monitoring for energy savings and diagnosis of systems for improvements.

3.1.3. Smarti€S project

The **Smarti€s project** realizes and defines protocols and algorithms to manage network assets relating to the energy balance of smart grids. They are powered by solar panels integrated with other energy sources available in the building (such as microturbine co-generators), which use energy storage systems and chargers for electric cars, as well. The project implements advanced solutions to collect and track consumption and the data required based on laser scanning techniques (terrestrial lidar), photogrammetry, Google Tango to scan and reconstruct environments in 3D such as buildings and infrastructures which are integrated with the cartographic environment and the mapping tools made available by GIS/BIM systems. This advanced solution can be used to collect data in existing or Historical buildings, in which the collection of the data required is either financially or technically unviable.

The University of Udine partially realized and will complete a photovoltaic system. After ended the system, the plant will be integrated with a power network supplying both Campus and laboratories. It will also connect the energy storage system, which is already present in the Campus, and the chargersfor electric cars. In the project algorithms will be realized and applied to examine the photovoltaic potential of buildings' roofs in urban settings. By using LIDAR data, it will also specify how to optimize heating/cooling technologies in order to get both design criteria and reference indicators for monitoring and maximizing the energy and environmental efficiency.

3.2. University of Trieste

The campus technical solution in the following has been already proposed and discussed in a paper[1], during the **scientific conference IEEE CPE-POWERENG 2021** (14-16 July, Florence, Italy). Therefore, the considerations here discussed have already received a scientific review, which has demonstrated how the proposed design procedure has value and potentiality.

To implement the real-time system for monitoring the University of Trieste campus distribution grid, several implementation and calibration activities are to be achieved. The real-time platform under study has been conceived in the "**Smart Campus**" project, launched by the **S3** (**Smart Specialization Strategy**) platform "**Sustainable Buildings**", and co-financed by the University of Trieste. As a follow up of the Smart Campus project, the **Interreg Europe "S3UNICA" project** wants to promote the collaboration with nine European partners to develop new policies towards the building energy sustainability. In the S3UNICA research project, the University of Trieste is involved in the definition of a methodology to evaluate the energy performance of buildings by means of the so-called Smart Readiness Indicator (SRI). The precise status of buildings testified by SRI indexes can steer the regional policies towards the implementation of an effective sustainability. On the other hand, the "Campus Technical Solution Publication" provides all the activities to be performed to install and run a real-time system for monitoring the campus distribution electrical grid. Evidently, the monitored data constitute the basis on which assess the SRI.

[1] M. Dalle Feste, M. Chiandone, D. Bosich and G. Sulligoi, " The Control and Monitoring System on a Medium Voltage AC Distribution Grid: Device Implementation and Calibration Procedure", IEEE CPE-POWERENG 2021, 14-16 July, Florence, Italy.

The real-time measurement system works by means of a **Conditioning Interface Board** (**CIB**). This board is a versatile multipurpose signal conditioning interface between monitored electrical system and analog-to-digital input/output board of the PC. The **100-pins SCSI cable pinout** is in Figure 14. The CIB consists of some channels: **3 analog input channels as voltage input stage** (**CH0**, **CH1**, **CH2**), **9 analog input channels** as current input stage (from **CH3 IN** to **CH11 IN**), **2 analog output channels** (**D/A OUT1** and **D/A OUT 2**), 4 **digital outputs ch**. (from **DIO0** to **DIO3**) and **4 digital input ch**. (from **DIO4** to **DIO7**).

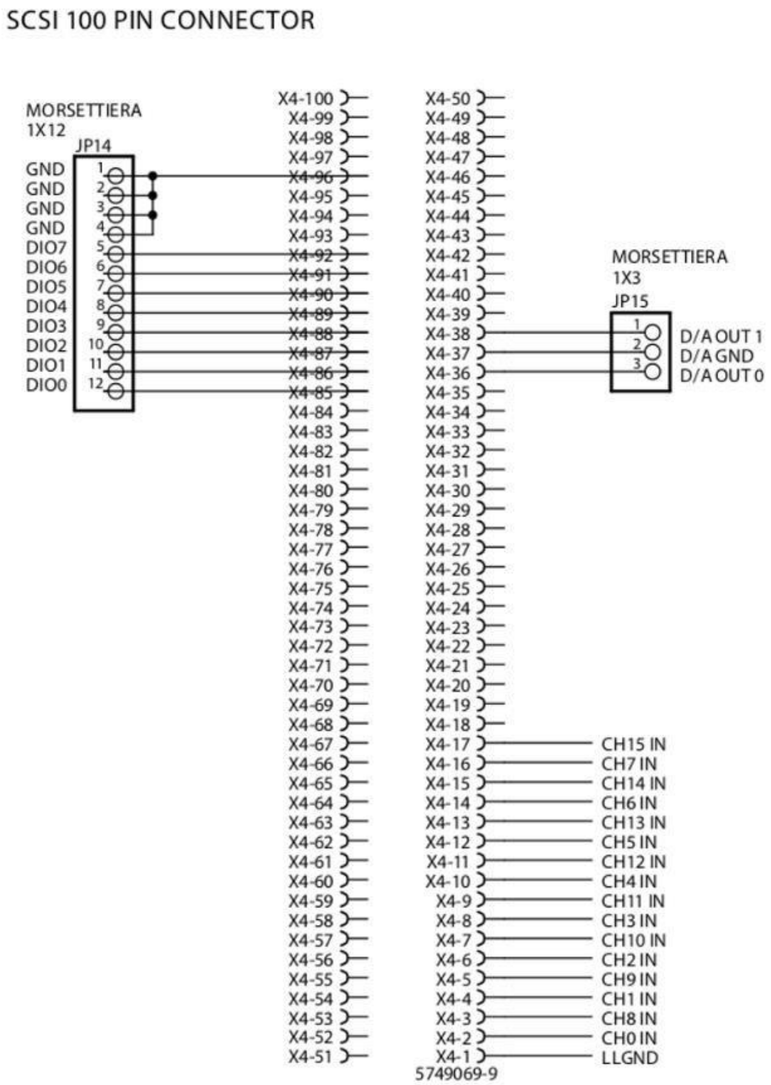


Figure 14:100 pin SCSI cable pinout

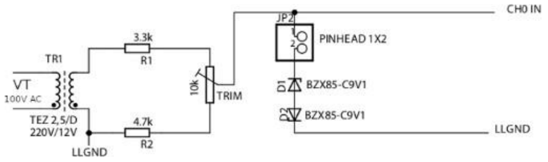


Figure 16: Single conditioning voltage input channel

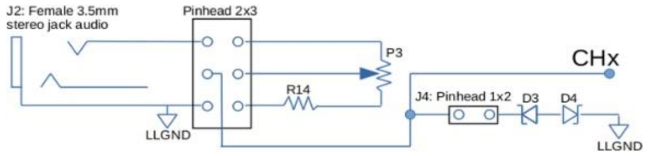


Figure 15: Single conditioning current input channel

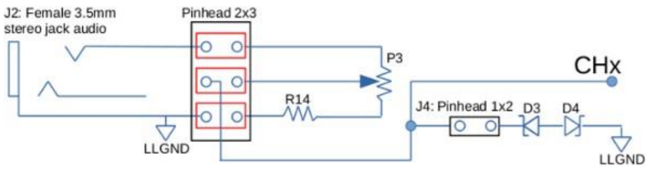


Figure 17: Single current input ch. in current signal mode

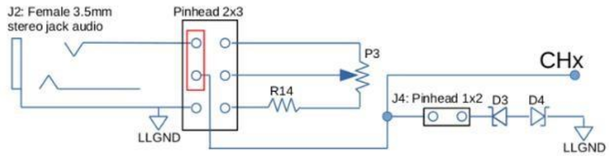


Figure 18:
Single current input ch. in voltage signal mode

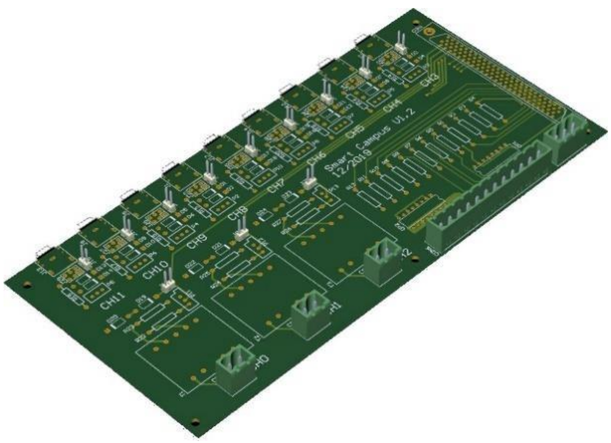


Figure 19: Printed Circuit Board of CIB

Thanks to **8 optoisolators** (ACPL-847-000E, 4 in the input and 4 in the output configuration), each **digital channel** has been **protected and isolated**. The optoisolators provide the decoupling between the monitored/controlled system and the delicate IO board mounted on the PC. For future developments, the **analog output channels are left directly connected to the 100 pin SCSI cable, thus to the IO board**. In analog input channels, a distinction must be made between **voltage channels** and **current channels**. The **single voltage input channel** is drawn in Fig. 15, while the electronic scheme components are **TR1** (**220/12V voltage transformer**), which adjusts the voltage around the **5.45 V value**. Then, **R1, R2 and TRIM** are the **voltage divider** with a variable static gain and **D1-D2 diodes** are the protective shunt to prevent that output voltage over 9.8 V. The current stage is shown in Fig. 16: here, **J2 is a 3.5 mm stereo jack connector**, **D3** and **D4** are **protective shunt diodes** and **PINHEAD 2x3** allows to configure the **current channel** in **two different setups**. The setup in Fig. 17 is for **current signal current probes**, while the configuration in Fig. 18 is for **voltage signal current probes**. In this case, the **R14-P3 series** convert the **current signal into a voltage signal** and their values determine the stage static gain. The **Printed Circuit Board** (**PCB**) **layout** is depicted in Fig. 19. A **validation/calibration bench** is developed to check the **conditioning board**. By adjusting the acquisition mathematical model gain compensation and then replicating the tuning process for the other CIBs, the calibration wants to identify the right static gain value of each input channel. Several components are used to achieve the calibration: an **AC-3F-380V-supply**, **two measurement transformers** (ratio 380V/100V), **one precision variable load** and finally **two current transformers** (**ratio 3A/5A**). This setup (Fig. 20) is implemented in the **D-ETEF laboratory** at the University of Trieste to reproduce the **MV secondary substation conditions**. The activity wants to determine/impose the static gain of each **CIB input channel**, both for **current** and **voltage channels**. As **voltage channels**, also the network power supply voltage is read through a measurement tester. In this case, the **TRIM trimmer** is tuned to the half scale in order to allow regulation and adequate value margins: the **chosen value** is around **5 kOhm**, whereas the **static gain of the voltage divider stage** is **0.54**. This factor must be assumed in cascade to the input **220V/12V measurement transformer**. Regarding current channels, **for each of them a known symmetrical load current is set**. Then, the input stage is adjusted with the same process already used on voltage channels. To check linearity, the measurement is repeated for different current values. By starting from dummy load, the static gain value on the current channel is calculated basing on some ratios. The **3:5 ratio of the measurement current transformer**, the **6:1 ratio** given by the **number of coils concatenated with the current probe**, the **1:2000 ratio** of the **measuring probe** and the **ratio 180:1 for the CIB resistances stage**. To ensure the proper tuning, also the **100 Ohm trimmer** (**P3**) is regulated in the middle of its scale. During the process setup, the raw calibration data are acquired. The Fig. 21 finally shows the **final system set installed in each substation of the campus**.

Figure 20: Setup and calibration assets used in the laboratory

Figure 21: Real-time monitoring system installed setup

Annex 1

Self-Assessment Tool

questionnaire

Contribution ID:

Date: 14/09/2020 10:35:56

S3Unica - Interreg Europe
Self-Assessment Tool questionnaire

INTRODUCTION

S3UNICA project is based on the methodology adopted by the Smart Campus Interregional Innovation Pilot Action project which established a classification of partners' University Campuses and provided basic information about the dimension and the localization of technologies that have been adopted or are still in the testing phase. The main goal of the Smart Campus project was to develop the concept of smartness at University Campuses in the partnership regions: this should lead energy generation, distribution systems and energy use in university buildings in a more efficient and innovative way, in University Campus Buildings as far as technical, financial, and planning aspects are concerned.

S3UNICA aims to:

- capitalize the experience gained by Smart Campus project partners (PPs). extend the acquired outputs to new PPs (Romania and Poland).
- Develop a common vision based on the quadruple helix approach, according to Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 on the energy performance of buildings and the Smart Readiness Indicator, in order to improve policy instruments through the adoption of action plans

S3UNICA activities will be developed on the basis of the following 3 steps:

1. **Identification and Analysis**": development of the self-assessment tool fist part enabling regional stakeholders to identify their strengths and weaknesses on the innovation cycle, policy framework, technical and financial performance.
2. "**Interregional mutual learning**": after the first step, S3UNICA will plan strategies, technical solutions, policy framework and ecosystem of the beneficiary region in order to increase smart energy saving, to improve distribution and production measures, as well as methods, resources, results and acquired experience throughout the innovation cycle.
3. "**Knowledge transfer and action plans**": given the lessons learnt from the Smart Campus project partners and considering the rich experience acquired by the new S3UNICA partners experienced, a common methodology will be drafted to support the growth of transnational markets by identifying action plans.

The assessment tool includes the above-mentioned steps 1 and 2 and it will be implemented in two phases: The first phase will be approved during the first Steering Group (SG) and it is the subject of this document: it pursues the goal of collecting information in order to allow stakeholders to identify their strengths and weaknesses and of gathering quantitative data to build the next phase;

On the basis of the information received, the second phase will aim to define a common methodology to select technological roadmaps and the most appropriate policies.

The table below summarizes the implementation of the project activities:

	M0	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
KARELIA										SG approve AT1															
ANDALUSIA																SG approve AT2									
development AT |PP2, PP3|				T1part"identification and analysi							AT2part"kno" with Sri														
All PP answers al AT1part											answers AT1part														
All PP answers al AT2part																x	answers AT1part					x			
RAFVG																						SG analize report AT			

During the implementation of the assessment tool, the LP will capitalize on the previous experiences acquired in the management of European projects, such as SMART CAMPUS and CEEM (project financed by the Central Europe Program through ERDF funds which aimed to provide SMEs with environmentally friendly technologies, operating methods, good practices, and an IT tool to self-evaluate their performance), in order to achieve the following objectives of the S3UNICA project:

- collection of information provided by universities stakeholders and consequent sharing with other stakeholders during the RSM to create suitable conditions for involving new private actors and for promoting the use of public-private partnership (PPP) and public private procurement instruments.
- Identification of at least 20 good practices.
- Drafting of the “Technology and Policy Road Map”, selecting promising technologies and smart energy management systems.
- Drafting of 5 action plans to enhance regional policy instruments.

The first part of the assessment tool is structured as a survey, subdivided into four sections:

1. **POLICY SECTION**: it concerns the collection of information to monitor the current state of the policies implemented by the PPs in order to achieve energy efficiency on university campuses buildings and infrastructures.
2. **FINANCIAL SECTION**: on the basis of the data provided by the partners, it allows to check the availability of financial instruments aimed at implementing energy efficiency interventions on university campuses.
3. **TECHNICAL SECTION**: (a) it collects general information concerning University campuses buildings and infrastructures; (b) it reports the matrix of information necessary to the application of the SRI methodology, identifying the questionnaire for the collection of information related to row 1. "**Monitoring and measurement**" and row (2.) "**Technical solutions**".
4. **ENERGY EFFICIENCY, FUTURE SCENARIOS AND VISION**: it is requested on one hand, a self-assessment of the energy performance detected in campuses analysing the obstacles encountered and the extent of the energy efficiency of the measures adopted, on the other hand it is requested the indication of the objectives of the political actions undertaken at various levels.

POLICY SECTION

[To be completed by PP and University]

In order to understand the situation of the regulations supporting energy efficiency on university campuses, the following information is required from the partners, therefore the following questions need an answer from the single partner.

Are there policy [1] measures at any level (local, national) encouraging the **development of nZEB university buildings?** What has been already done and what results were achieved? Please give some examples.

[1] A policy is a principle or protocol to guide decisions and achieve rational outcomes, defined by political agreement at local/national/EU levels and adopted by law).

1000 character(s) maximum

In Italy there are incentives for actions in public facilities: The "conto termico" (provides a contribution of 65% of the costs for interventions in buildings energy efficiency), The "certificati bianchi" and "cogenerazione ad alta efficienza" (reward the energy savings obtained after the energy requalification measures). The University of Udine has taken advantage of the "conto termico" for two historic buildings restructuring and is evaluating “certificate bianchi” for the lighting efficiency of the “Rizzi” Campus (the scientific pole).

Are there policy measures at any level (local, national) for encouraging the adoption of **smart monitoring and control systems?** What has been already done and what results were achieved? Please give some examples.

1000 character(s) maximum

The University of Udine has not identified or adopted these instruments.

Are there policy measures at any level (local, national) for encouraging an **integrated energy management system for university/public buildings?** What has been already done and what results were achieved? Please give some examples.

1000 character(s) maximum

The University of Udine is not aware of any incentives tools to integrate energy management systems.

Are there **self-implemented [1] energy efficiency policies** in place, not part of mandatory policies? Whathas been already done and what results were achieved? Please give some examples.

[1] Specify if the university campus has implemented additional policy regulations not mandatory requested by the regional-national-EU levels).

1000 character(s) maximum

The University of Udine has promoted and implemented with a PPP a new district heating model based on the use of energy cascade on the territory that encourages circular economy, urban symbiosis and synergies between different public and private stakeholders towards common goals of energy saving (starting from the enhancement and specificity of the territories). In Italy, it is the first planning model for the recovery of thermal waste from the hospital to satisfy in cascade the thermal needs of university buildings, schools, private of public buildings (swimming pool,

Does your university campus **adhere to mandatory energy policies at any level** (local, national, EU)? If yes, please specify.

1000 character(s) maximum

Legislative Decree 48/2020 requires that for any extraordinary maintenance or revamping/refurbishingactions, energy efficiency standards are respected.

Are there **measurable objectives or targets achieved or to be achieved by your university campus?** Please specify if the campus has set up/achieved targets and objectives, both quantitative (e.g., numbers to be achieved) or qualitative (e.g., general final objectives expressed in a to-do-list levels).

1000 character(s) maximum

The University of Udine has an EPC that provides for energy efficiency interventions in university buildings (excluding "Rizzi" campus): heat generator renewal, thermostatic valve installation and windows replacement. The measures have been implemented and have allowed energy savings in the order of 5% of the initial consumption for the buildings with a private investment of 550,000€.
The district heating management service ("Rizzi" Campus), which lasts for another 10 years, provides that every year there will be a 2% reduction in consumption.

Which policies have been implemented at local/regional national level or at campus level to promote the energy efficiency sector (i.e., development of innovative solutions, collaboration with private companies, support for the creation of universities spin-offs/start-ups to commercialize these new technologies, promotion of the interregional collaboration and projects at European level)? Please give some examples.

1000 character(s) maximum

In Italy there are public-private partnerships (PPP) that propose energy performance contracts (EPC) with the aim to improve energy efficiency in public buildings.

What are the bottlenecks you have experienced with regard to the energy efficiency policy implementation?

1000 character(s) maximum

- lack of specialized personnel in the technical staff of the University in managing the correct implementation of measures
- lack of public financial support

Being S3 an "ex ante " conditionality to access cohesion funds, S3Unica project will contribute to influence regional policy, starting from university achievements. Has your university contributed to the definition of your Regional S3/ development trajectories? Or has your university benefited from existing S3 (i.e., energyrelated projects funded through ERDF)?

1000 character(s) maximum

The University of Udine cooperates with the FVG region for the definition of energy strategies and planning. It has developed several models to plan and evaluate the economic and employment effects of energy efficiency measures and has produced studies on the recovery of waste heat for district heating and for the creation of smart energy grids (thermal, electrical, and cooling) in industrial districts. The University of Udine collaborates with the Region in the definition of S3 strategies in the field of energy, agrifood and industry.

FINANCIAL SECTION

[To be completed by PP and University]

To understand the availability of financial instruments for the implementation of energy efficiency interventions on university campuses, each single partner should provide the following information. **Are the following financial instruments available?**
Energy Performance Contract.

1000 character(s) maximum

Yes, see above

Mortgages for energy efficiency/Bank loans.

1000 character(s) maximum

Italian banks are equipped to finance energy efficiency policies.

State Incentives dedicated to universities.

1000 character(s) maximum

Limited funds from the Ministry of Universities and Research can be accessed.

National programs dedicated to energy efficiency works for public buildings.

1000 character(s) maximum

Yes, see above.

Dedicated credit institutions/bodies (EE funds) for energy efficiency works/Investments.

1000 character(s) maximum

Yes, see above.

Other financial systems or initiatives: specify

1000 character(s) maximum

None

Which financial schemes have been implemented to promote policies in the energy sector (i.e., development of innovative solutions, collaboration with private companies, support for the creation of universities spin-offs/start-ups to commercialize these new technologies, promotion of the interregional collaboration and projects at European level)? Please give some examples.

1000 character(s) maximum

As mentioned, the EPC is a scheme of collaboration between the public and private sectors.

TECHNICAL SECTION

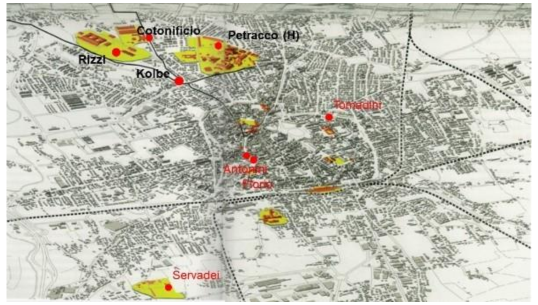
[To be completed by university]

The following answers are required from the stakeholders (campuses) to collect general information within university campuses and to understand the technological state of the buildings:

TECHNICAL SECTION

[To be completed by university]

The following answers are required from the stakeholders (campuses) to collect general information within university campuses and to understand the technological state of the buildings:

	Question Description
University Name	Università degli Studi di Udine
Country	Italy
City	Udine
ZIP code	33100
Street name Number	via Palladio, 8
Description of the campus *[Insert a short and clear description of the campus: buildings (single or group of buildings, modern or historical), activities carried out (teaching rooms, labs, auditorium, offices, hospitals, sports facilities,) (max. 1000 characters).]*	The University of Udine was founded in 1978 and wanted, the only one in the Italian panorama, by popular demand. Udine Campus is composed of a variety of buildings, The "*Rizzi*" building (scientific pole – 90.415m^2, 346.940m^3) is the one which hosts the largest number of students and the one which accounts for half of the consumption of the entire university. The others university buildings (60.930m^2, 244.450m^3) are spread on the city area between other private and public buildings. 

Campus ownership *[Property is the state of full possession of the assets used by the University. Rent is the state of contractual duty of these assets with an external owner.]*	Propriety
Location *[Specify if the University is located in a fully independent building or if it is shared. Specify if the buildings are isolated or integrated into a district with other activities, or if they are included like the other civil residences in the city]*	Located in a fully independent building
Number of employees *[Indicate the number of students, lecturers, researchers, technicians, other staff present daily in buildings (reference: year 2019)]*	It is a university with about 15.400 students, 250 PhD students, 175 research 650 professors and researchers, 588 technicians and administrative staff. It provides 38-degree courses, 36 master'sdegree courses and 15 PhD courses.
Area [m^2] *[Indicative value. Specify the net floor area occupied by the buildings, taking into account all features allocated (offices, teaching rooms, etc).]*	151.340 m^2 as usable area
Volume [m^3] *[Indicative value. Specify the net volume of the campus, taking into account all features allocated (offices, teaching rooms, etc).]*	591.400 m^3 as gross volume

In this section detailed information about different energy sources, final energy usage, consumption behaviour, building structure, planned, and adoptedmeasures will be collected

	ABILITY TO MAINTAIN ENERGY PERFORMANCE AND OPERATION	ABILITY TO REPORT ON ENERGY USE	ADAPT ITS OPERATION MODE IN RESPONSE TO THE NEEDS OF THE OCCUPANT	MAINTAINING HEALTHY INDOOR CLIMATE CONDITIONS	FLEXIBILITY OF A BUILDING'S OVERALL ENERGY DEMAND
MONITORING AND MEASUREMENT	Centralized monitoring for electricity, natural gas, and heat in all buildings at individual level	Thermal energy: In the scientific pole hourly measure on entire building; in the other building monthly monitoring for electricity and natural gas	In the buildings fancoil units are controlled by individual room thermostats.	Technical readiness for electricity and district heating demand response	See technical section
TECHNICAL SOLUTIONS	Heating energy demand are fulfilled with district heating supply in the Scientific pole; the other buildings each individually endowed with natural gas boilers. Cooling demand is fulfilled with chiller. Electrical demand is supplied by the national grid and PV		Adjustable temperature thermostatson room level.	Only temperature is maintained, and heat/cold generation is independently weather controlled.	The only building endowed with RES is "*Rizzi*" campus. PV plant with installed capacity of 15kWp and 18 kWp

	ABILITY TO MAINTAIN ENERGY PERFORMANCE AND OPERATION	ABILITY TO REPORT ON ENERGY USE	ADAPT ITS OPERATION MODE IN RESPONSE TO THE NEEDS OF THE OCCUPANT	MAINTAINING HEALTHY INDOOR CLIMATE CONDITIONS	FLEXIBILITY OF A BUILDING'S OVERALL ENERGY DEMAND
MONITORING AND MEASUREMENT	Quality of the measure (entire building, single thermal zone, single service for example: lighting, air conditioning, other services	Frequency of measurements (annual, monthly, weekly); Quality of energy consumption measurement (system of buildings single building, single service for example: lighting, air conditioning, driving force);	Quality of the measure (system of buildings , building, single service for example: lighting, air conditioning, driving force) of temperature, relative humidity, CO_2 rate; lighting;	Quality of the measure (entire building, single service for example: lighting, air conditioning, driving force) of temperature, relative humidity, CO_2 rate;	Availability of system to monitor energy demand and local energy ailability (in direct or mulated production);
	A	B	C	D	E
TECHNICAL SOLUTIONS	Supply capacity of thermal and cooling energy for system of buildings, single building or single thermal zone;		Supply capacity of thermal and cooling energy and adjustment of air changes depending on the needs of the occupants in the single areas;	Supply capacity of thermal and cooling energy and adjustment of air changes depending on the needs in the single areas;	Presence of energy production from renewable sources (Photovoltaic, geothermal, solar thermal); Availability of electrical energy storage; Availability of thermal energy storage; Ability to supply the necessary energy through the purchase of energy or local production from renewable sources or, also, through the integration with other availability in the territory (e.g. waste heat)

Monitoring and measurement:

	A
Is there a dedicated office or person for energy management? *[Specify.]*	Currently a person is dedicated
Is there a Building Management System (BMS) implemented? *[A Building Management System (BMS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems]*	No. We are implementing one
Data Collection *[Specify. which quantities are measured (e.g., energy consumption, temperature, relative humidity, CO2 rate); indicate if the measurement is aggregated (for whole campus, single building, building zone) or single service (example: lighting, air conditioning; thermal energy, driving force). for each of them give the measurement frequency (e.g., annual, monthly) weekly).]*	Electrical Flows are monthly verified on single building. Thermal energy consumption is daily measured in the scientific pole ("Rizzi"); in the other buildings thermal flows are monthly verified.
Energy flow measurements *[Specify if this specific action is performed on campus and if it is implemented in the BMS]*	Energy flows are monthly measured on single buildings, and we are implementing a BMS
Energy cost analysis *[Specify if this specific action is performed on campus and if it is implemented in the BMS]*	Currently a dedicated person makes a cost analysis with individual spreadsheets
Emission measurement *[Specify if this specific action is performed on campus and if it is implemented in the BMS]*	No
Other measurements *[Specify]*	No
Was an indoor air quality test ever conducted in the building? *[Specify]*	No
Did customers or employers ever report thermal comfort dissatisfaction? *[Specify]*	Yes

Technical solutions

	A
Main Source for Electrical Power *[Specify which is the main source for electrical power used within the campus]*	Electricity supplied by the national grid
Additional Relevant Source for Electrical Power *[Specify if you are using an additional relevant source for electrical power in your university]*	32 kW Photovoltaic power plant
Type of Supply Electrical Energy Contract *[Answer "metered" if you receive a bill from the utility company. Alternatively specify other methods]*	Metered. Energy supplier DSO (Engie)
Yearly Electrical Energy Consumption [kWh] (reference year 2019) *[Fill in the value of the electric energy consumption of one year]*	9.266.715 kWh
Yearly Electrical Energy Cost *[Fill in the value for the total energy cost of one year of activities]*	1.45 M€/yr
Main Source for Space Heating *[Specify the main source for space heating in the buildings]*	The scientific pole (336.500 m^3) is powered by a public district heating that recovers the waste heat produced by thecivil hospital plant (trigeneration plant with biofuel: natural gas and bio-oil). The other buildings (234.180 m^3) the main source is natural gas
Main Fuel Type *[Specify the main fuel type used by your company]*	Heat from district heating network and natural gas
Yearly main fuel Consumption (referred year: 2019) *[Fill in the value for your total energy consumption of one year of operation and specify the reference unit for the specific fuel]*	5.050 MWt for heat 90.500 m^3 for natural gas
Yearly main fuel Cost *[Fill in the value for the total energy cost of one year of activities.]*	The total amount is 1,5 M€/yr
Main heating Conversion Technology *[Specify which is the main conversion technology for space heating]*	District heating network and Boiler
Main Heating Distribution Technology *[Specify the main distribution technology for space heat]*	Hot water distribution by pipeline
Main Source for Space Cooling *[Specify which is the main source for buildings cooling]*	Electrical energy
Main Cooling Conversion Technology *[Specify which is the main conversion technology for space cooling]*	Refrigeration units

Main Cooling Distribution Technology *[Specify the main distribution technology for space cooling]*	Water pipelines
Additional relevant Fuels Type *[Specify if the University utilizes an additional relevant fuel type beside the main fuel type stated before]*	-
Type of additional fuels Supply Contract *[Answer "metered" if you receive a bill from the utility company. Alternatively specify other methods]*	metered
Yearly additional fuel Consumption (reference year: 2019) *[Fill in the value for your total energy consumption of one year of operation and specify the reference unit for the specific fuel]*	See above
Is there an on-site or off-site renewable energy system installed? *[Specify if the Campus has installed an energy system based on renewable sources (e.g., solar, biomass, wind, geothermal, hydro)]*	Yes
Which kinds of renewable energy systems are installed? *[Select the proper system(s)]*	Photovoltaic power plant
Percentage of Electrical Energy Consumption from Renewable Sources *[Specify the range of electrical energy consumption from renewable resources according to the overall electrical energy consumption in your campus]*	< 1%
Percentage of Thermal Energy Consumption from Renewable Sources *[Specify the range of thermal energy consumption from renewable resources according to the overall thermal energy consumption in your campus]*	0%
Renewable Electric Energy Self-Consumption [%] *[Specify percentage of self-consumed renewable electrical energy according to the total self-produced renewable electrical energy]*	100%
Renewable Energy Systems Added Value [€] *[Specify the approximative added value in euros per year obtained from renewable energy systems installed by your campus, as a sum of both energy discounts and feed-in tariff]*	0 € (is included in EPC contract and “District heating contract”)
Can you quantify approximately the overall savings achieved [%]? *[Indicate the approximate percentage for improvements yet achieved by the university after above selected measures have been taken*]	6%
Is there any additional potential for improvement in terms of energy efficiency? *[Specify if you consider that the University has a relevant potential for improving the energy efficiency at any level of building, indoor, lab]*	yes, by introducing point control systems (we are implementing)

Is there any additional potential for improvement in terms of energy efficiency? *[Estimate the approximate percentage of improvements that could be achieved by the university through additional energy efficiency measures]*	>25%
Is there any innovative technologies/solutions developed by the University for improvement of energy efficiency and environment? *[To describe other innovative solutions that are being developed by the University or even implemented at the testing level]*	The University of Udine has created a set of patents related to energy efficiency from management systems to electronic components. Some spin-offs have been activated
Are there any innovative solutions developed at your university that need a scale up from TRL 5 to TRL9? *[NOTE] The idea of the Smart Campus project was to foster the interregional collaboration to promote innovation in the Universities Campuses, supporting innovative technologies to advance them from TRL 6 to TRL 8 or 9 through the collaboration between different universities.* *One of the conclusions of the Smart Campus project was the need to enlarge the portfolio of innovative solutions.]*	The good practice "Aton project" within the Smart Campus project is implemented in the "Rizzi campus". The objective of the project was to create a district heating model based on the use of cascading energy in the territory that would encourage cooperation and synergies between different public and private stakeholders towards common energy saving objectives starting from the valorisation and specificity of the territories. In Italy, it is the first project in which a hospital's trigenerative power plant feeds a city network. The system consists of a trigenerative plant (86 MWt, 9.7 MWe, 26 MWf) fuelled by methane and bio-oil with an adjoining photovoltaic plant and a 13 km long district heating network that recovers the thermal waste from the hospital to meet the thermal requirements of university buildings and schools. The good practice "Smart€R" within the Smart Campus project is going to be implemented and it can be scaled up to reach the TRL 9. The project foresees to make "smart" fan coils and environments through the concept of IOT by inserting the electronic system designed with the aim of optimizing (reduce) energy consumption (electric and thermal) of the fan coil heating rooms (offices, laboratories, meeting rooms, warehouses, etc.) in buildings where the presence of people is occasional, and the plants are centralized. The existing fan coils with this system becomes a component connected to the Internet, visible and accessible on "cloud" space; this allows for advanced fan coiler management in order to implement innovative features such as: timed and/or scheduled local and/or remote timing and/or timer shutdown (via a specific "app" to be used on a common smartphone) or automatically when the user (and his /her smartphone) enters a space well-defined near the system; centralized management of the entire network for monitoring, diagnostics, optimization; replacement of the mechanical thermostat and the "electromechanical" management system of the seasonality; short term monitoring and data logging of machinery and environments. About 260 k€ are to be added for getting the final TRL 9.
If yes, what are the main bottlenecks you face for the scaling up?	Main bottlenecks identified is the lack of financial support

ENERGY EFFICIENCY, FUTURE SCENARIOS AND VISION SECTION

[To be completed by university]

In this section both a self-assessment of campus performance (in accordance with the barriers, obstacles,and relevance of energy efficiency) and targets at various levels of policy actions is required.

Relevance of energy efficiency, future outlook and Vision:

	A
Impact of energy efficiency measures during last three years? *[Specify if the university is considering receiving back a positive impact fromenergy efficient measures adopted in last three years (1 means not receiving any positive impact, 5 means very high positive impact).*]	3
Did you find obstacles on energy efficiency measures and their implementation? *[Specify, whenever the university has had some obstacles, in implementing EE measures]*	None relevance
Have you been able to overcome obstacles on energy efficiency measures and their implementation? *[Specify, whenever the university has had some obstacles, if it has been able to overcome them and correctly implement target actions]*	-
No idea of energy efficient measures *[Rate the relevance of this obstacle or barrier for the university energy efficiency either on the basis of your direct experience or according to your knowledge of the field (give a score between 1 and 5, 1 means small obstacle or low relevance, 5 means big obstacle or high relevance)]*	2
Time and staff resources in the company *[See above]*	5
External support (technical or economic) *[See above]*	4
Financial issues: Absence of dedicated budgetfor improvement of energy efficiency *[See above]*	5
Long pay-back period for possible projects *[See above]*	1
Other obstacles *[Specify]*	-

Which are the obstacles for the development/application of innovative technologies/solutions developed by the University (if any) for improvement of energy efficiency? *[On the basis of your direct experience specify the bottlenecks of innovative solutions that are being developed by the University or even implemented at the testing level]*	-
Have you planned to implement (additional) energy efficiency policies in your university? *[Specify an already planned intention to implement energy efficiency measures in the University]*	Implementation of a BMS and renewable sources
In which time framework *[Indicate the time horizon of eventually planned actions to be implemented by the university in the next future]*	4 years
Which reduction in overall energy consumption is expected? *[Indicate the percentage of expected reduction in energy consumption expected from the planned actions to be implemented by the university in the next future]*	A moderate decrease (3-4%) in energy consumption year-by-year is to be expected
Which reduction of fossil fuels is expected? *[Indicate the percentage of expected reduction in energy from fossil fuels expected from the planned actions to be implemented by the university in the next future]*	Over 15%
What is the “energy culture” spread at your university campus? (i.e. do students know about campus energy savings goals, is there any piece of information on this,…) *[Specify]*	Sustainability, circular economy, and energy are in the core of University of Udine, both in research and teaching

Annex 2

Smart Readiness

Indicator

Domain	Theme	Code	Service group	Smart ready service	Functionality level 0 (as non-smart default)	Functionality level 1	Functionality level 2	Functionality level 3	Functionality level 4	part of the proposed simplified indicator	Preconditions / Dependency on other services or building types
Heating	Controllability of Performance: Emission	Heating-S1	Heat control - demand side	Heat emission control	No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and presence control	1	Always to be assessed (if domain isrelevant)
Heating	Controllability of Performance: Production	Heating-S2a	Control heat production facilities	Heat generator control (all except heat pumps)	Constant temperature control	Variable temperature control depending on outdoor temperature	Variable temperature control depending on the load (e.g. depending on supply water temperature set point)			1	Not applicable to heat pumps
Heating	Controllability of Performance: Production	Heating-S2b	Control heat production facilities	Heat generator control (heat pumps)	On/Off-control of heat generator	Multi-stage control of heat generator capacity depending on the load or demand (e.g. on/off of several compressors)	Variable control of heat generator capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	Variable control of heat generator capacity depending on the load AND external signals from grid		1	Only applicable in case of a heatpump
Heating	Storage & Connectivity	Heating-S3	Control heat production facilities	Storage and shifting of thermal energy	None	HW storage vessels available	HW storage vessels controlled based on external signals (from BACS or grid)			1	Only applicable if storage is present
Heating	Reporting functionalities	Heating-S4	Information to occupants and facility management	Report information regarding heating system performance	None	Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage)	Central or remote reporting of current performance KPIs and historical data	Central or remote reporting of performance evaluation including forecasting and/or benchmarking	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1	Always to be assessed (if domain isrelevant)
Domestic hot water	Controllability of Performance	DHW-S1	Control DHW production facilities	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	Automatic control on / off	Automatic control on / off and scheduled charging enable	Automatic on/off control, scheduled charging enable and demand-based supply temperature control or multi-sensor storage management			1	Only applicable in case of DHWstorage with electric heating
Domestic hot water	Storage & Connectivity	DHW-S2	Flexibility DHW production facilities	Control of DHW storage charging	None	HW storage vessels available	Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)			1	Only applicable if storage is present
Domestic hot water	Information to occupants	DHW-S3	Information to occupants and facility managers	Report information regarding domestic hot water performance	None	Indication of actual values (e.g. temperatures, submetering energy usage)	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1	Always to be assessed (if domain isrelevant)
Cooling	Controllability of Performance: Emission	Cooling-S1	Cooling control - demand side	Cooling emission control	No automatic control	Central automatic control (e.g. central thermostat)	Individual room control (e.g. thermostatic valves, or electronic controller)	Individual room control with communication between controllers and to BACS	Individual room control with communication and occupancy detection	1	Always to be assessed (if domain isrelevant)
Cooling	Controllability of Performance: Production	Cooling-S2	Control cooling production facilities	Generator control for cooling	On/Off-control of cooling production	Multi-stage control of cooling production capacity depending on the load or demand (e.g. on/off of several compressors)	Variable control of cooling production capacity depending on the load or demand (e.g. hot gas bypass, inverter frequency control)	Variable control of cooling production capacity depending on the load AND external signals from grid		1	Always to be assessed (if domain isrelevant)
Cooling	Storage & Connectivity	Cooling-S3	Flexibility and grid interaction	Flexibility and grid interaction	No automatic control	Scheduled operation of cooling system	Self-learning optimal control of cooling system	Cooling system capable of flexible control through grid signals (e.g. DSM)	Optimized control of cooling system based on local predictions and grid signals (e.g. through model predictive control)	1	Only applicable if storage is present

Functionality level	
3	Level 3
2	Level 2
0	Level 0
1	Level 1
3	Level 3
2	Level 2
2	Level 2
2	Level 2
2	Level 2
2	Level 2
1	Level 1

Cooling	Reporting functionalities	Cooling-S4	Information to occupants and facility managers	Report information regarding cooling system performance	None	Central or remote reporting of current performance KPIs (e.g. temperatures, submetering energy usage)	Central or remote reporting of current performance KPIs and historical data	Central or remote reporting of performance evaluation including forecasting and/or benchmarking	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1	Always to be assessed (if domain is relevant)	1	Level 1
Controlled ventilation	Controllability of Performance	Ventilation-S1	Air flow control	Supply air flow control at the room level	No ventilation system or manual control	Clock control	Occupancy detection control	Central Demand Control based on air quality sensors (CO2, VOC,...)	Local Demand Control based on air quality sensors (CO2, VOC,...) with local flow from/to the zone regulated by dampers	1	Always to be assessed (if domain is relevant)	1	Level 1
Controlled ventilation	Reporting functionalities	Ventilation-S3	Feedback - Reporting information	Reporting information regarding IAQ	None	Air quality sensors (e.g. CO2) and real time autonomous monitoring	Real time monitoring & historical information of IAQ available to occupants	Real time monitoring & historical information of IAQ available to occupants + warning on maintenance needs or occupant actions (e.g. window opening)		1	Always to be assessed (if domain is relevant)	0	Level 0
Lighting	Controllability of Performance	Lighting-S1	Artificial lighting control	Occupancy control for indoor lighting	Manual on/off switch	Manual on/off switch + additional sweeping extinction signal	Automatic detection (auto on / dimmed or auto off)	Automatic detection (manual on / dimmed or auto off)		1	Always to be assessed (if domain is relevant)	3	Level 3
Dynamic building envelope	Controllability of Performance	DE-S1	Window control	Window solar shading control	No sun shading or only manual operation	Motorized operation with manual control	Motorized operation with automatic control based on sensor data	Combined light/blind/HVAC control	Predictive blind control (e.g. based on weather forecast)	1	Only applicable in case movable shades, screens or blinds are present	1	Level 1
Dynamic building envelope	Reporting functionalities	DE-S3	Feedback - Reporting information	Reporting information regarding performance	No reporting	Position of each product & fault detection	Position of each product, fault detection & predictive maintenance	Position of each product, fault detection, predictive maintenance, real-time sensor data (wind, lux, temperature...)	Position of each product, fault detection, predictive maintenance, real-time & historical sensor data (wind, lux, temperature...)	1	Only applicable in case movable shades, screens or blinds are present	1	Level 1
Electricity	Storage & Connectivity	Electricity-S1	Storage	Storage of (locally generated) electricity	None	On site storage of electricity (e.g. electric battery)	On site storage of energy (e.g. electric battery or thermal storage) with controller based on grid signals	On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity	On site storage of energy (e.g. electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid	1	Only applicable in case of local energy generation	1	Level 1
Electricity	Reporting functionalities	Electricity-S2	Electricity Loads	Reporting information regarding electricity consumption	None	Reporting on current electricity consumption on building level	Real-time feedback or benchmarking on building level	Real-time feedback or benchmarking on appliance level	Real-time feedback or benchmarking on appliance level with automated personalized recommendations	1		2	Level 2
Electricity	Reporting functionalities	Electricity-S3	Renewables	Reporting information regarding local electricity generation	None	Current generation data available	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1	Only applicable in case of local energy generation	3	Level 3
Electricity	Reporting functionalities	Electricity-S4	Storage	Reporting information regarding energy storage	None	Current state of charge (SOC) data available	Actual values and historical data	Performance evaluation including forecasting and/or benchmarking	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	1	Only applicable in case of local energy generation	1	Level 1
Electric vehicle charging		EV-S1	EV Charging	Charging capacity	Not present	Ducting (or simple power plug) available	0-9% of parking spaces has recharging points	10-50% or parking spaces has recharging point	>50% of parking spaces has recharging point	1	Always to be assessed (if domain is relevant)	0	Level 0
Electric vehicle charging	Storage & Connectivity	EV-S3	EV Charging - Grid	EV Charging Grid balancing	Not present (uncontrolled charging)	1-way controlled charging (e.g. including desired departure time and grid signals for optimization)	2-way controlled charging (e.g. including desired departure time and grid signals for optimization)			1	Only to be assessed if EV charging available on site	0	Level 0

Electric vehicle charging	Reporting functionalities	EV-S4	EV Charging - connectivity	EV charging information and connectivity	No information available	Reporting information on EV charging status to occupant	Reporting information on EV charging status to occupant AND automati identification and authorization of the drive to the charging station (ISO 15118 compliant)			1	Only to be assessed if EV charging available on site
Monitoring and control	Controllability of Performance	MC-S1	TBS interaction control	Single platform that allows automated control & coordination between TBS - optimization of energy flow based on occupancy , weather and grid signals	None	Single platform that allows manual control of multiple TBS	Single platform that allows automated control & coordination between TBS	Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather and grid signals		1	Always to be assessed
Monitoring and control	Flexibility	MC-S2	Smart Grid Integration	Smart Grid Integration	None - No harmonization between grid and TBS; building is operated independently from the grid load	Demand side management possible for (some) individual TBS, but not coordinated over various domains	Coordinated demand side management of multiple TBS			1	Always to be assessed
Monitoring and control	Information to occupants	MC-S3	Feedback - Reporting information	Central reporting of TBS performance and energy use	None	Central o rremote reporting of realtime energy use per energy carrier	Central or remote reporting of realtime energy use per energy carrier, combining TBS of at least 2 domains in one interface	Central or remote reporting of realtime energy use per energy carrier, combining TBS of all domains in one interface		1	Always to be assessed

0	Level 0
1	Level 1
2	Level 2
1	Level 1

SRI CALCULATION WITHOUT WEIGHTING FACTORS

	Energy Saving and operation		Respond to user needs				Respond to needs of the grid	
MAX VALUE	Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage	
Heating	8	4	6	4	2	3	5	**32**
Domestic hot water	3	2	0	5	0	3	4	**17**
Cooling	8	4	7	7	3	3	6	**38**
Controlled ventilation	3	2	3	3	6	3	0	**20**
Lighting	3	0	2	2	0	0	0	**7**
Dynamic building envelope	3	2	3	4	3	3	0	**18**
Electricity	5	6	0	5	0	9	3	**28**
Electric vehicle charging	0	0	0	6	0	3	4	**13**
Monitoring and control	4	4	0	7	0	3	3	**21**
TOTAL	**37**	**24**	**21**	**43**	**14**	**30**	**25**	**194**
	19,07%	12,37%	10,82%	22,16%	7,22%	15,46%	12,89%	100,00%

	Energy Saving and operation		**Respond to user needs**				Respond to needs of the grid	
SRI VALUE	Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage	
Heating	5	2	4	3	2	3	1	**20**
Domestic hot water	3	1	0	4	0	2	4	**14**
Cooling	5	1	4	3	2	1	1	**17**
Controlled ventilation	1	0	1	1	1	0	0	**4**
Lighting	3	0	2	2	0	0	0	**7**
Dynamic building envelope	1	1	1	1	0	1	0	**5**
Electricity	3	2	0	2	0	6	1	**14**
Electric vehicle charging	0	0	0	0	0	0	-2	**-2**
Monitoring and control	2	2	0	3	0	1	3	**11**
TOTAL	**23**	**9**	**12**	**19**	**5**	**14**	**8**	**90**
	25,56%	10,00%	13,33%	21,11%	5,56%	15,56%	8,89%	100,00%

	Energy Saving and operation		Respond to user needs				Respond to needs of the grid
SRI %	Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage
Heating	63%	50%	67%	75%	100%	100%	20%
Domestic hot water	100%	50%	Not applicable	80%	Not applicable	67%	100%
Cooling	63%	25%	57%	43%	67%	33%	17%
Controlled ventilation	33%	0%	33%	33%	17%	0%	Not applicable
Lighting	100%	Not applicable	100%	100%	Not applicable	Not applicable	Not applicable
Dynamic building envelope	33%	50%	33%	25%	0%	33%	Not applicable
Electricity	60%	33%	Not applicable	40%	Not applicable	67%	33%
Electric vehicle charging	Not applicable	Not applicable	Not applicable	0%	Not applicable	0%	-50%
Monitoring and control	50%	50%	Not applicable	43%	Not applicable	33%	100%

Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage
62%	38%	57%	44%	36%	47%	32%
Energy Saving and operation		Respond to user needs				Respond to needs of the grid
52%		46%				32%
SMART READINESS INDICATOR						
46,39%						

SRI CALCULATION WITH WEIGHTING FACTORS

	Energy Saving and operation		Respond to user needs				Respond to needs of the grid
	Energy savings	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupant	Flexibility for the grid and storage
FACTOR TO SET	50%	50%	25%	25%	25%	25%	100%
FACTOR TO SET	33%		33%				33%
	16,7%	16,7%	8,3%	8,3%	8,3%	8,3%	33,3%

Figure 13 – Aggregation of impact scores to three key functionalities or to a single score

	Energy Saving and operation		Respond to user needs				Respond to needs of the grid	
MAX VALUE	Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage	
Heating	6,99	5,39	4,62	1,50	2,31	1,62	12,93	**35**
Domestic hot water	2,62	2,69	0,00	1,88	0,00	1,62	10,35	**19**
Cooling	6,99	5,39	5,39	2,63	3,46	1,62	15,52	**41**
Controlled ventilation	2,62	2,69	2,31	1,13	6,93	1,62	0,00	**17**
Lighting	2,62	0,00	1,54	0,75	0,00	0,00	0,00	**5**
Dynamic building envelope	2,62	2,69	2,31	1,50	3,46	1,62	0,00	**14**
Electricity	4,37	8,08	0,00	1,88	0,00	4,85	7,76	**27**
Electric vehicle charging	0,00	0,00	0,00	2,26	0,00	1,62	10,35	**14**
Monitoring and control	3,50	5,39	0,00	2,63	0,00	1,62	7,76	**21**
TOTAL	**32,33**	**32,33**	**16,17**	**16,17**	**16,17**	**16,17**	**64,66**	**194**
	32,33	**32,33**	**16,17**	**16,17**	**16,17**	**16,17**	**64,66**	**194**
	16,67%	16,67%	8,33%	8,33%	8,33%	8,33%	33,33%	100,00%

	Energy Saving and operation		Respond to user needs				Respond to needs of the grid	
SRI VALUE	Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage	
Heating	4,37	2,69	3,08	1,13	2,31	1,62	2,59	
Domestic hot water	2,62	1,35	0,00	1,50	0,00	1,08	10,35	
Cooling	4,37	1,35	3,08	1,13	2,31	0,54	2,59	
Controlled ventilation	0,87	0,00	0,77	0,38	1,15	0,00	0,00	
Lighting	2,62	0,00	1,54	0,75	0,00	0,00	0,00	
Dynamic building envelope	0,87	1,35	0,77	0,38	0,00	0,54	0,00	
Electricity	2,62	2,69	0,00	0,75	0,00	3,23	2,59	
Electric vehicle charging	0,00	0,00	0,00	0,00	0,00	0,00	-5,17	
Monitoring and control	1,75	2,69	0,00	1,13	0,00	0,54	7,76	
TOTAL	**20,10**	**12,12**	**9,24**	**7,14**	**5,77**	**7,54**	**20,69**	**83**
	24,33%	14,68%	11,18%	8,65%	6,99%	9,13%	25,05%	100,00%

	Energy Saving and operation		Respond to user needs				Respond to needs of the grid
SRI %	Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage
Heating	63%	50%	67%	75%	100%	100%	20%
Domestic hot water	100%	50%	Not applicable	80%	Not applicable	67%	100%
Cooling	63%	25%	57%	43%	67%	33%	17%
Controlled ventilation	33%	0%	33%	33%	17%	0%	Not applicable
Lighting	100%	Not applicable	100%	100%	Not applicable	Not applicable	Not applicable
Dynamic building envelope	33%	50%	33%	25%	0%	33%	Not applicable
Electricity	60%	33%	Not applicable	40%	Not applicable	67%	33%
Electric vehicle charging	Not applicable	Not applicable	Not applicable	0%	Not applicable	0%	-50%
Monitoring and control	50%	50%	Not applicable	43%	Not applicable	33%	100%

Energy savings on site	Maintenance & fault prediction	Comfort	Convenience	Health & wellbeing	Information to occupants	Flexibility for the grid and storage
62,16%	37,50%	57,14%	44,19%	35,71%	46,67%	32,00%
Energy Saving and operation		**Respond to user needs**				Respond to needs of the grid
49,83%		45,93%				32,00%
SMART READINESS INDICATOR						
42,59%						