Climate change REsilience framework for health SYStems and hospiTALs

DD1.2: [Physical Monitoring Design]	
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Executive summary

This deliverable is produced as part of action D.1 "*Development of a common monitoring methodology*" of the LIFE RESYSTAL project. Action D1 aim at developing a common monitoring methodology pilot scale/level to allow proper evaluation of the project actions and their expected results along the project duration and beyond for the seven pilot hospitals shown in the table below (Table 0.1).

Table 0.1: LIFE RESYSTAL Pilot Hospitals

Country	City	Involved hospitals
France	Millau	Hospital Center of Millau: - Hospitals of Millau - Hospital of Saint-Affrique
Spain	Ourense	Galician Health Service (SERGAS): - University hospital of Ourense - Public hospital of Verin - Public hospital of Valdeorras
Greece	Athens	Nikaia General State Hospital (NHOSP)
Italy	Bari	University hospital complex: - Polyclinic of Bari - Giovanni XXIII hospital

The scope of this deliverable is to provide an overview of the measurement equipment that will be used for the monitoring of the Key Performance Indicators (KPIs)/parameters, aimed at monitoring the progress of the hospital in term of climate change adaptation for the entire duration of the project, covering climate, environmental, social, economic and political aspects identified in the first deliverable of action D1, deliverable DD1.1. "*Monitoring methodology*", with which this deliverable is intrinsically connected.

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Table of abbreviations	
Abbreviations	**Meaning**
CCA	Climate Change Adaptation
EWS	Early Warning System
KPIs	Key Performance Indicators
VGS	Vertical Green System

1. Introduction

This deliverable is part of action D.1 "*Development of a common monitoring methodology*" of LIFE RESYSTAL project; D1 is aimed at developing a common pilot scale monitoring methodology to allow proper evaluation of the project actions and their expected results along the project duration and beyond for the seven pilot hospitals.

It is based on the Key Performance Indicators (KPIs)/parameters identified in deliverable DD1.1 aimed at monitoring the progress of the hospitals in term of climate change adaptation for the entire duration of the project and beyond.

In particular, it is focused on the fact that "in order to guarantee the effectiveness and the optimum management of the physical interventions realized during the project in the short and long term, it will be needed to measure and record the parameters that are affected by these interventions".

In this deliverable measurement instruments/sensors to be used in order to measure KPIs/parameters are shown.

The following chapters describe the scope and the structure of the current deliverable.

Scope of the Deliverable

The scope of this deliverable is to provide, based on the good practices currently used, an overview about the monitoring system that will be used for the monitoring of the KPIs/parameters identified in deliverable DD1.1.

The monitoring system in each pilot hospital site will be mainly composed by measurement equipment/sensors and data acquisition system facilitating data analysis, interpretation and storage. Its features will depend on the specific type of interventions foreseen in the pilot (e.g.: temperature air reduction, reduction of heat island effect due to the use of green infrastructure, runoff reduction, etc.).

It is pointed out that in this deliverable *type* of measurement equipment/sensors will be provided, whereas, regarding the *number* and *position* of the measurement equipment/sensors, additional details will be given later during the execution of the project, once more information are available. For example, as regards the green infrastructure, further investigation will bring to know:

- ✓ the type of green infrastructure that will be realized (i.e.: a green facade or a living wall), if they will be directly attached to the building facades/the interior walls, or if they will be placed on support structures such as wire, mesh, trellis, located to a certain distance to the building facades, or on a free-standing system, such as fence or column;
- ✓ the surface (m^2) and height (m) of the green infrastructures that will be installed on building facades/interior walls;
- ✓ the orientation of the green infrastructures, i.e.: south, west, south-west, east, south-east;

Moreover, a draft design, including drawings (e.g.: front, section) of the green infrastructures that will be installed on the building facades and on the interior walls would be helpful.

Another aspect to be investigated regards the air pollution removal (PM_{10}/$PM_{2.5}$ and O_3) for which it will be needed to define which kind of monitoring stations will be used in each of the seven pilot hospitals (i.e.: fixed monitoring stations or mobile stations/laboratories).

Structure of the Deliverable

Within this Deliverable, besides **Chapter 1** that constitutes the present Introduction and the Scope of the deliverable, the following sections are included:

- **Chapter 2** outlines the methodological approach;
- **Chapter 3** presents an overview of the measurement equipment that can be used for the KPIs monitoring;
- **Chapter 4** draws the conclusion remarks;
- **Chapter 5** shows the main references used.

2. Methodological approach

The approach followed in this deliverable is based on RINA-C experience and knowledge in the monitoring field and it consists of a desk analysis and literature review regarding the good practices used in the monitoring of the KPIs/parameters similar to those identified in deliverable DD1.1 of LIFE RESYSTAL project.

Attention has been paid to documents, studies and articles showing the measurement devices used for monitoring purposes, in particular concerning:

- the monitoring campaigns carried out to check the performances of green infrastructure on buildings (i.e.: green facades and green roofs). These performances, concerning temperature reduction of the air surrounding the buildings, consist mainly in a reduction of the energy consumption for air conditioning in summer and in an increase of the thermal insulation in winter allowing a higher comfort to people living inside buildings (green control of microclimate in buildings);
- the reduction of the Urban Heat Island (UHI) effect thanks to the installation of green infrastructures, mainly green facades and green roofs;
- the runoff reduction that can be reached through the use of balancing tanks operating as a temporary storage unit and having the purpose of regulating the flow of rainwater discharged into a final receptor. In fact, in case of heavy rainfall events, the water exceeding the maximum allowable discharge rate is stored temporarily in the tank and released over a longer period of time;
- the air pollution removal with specific focus on the reduction of particulate matter (PM_{10} and $PM_{2.5}$) and ozone.

3. Measurement equipment

In this chapter measurement equipment/sensors to use for monitoring purposes are shown. The monitoring equipment are described based on the objectives mentioned in the "Scope of the deliverable". The measurement equipment are organized as for their goals listed below:

- Improved Environmental and Climate Performance (including resilience to climate change);
- Better use of resources;
- Social, Political and Economic Performance, Market Uptake, Replication;
- Communication, dissemination, awareness rising.

For a summary of the seven hospitals' KPIs, including information on monitoring (e.g.: frequency, devices, actors involved, etc.), please see the specific tables included in deliverable DD1.1 *Monitoring methodology.*

3.1 Improved Environmental and Climate Performance (including resilience to climate change)

3.1.1. Green and Blue infrastructure

Indicator: Hectares of green and blue infrastructure

This indicator depicts the hectars of green (i.e.: tree planting, rewilding of lawns, green roof, absorbent parks) and blue (i.e.: rivers, canals, ponds, wetlands, floodplains, water treatment facilities, sustainable urban drainage systems) infrastructures that will be created in the pilot hospitals.

Monitoring of this indicator will be carried out by checking m^2/ ha of green/blue infrastructure created through **laser distance meters** or using hospitals' planimetry; it has been assumed that 10 trees correspond to 100 m^2 of green infrastructures.
A monitoring frequency of six months for this indicator has been assumed.

3.1.2 Climate hazards - Infrastructure resilience

Indicator: Total hospitalized patients

This indicator depicts the total hospitalized patients in buildings at risks. Monitoring of this indicator will be carried out through the **examination of medical records**. A monitoring frequency of 1 year for this indicator has been assumed.

Indicator: Patients' health/status benefit since the introduction of green infrastructures compared to the total number of hospitalized patients

This indicator depicts the patients health (status benefit) since the introduction of green infrastructures compared to the total number of hospitalized patients. Monitoring of this indicator will be carried out based on information provided by hospitals and patients through **patients medical records**. Moreover, the use of **short voluntary questionnaire or alternative easier ways** (i.e.: use of phone "sms") aimed at checking any improvement in the patient's health and status due to the green infrastructure installation will be investigated.
A monitoring frequency of one year for this indicator has been assumed.

Indicator: Buildings with improved resilience thanks to Green and Blue infrastructure

This indicator depicts buildings that reached an improved resilience due to the Green and Blue infrastructure. Monitoring of this indicator will be carried out by counting **the number of those buildings**.
A monitoring frequency of six months for this indicator has been assumed.

3.1.3 Climate hazards - Flooding

Indicator: Hectars (improved conditions)

This indicator depicts the contribute provided by green infrastructure (i.e.: tree planting, rewilding and green corridors) to improved flooding resilience. Monitoring of this indicator will be carried out by checking m^2/ha of green area covered through **laser distance meters** or using hospitals' planimetry.
A monitoring frequency of six months for this indicator has been assumed.

Indicator: Runoff reduction

Extreme precipitation events are the climatic drivers of urban runoff and urban flooding and are expected to increase in the future due to climate change. Urban runoff does not only depend on *the intensity of rainfall* events but also on *the degree of soil permeability.*

In the natural environments the meteoric waters are washed and filtered slowly from and through the soil. In the urban environment the impermeable surfaces hamper the natural water infiltration and cause a rapid water runoff towards the final receptor systems. In case of extreme precipitation events, the excessive runoff and the limited capacity of receptors can cause temporary flooding in the urban spaces.

The intensity of flooding phenomena directly depends on the intensity of the surface runoff, which, in turn, depends on the intensity of rainfall in relation to the absorption capacity of the soil. In general, the higher the intensity of rainfall, the more likely it is that the soil's ability to absorb water is exceeded and therefore an intense surface runoff is generated.

A method currently used to limit the urban runoff and urban flooding during extreme precipitation events consists in the use of storage unit, called "**balancing tanks**[1]" where rainwater flow is stored and regulated. The rainwater flow shall be measured, through flow sensors, both at the inlet and at the outlet of the balancing tanks. This allows to estimate the **runoff reduction** given by the rainwater flowrate measured at the outlet of the balancing tanks; this flowrate depends on the maximum allowable flowrate that can be discharged into the receiving body.
Balancing tanks are usually buried and they can be prefabricated or in reinforced concrete material.
They are sized based on:

- the rainwater collection surface (extension and type);
- the average and maximum rainfall (height) on the area where balancing tank will be installed;
- the maximum flow rate, provided by the competent bodies, that can be discharged into the receiving body.

Sizing of balancing tanks consists in identifying the volume of the storage tank and the diameter of the discharge pipe (therefore the flow rate).
There are two types of balancing tanks on the market: gravity balancing tanks and balancing tanks with electric pump below described.

A. Gravity balancing tanks

The balancing tank is a storage unit that has the purpose of regulating the flow of rainwater discharged into the final receptor (public sewer, ditch, watercourse, etc.); the aim is to discharge a flow that does not exceed the limit specified by the regional and local governments and/or the water authority.
Balancing tanks are required in all those areas where high soil impermeability overloads stormwater sewerage systems, ditches or natural watercourses, thus creating rainwater disposal problems, in particular during severe meteorological events.
Gravity balancing tanks (Figure 3.1) are used as temporary storage of rainwater collected from an impermeable surface (roads, car parks, roofs, coverings in general, warehouses, pavements, etc.) during a meteorological event.

[1] : https://rototec.it/en/gravity-balancing-tanks/

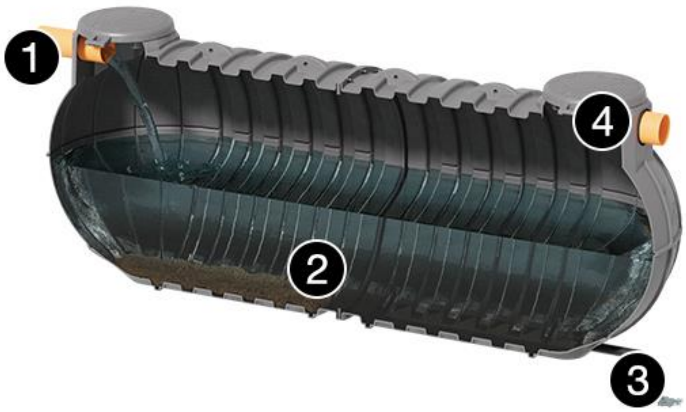

Figure 3.1: Gravity balancing tanks

Legend:

1. **Inlet pipe:** to feed in the flow
2. **Stilling zone:** where sedimentation of the incoming water takes place
3. **Outlet pipe:** to regulate the flow of rainwater to discharge to the final receptor
4. **Safety overflow:** a safety device

The rainwater is fed to the gravity balancing tank through an inlet pipe and is discharged into the receptor through an outlet pipe located at the bottom of the tank. The diameter of the outlet pipe is such that the maximum discharge flow is never more than the permitted discharge to the receptor. In this manner, in the case of heavy rainfall, the water exceeding the permitted discharge rate is stored temporarily in the tank and released over a longer period of time.

B. Balancing tanks with electric pump

The difference between gravity balancing tanks and balancing tanks with electric pump (Figure 3.2) is that, in this case, the rainwater is fed to the balancing tank with pump through an inlet pipe and it is discharged to the receptor by a submersible pump. The discharge flow rate of the pump can be controlled using a manual valve located on the pump delivery pipe. In this manner, in the case of heavy rainfall, the water exceeding the pump discharge rate is stored temporarily in the tank and released over a longer period of time.

Figure 3.2: Balancing tanks with electric pump

Legend:

1. **Inlet pipe:** to transfer the flow into the tank
2. **Stilling zone:** for sedimentation of the suspended solids
3. **Submersible electric pump:** to regulate the flow of rainwater to discharge to the final receptor
4. **Safety overflow:** a safety device

In conclusion, as abovementioned runoff reduction can be measured through flow sensor that shall be placed both at the inlet and at the outlet of the balancing tank.

Early Warning System (EWS)

In this section a preliminary overview of a system aimed at forecasting extreme weather events in order to avoid or reduce damages caused by natural hazards is shown.

From literature, to cope with climate change and the increasingly frequent occurrence of extreme rainfall events, the implementation of a forecasting system for meteoric events is recommended; in particular, a system of Early Warning (EW), combined with a better management of the urban drainage network during the forecast meteoric event. EW systems are key elements of climate change adaptation and disaster risk reduction and are aimed at avoiding or reducing the damages caused by hazards. EW systems increase flood preparedness and lead to substantial reduction of damages in case of a heavy rain and flood event.

In fact, the main objective of an EW system is to empower individuals and communities to act in time and in an appropriate manner to reduce the possibility of loss of life, damage to property and the environment, and loss of livelihoods. These systems include detection, analysis, prediction, and then warning dissemination followed by response decision-making and implementation. Early warning information are standardized messages (signs, words, sound or images) that announce an imminent danger, for example from natural hazards.

It is worth mentioning that early warning information itself does not keep hazards from turning into disasters. It needs entire EW systems for enabling individuals at-risk, communities and organizations to prepare and act, appropriately, in advance and during impending hazard events.

To be effective and complete, an EW system needs to comprise four interacting elements namely: (i) risk knowledge, (ii) monitoring and warning services, (iii) dissemination and communication and (iv) response capability. The EW system is a tool of fundamental importance in the management and prevention of risks associated with extreme weather events. It is based on two basic steps: a) the identification and b) tracking of the event.

Based on the radar observations, the system identifies the storm cells, classifies them and, thanks to the processed data relating to the radial velocity, estimates their movement and direction. The storm cells are tracked and characterized by different parameters derived from radar and satellite data as: maximum echo, area, cloud temperature and the "vertical integrated liquid" (VIL) that is the estimate of the amount of water included in an air column.

The EW systems consist of:

- *weather station, composed of a network of rain gauges: these data can be used for the calibration of the radar reflectivity field and thus obtain reliable estimates at high spatial density; they also serve to expand the site's rainfall database;*
- *radar: allows to determine the intensity and movement of the event. It defines the displacement vector of the radar echoes and, knowing the time scan, the speed vector;*
- *satellite: offers the possibility to see the areas not reachable by the radar;*
- *platform for the event modeling: data are processed and the level of risk and the procedures to adopt are defined;*
- *database: digital archive of rainfall and significant events related to the site of interest.* [1]

3.1.4 Air - Improved resilience to heat waves

Indicator: Temperature air reduction from green roofs and facades outdoor

These indicators are referred to the reduction of air temperature due to green roofs and green facades (i.e.: greening vertical system applied to a facade of a building).
Before showing which instruments are generally used for monitoring purposes, a brief overview on green facades and green roofs and their contribution to the climate performance is given below.

Green roofs and facades consist in the application of living vegetated horizontal and vertical layers on buildings with the main aim of allowing a higher comfort to people living inside the buildings.
The design of green roofs and facades depends on factors as the building characteristics, the climatic conditions of the area and the surrounding conditions. Their social, environmental and aesthetical positive impacts depend on the climatic conditions of the area, on the urban context, on the greening technology and on the building characteristics.

The cooling effect of green facades and green roofs is achieved by shading the buildings from solar radiation, by providing evapo-transpirative cooling, by reflecting the solar radiation, by thermally insulating the building with an air cavity, by influencing air speed on buildings.
The importance of green systems applied on building roofs or facades in cities has been increased due to their ability to sustainably improve the energy efficiency of buildings and to mitigate the Urban Heat Island (UHI) effect.

It has been demonstrated by experimental measurement campaigns, as several green facade and green roofs interventions help to reduce the surface temperature of the facade below the green, which is exposed to direct solar radiation, compared to the same bare facade. This phenomenon is more evident when the incident solar radiation increases and when solar radiation reaches its maximum. The green facade effectiveness, in this way, is due to the shielding from solar radiation, involving also complex phenomena of "evapotranspiration", and modifying convection and radiation heat transfer from the facade or roof surface to the surroundings. [2]

Green systems moderate the indoor thermal environment by handling the building envelope heat transfer processes (radiative, convective and conductive). The transfer of a heat wave through a vertical green is a multifaceted phenomenon due to the interposition of the plant layer between the outdoor environment and the building envelope. Green systems can permit the physical shading of the building and promote evapotranspiration in summer and increase the thermal insulation in winter.

The main effects of a green facade and a green roof are:

- the shading action against the solar radiation which hits the external facade and roof;
- the evapotranspiration action which limits the temperature fluctuation of the external facade;
- the modification of convective and radiative heat transfer at the façade, because of the air gap created between it and the green layer;
- to limit the heat island effect;
- to improve air quality;
- to control thermal loads for summer cooling.

<u>Green vertical systems</u>

Green vertical systems consist of vertical structures that spread vegetation that may or may not be attached to a building façade or to an interior wall. Attending to the level of complexity, there are several green facade typologies that range from the simplest configuration to the most complex and high-tech design. Based on the type of vegetation, growing method, construction techniques and support structures used, these systems can be divided into two major groups: green facades and living walls (Figure 3.3).
Green facades are characterized by climbing plants rooted in the ground or in pots at different heights of the facade. The vegetation cover is formed by climbing plants or cascading groundcover. Specially designed structures can be used to force the plant development through the building's wall, which can serve as support for the climbing vegetation. [3]

Green facades are classified as *direct or indirect* due to the absence or presence of a support, respectively. In the direct greening facades plants climb directly on the facade of the building through morphological features, such as aerial roots, leaf tendrils and adhesion pads, without any added support. Indirect greening facades are characterized by plants that climb on a structural support, such as wire, mesh, trellis, located to a small distance to the wall or on a free-standing system, such as fence or column.

Living walls are generally more complex infrastructures that involve a supporting structure with different attachment methods. They are wall-based greening methods, composed of pre-cultivated modular panels or planted bags, containing a growing medium (soil, foam, felt, mineral wood, perlite) and an irrigation system, fixed to a wall or free-standing frame.
Living walls are classified as continuous or modular: the former is based on lightweight and permeable screens in which plants are inserted individually; the latter is composed of modular elements, such as trays, vessels, planter tiles and flexible bags, which include the growing media where plants can grow. The modular elements are fixed to a wall or free-standing frame with artificial irrigation and fertigation system. The presence of a gap between the building wall and the greening system (generally from 3 cm to 15 cm) acts as a thermal buffer, improving its thermal insulation impact on building. [4]

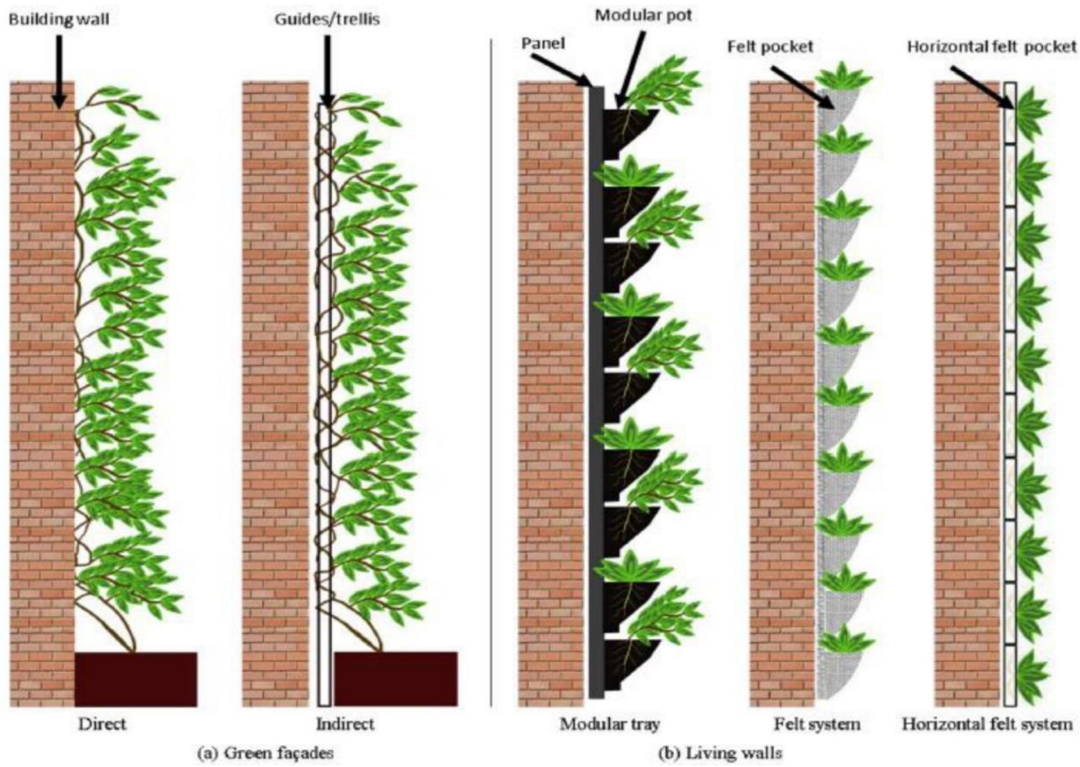

Figure 3.3: Green facades and living walls

The benefits of living walls consist in an increment of facade thermal insulation, an extension of its lifetime, a reduction of solar and noise absorbance. The benefits produced on the building include a mitigation of the Urban Heat Island (UHI) effect, a decrease of heat load and of energy consumption, an improvement of the indoor thermal and acoustic comfort, the air pollution mitigation, the enhancement of the commercial value of the real estate.
With respect to a living wall system, a green facade is characterized by a smaller selection of plants; it has fewer variables to manage in relation to the supporting structure, the nutrients and watering system management. It is, therefore, a cheaper solution, easy to maintain, and requires little energy.

As regards green facades from literature and, in particular, from good practices used during experimental campaigns, the following parameters are measured in order to evaluate the performance of the green facade (i.e.: reduction of the air temperature surrounding the buildings):

- external surface temperature of the bare facade;
- external surface temperature of the green facade;
- external air temperature and relative air humidity;
- air temperature and relative humidity in the cavity between the facade and the plant layers/modules of green façade systems (if present);
- solar radiation on the building facade (through a pyranometer);
- wind velocity and direction (through an anemometer).

The measurement instruments/sensors used for monitoring the above-mentioned parameters are:

- **thermoresitors**/resistance thermometers to measure the temperature of the external bare and green facades exposed to the solar radiation (i.e.: Tecno.EL s.r.l, Rome, Italy, or Tre C-Everwatt, Milan, Italy, or similar manufacturers);
- **sensors to measure the temperature and the relative humidity** of the external air and of the air in the cavity between the wall and the plant layers (i.e.: Rotronic, a Switzerland company of the Process Sensing Technologies (PST) group, or similar manufacturers such as Sensirion AG, Switzerland, or R.M. Young company, USA);
- **a pyranometer** to measure the solar radiation (EKO Instruments, or the Eppley Laboratory USA, Europe, Japan,or similar manufacturers);
- **an anemometer** to measure the wind velocity and wind direction (i.e.: Young Company, USA, MeteoLabor AG Products, or similar manufacturers).

Sensors are shielded from solar radiation.

Parameters can be monitored *automatically*, for example, with a frequency of 60 s, averaged every 15 minutes, and recorded and stored by means of a *data logger* for measurement and control (i.e.: Campbell Scientific, Logan, USA, with worldwide offices, also in Europe, or similar manufacturers[2]).

It is worth mentioning that measurement of wind velocity is strictly connected to the evapotranspiration of the plants. Evapotranspiration is the loss of water from the soil both by evaporation from the soil surface and by transpiration from the leaves of the plants growing on it. Evapotranspiration represents the amount of total water in the gaseous state that passes from the substrate and plants to the atmosphere. This change in state involves an energy absorption which results in a decrease of the surrounding air temperature.

For this reason, if the wind velocity is high, the evapotranspiration is strongly accentuated, and the layers of wet air that would tend to accumulate on evaporating surfaces are removed thus decreasing the change in state of water and consequently decreasing the energy absorption (which allows a decrease of the air temperature).

Factors that affect the rate of evapotranspiration include also, besides wind velocity, the amount of solar radiation, temperature, and soil moisture.

Green horizontal systems (green roofs)

Green roofs, also known as ‘eco-roofs’ or ‘living roofs’, are engineered ecosystems covering the rooftops, in which specific materials and layering support the growth of vegetation connecting plants with the natural ground.

They are engineered systems typically consisting of a series of layers including (from bottom to top): a waterproofing root resistant barrier preventing root penetration and damage of the roof membrane, a water retention layer designed to store water, a drainage layer made up by grained porous media or plastic profiled elements which carry away the excess of water, a filter membrane

[2] Effects of vertical green technology on building surface temperature, Department of Agricultural and Environmental science DISAAT, University of Bari, Italy

preventing the washout of fine soil particles, a lightweight substrate typically consisting of expanded shales and clay minerals, and vegetation.

Green roofs provide ecosystem services in urban areas, including reduction of storm-water runoff, better regulation of building temperatures, reduction of urban heat-island effects and increase of urban wildlife habitat.

There are two main types of green roofs: extensive and intensive. Extensive green roofs are shallow, usually with 4 inches of substrate, and do not typically support a large diversity of plant species because of root zone limitations. Intensive green roofs are more like rooftop gardens with deep substrate (from 4 inches to several feet) and a wide variety of plants. Most buildings are not designed to withstand the additional weight loading for intensive roofs. For this reason, they are typically limited to new construction. Extensive green roofs are shallower and generally much better suited to the structural capabilities of existing buildings and, therefore, are installed more often. [5]

The main aim of green roofs, similarly to green facades, is to allow a higher comfort to people living inside the buildings. Their design depends on factors as the building characteristics, the climatic conditions of the area and the surrounding conditions.

The following parameters are normally measured to evaluate the performance of the green roofs:

- air temperature and relative humidity;
- solar radiation;
- wind velocity and direction.

Measurement instruments / sensors that can be used for parameters monitoring are:

- **sensors to measure the temperature and the relative humidity** of the air surrounding the roof (i.e.: Rotronic, a company of the Process Sensing Technologies (PST) group, Switzerland, or similar manufactures such as Sensirion AG, Switzerland, or R. M. Young Company, USA)
- **a pyranometer** to measure the solar radiation (EKO Instruments, or the Eppley Laboratory USA, Europe, Japan, or similar manufacturers);
- **an anemometer** to measure the wind velocity and wind direction (i.e.: Young Company, USA, or similar products by other manufacturers);
- soil moisture probes.

Parameters will be monitored *automatically* and recorded and stored by means of a *data logger* for measurement and control (i.e.: Campbell Scientific, Logan, USA, with worldwide offices, also in Europe, or similar manufacturers).

- Indicator: Temperature air reduction from green indoors (i.e.: walls, facades) and green corridors

Green indoors (walls, facades)

As above-mentioned the *main benefits of vertical green systems (VGS) on the buildings are mitigation of the heat island effect in cities, passive cooling of buildings by means of shading the walls and increasing the thermal insulation of the building envelope, or biodiversity enhancement. Besides air temperature reduction, there are also numerous advantages if these vertical greening systems are* *used inside buildings, such as indoor air purification or biofiltration, retention of suspended particles or fixation of CO_2 and VOCs*. [6]

VGS protects building facades from extreme heat radiation as well as high precipitation besides creating an attractive visual presentationhttps://www.sciencedirect.com/science/article/pii/S2666123321000635 - bib0183. This is the way through which VGS reduces the building's maintenance cost and prolongs the lifespan. Nowadays, VGS has been rapidly used in urban areas which increase awareness amongst city residents to become more environmentally friendly and to conserve and preserve natural biodiversity.

Moreover, the indoor vertical greenery system provides fresh indoor environment, acoustic comfort and thermal conditions to the building occupants. Also, human psychological improvement can be provided by indoor vertical greenery system. For example, to develop medical and psychological status amongst heart and lung disease patients or surgery patients, it is valuable to integrate both the indoor and outdoor VGS in rehabilitation centers and hospitals. [7]

The main variables affecting the environment inside buildings are temperature and humidity. Therefore, the following parameters are normally measured to assess the performance of the green indoors (walls, facades) on the environment: *the indoor air temperature and relative humidity*.

Measurement instruments that can be used for parameters monitoring include:

- **sensors to measure the air temperature** (i.e.: Rotronic, a company of the Process Sensing Technologies (PST) group, Switzerland, or similar manufactures);
- **sensors to measure the air relative humidity** (i.e.: Rotronic, a company of the Process Sensing Technologies (PST) group, Switzerland, or similar manufactures).

Parameters will be monitored *automatically* and recorded and stored by means of a measurement and control *data logger* (i.e.: Campbell Scientific, Logan, USA, with worldwide offices, also in Europe, or similar manufactures). The data logger can be connected to a computer to ease the analysis of the information. Temperature and humidity data can be recorded every 15 min.

It is worth mentioning that literature shows that promising results are obtained (i.e.: temperature decrease inside buildings) and cooling effect is observed using green indoor systems. Therefore, they allow a reduction of the air conditioning requirements with the associated energy savings.
It is important to point out that high humidity levels could occur near the green system due to irrigation and plant evapotranspiration, which is beneficial in case of dry indoor environments.
If necessary, proper ventilation is advised to avoid problems associated with excessive moisture. In fact, an excess of indoor humidity can cause problems, so monitoring this value is advisable to moderate the condition by ventilation when required.

Green corridors (connecting hospital buildings)

Green corridors are long green spaces or linear parks that help renature cities by connecting green areas to one another to form urban green infrastructure networks. Green corridors are particularly beneficial for urban biodiversity as well as cooling cities and improving air quality by providing cool air pathways. They can change the microclimate of the area and improve urban ventilation as they create a path for cooler air from outside to penetrate into the more densely built areas, also reducing the Urban Heat Island (UHI) effect that occurs due to the modification of land surfaces and generation of waste heat.

In particular, as regards the pilot hospitals, green corridors will be realized in the hospital surroundings connecting the different hospital buildings.

The parameters that should be measured to assess the performance of the green corridors on the environment are the air temperature and the air relative humidity.

Measurement instruments for parameters monitoring shall include:

- **sensors to measure the air temperature** (i.e.: Rotronic, a company of the Process Sensing Technologies (PST) group, Switzerland, or similar manufactures);
- **sensors to measure the air relative humidity** (i.e.: Rotronic, a company of the Process Sensing Technologies (PST) group, Switzerland, or similar manufactures).

Parameters will be monitored *automatically* and recorded and stored by means of a measurement and control data logger.

Indicator: Reduction of external air temperature from trees planting

This indicator is referred to the reduction of external air temperature due to trees planting. In this case reduction of air temperature can be monitored through external **air temperature sensors** and **air relative humidity sensors.**
A monitoring frequency of six months for this indicator has been assumed.

3.1.5 Climate co-benefits

Indicator: Carbon sequestration from tree planting

This indicator is calculated by RINA based on the number of the trees planted (no monitoring is needed). The calculation is performed by considering an average net carbon sequestration annual value for a tree, and associated carbon dioxide amount. Then, the factor obtained is multiplied by the minimum number of trees expected to be planted in each pilot.
A monitoring frequency of six months for this indicator has been assumed.

Indicator: Reduction of heat island effect through green infrastructure

In dense urban areas the progressive replacement of green areas with artificial surfaces is one of the major causes of the so-called urban heat island (UHI) effect, the phenomenon that generates a temperature difference between cities and surrounding rural or suburban areas. As a city grows, more heat is trapped with a consequential increase of the air temperature in downtown even up to 6–8 °C higher in comparison to the surrounding areas. Building surfaces and pavements are made mainly with non-reflective and water-resistant construction materials, consequently accumulating incident solar radiation during daytime and then releasing heat at night. Heat is trapped also because the decrease of green areas in cities induces a reduction of shades and radiation interception, together with the reduction of the infrared radiation emitted towards the atmosphere, the limitation of the circulation of air in urban canyons and the high production of waste heat from cooling systems, motorized vehicular traffic and industrial processes. UHI negatively influences outdoor comfort conditions as well as induces a more use of air conditioning systems with a raise of peak electricity demand.

The indicator “reduction of heat island effect through green infrastructure” can be evaluated through the monitoring of the following parameters:

- external air temperature;
- external relative air humidity;
- external surface temperature of the bare facade/roof;
- external surface temperature of the green facade/roof;
- solar radiation on the building facade (through a pyranometer);
- wind velocity and direction (through an anemometer).

The measurement instruments/sensors to monitor the abovementioned parameters are:

- **thermoresitors/**resistance thermometers to measure the temperature of the external bare and green facades exposed to the solar radiation;
- **sensors to measure the temperature and the relative humidity** of the external air;
- a **pyranometer** to measure the solar radiation;
- an **anemometer** to measure the wind velocity and direction;

Parameters will be monitored *automatically* and recorded and stored by means of a measurement and control data logger.

Indicator: Air pollution removal (PM_{10} / $PM_{2.5}$ and O_3)

Air quality monitoring and control are key issues for environmental assessment and management in order to protect public health, ecosystem services and physical cultural heritage (intended as physical artefacts in outdoor spaces). Therefore, local and central authorities have developed measuring systems to evaluate air pollution and to provide strategic indications to improve air quality and optimize its monitoring. The most critical situations occur in urban areas, where emission sources (e.g., urban traffic, domestic heating) and sensitive receptors (e.g., population, physical cultural heritage) are concentrated.

At the European level, the reference regulation for the monitoring and evaluation of air quality is set by Directive 2008/50/EC and subsequent amendments (Directive 2015/1480/EC). This legislation establishes that fixed measurements shall be used to assess ambient air quality. These fixed measurements may be supplemented by modelling techniques and/or indicative measurements to provide adequate information on the spatial distribution of air pollutants.

As regards the monitoring of the air quality and, in particular, the monitoring of particulate matter (i.e.: $PM_{2.5}$, PM_{10}) monitoring stations can be used. These stations can be fixed or mobile.

Fixed monitoring stations represent the most conventional, consolidated and widespread approach for air quality monitoring and evaluation but have some limitations:

- monitoring is usually limited to a small set of strategically placed locations and the assessment results are significant only for specific areas;
- they have low flexibility. [8]

In recent years, mobile laboratories (laboratories transported by a vehicle and maintained in a fixed location for a period of time) have become increasingly widespread for activities involving the monitoring of air quality standards and pollutants. They can be applied for urban, rural, background, industrial or emergency monitoring and they can also be used for the assessment of a specific source.

Nowadays, the most popular vehicles for use in mobile monitoring activities with instruments able to assess air pollution parameters are vans and trucks, but other kinds of transport can also be used, such as trams, trailers and SUVs.

As reported in the literature the main parameters responsible for air pollution and dangerous for the environment and for human health that are tracked by fixed monitoring stations or by mobile laboratories are PM_{10}, $PM_{2.5}$, O_3, NOx, SOx, CO, CO_2, NH_3 and VOCs.

In this deliverable the focus is on the instruments used for the measurement of particulate matter with a diameter between 2.5 and 10 µm (PM_{10}), with a diameter less than 2.5 µm ($PM_{2.5}$) and ozone (O_3). Monitoring of particulate matter and O_3 is carried out through the use of **automatic instrumentation (analyzers)** as shown below.

The air pollution removal, for both the particulate matter and the ozone, will be calculated as the difference between the air pollution concentration in the baseline scenario and the air pollution concentration in the project scenario in the pilot hospitals. Baseline scenario is the current scenario without the installation of the green infrastructures, whereas project scenario includes the green infrastructures (i.e.: green facades, green roofs, green corridors) installed.

Particulate matter (PM_{10} and $PM_{2.5}$)

Concentration of PM_{10} and $PM_{2.5}$ can be measured through a gravimetric method for determining the mass concentration of suspended particulate.

Mode of operation: the reference method for the determination of PM_{10} and $PM_{2.5}$ particulate matter is based on the collection of the PM10 / $PM_{2.5}$ fraction on a special filter and subsequent determination of its mass by gravimetric way, in the laboratory, after the conditioning of the filter in controlled conditions of temperature (20°C ± 1) and humidity (50 ± 5%).

In addition to the reference method, there are equivalent methods for measuring PM_{10} and $PM_{2.5}$ (for example automatic instrumentation that uses the principle of absorption of β radiation by the sampled dust). The determination of fine particulate matter in the atmosphere is performed using different types of instruments, described below:

PM_{10}/$PM_{2.5}$ samplers

These instruments consist of a pump that sucks the ambient air through a sampling head able to select particulate matters with a diameter of less than 10 µm (or less than 2.5 µm) with an efficiency of 50%. The particulate selected by the head is conveyed through a filter membrane of suitable porosity. The membrane is then weighted in the laboratory and the difference with the tare weight is the mass of the particulate matter. The sampler also contains a volumetric counter capable of recording the volume of sucked air, continuously corrected by various internal and external temperature and pressure sensors, to bring it back to environmental conditions. Therefore, from the knowledge of the volume of sampled air and the mass of the particulate matter, the concentration of PM_{10} and $PM_{2.5}$ in µg / m^3 is calculated.

PM_{10}/$PM_{2.5}$ analyzers

These instruments, like samplers, record the air volume passed through a filter membrane. However, they are also able to determine the mass of the particulate matter, using the principle of attenuation of the β rays emitted by a small radioactive source. These analyzers can have a sampling system based on single filter (like samplers) or have a belt that runs at regular time intervals where the particulate is laid down. By combining the volume and mass data, these instruments directly provide the PM_{10} and $PM_{2.5}$ concentration value in µg / m^3.

For example, a manufacturer of PM_{10} / $PM_{2.5}$ analyzer is the company Aeroqual which produces monitoring instruments allowing a continuous real-time measurement of particulate matter (PM_{10}/PM2.5) "Dust Sentry PM_{10} / $PM_{2.5}$ Dust Monitor".

O_3 analyzer

Concentration of ozone is measured through an analyzer by means of ultraviolet photometry (measuring principle is the "UV absorption").
The ozone analyzer exploits the absorption of this gas in UV at 254 nanometers (nm) and then calculates its concentration.
Mode of operation: both the ambient air as it is, and the ambient air previously passed through a selective ozone filter, enter the measuring chamber alternately. A UV lamp, able to emit at the appropriate wavelength, allows part of the radiation to be absorbed by the ozone molecules, causing a decrease in intensity which is recorded by a detector. By alternating measurements with and without ozone, the instrument determines ozone concentration in ambient air.
For example, a manufacturer of ozone analyzer is the German company BMT Messtechnik Gmbh which produces analyzer exploiting the absorption of this gas in UV calculating the ozone concentration.

3.2 Better use of energy resources

3.2.1. Energy

Indicator: Reduced energy consumption

This indicator shows the reduction in % the of energy consumptions due to the installation of new grey equipment (i.e.: air conditioning devices, chillers, etc.) in the pilot hospitals. Monitoring of this indicator will be carried out by means of **energy bills, energy meters**.
For this indicator a weekly monitoring frequency has been assumed.

Indicator: Energy produced from Renewable

This indicator depicts the energy produced through renewable sources (i.e.: solar photovoltaic, thermal solar, biomass, wind, etc.) installed in the pilot hospitals, or that could be implemented in the hospitals. Also energy purchased by suppliers that produce it from renewable source can be considered. Monitoring of this indicator will be carried out by means of **energy bills, energy meters**. For this indicator a yearly monitoring frequency has been assumed.

Indicator: Monitoring of the energy savings due to the improvement of the existing air conditioning systems

This indicator has the aim to monitor the energy savings due to the enhancement of the existing air conditioning systems installed in the hospitals. Monitoring of this indicator will be carried out by means of **energy bills, energy meters.**
For this indicator a monthly monitoring frequency has been assumed.

3.2.2. Food

Indicator: Meal with locally and sustainably food on total meal served

This indicator has the aim to define the percentage of meal with local and sustainable food on the total meal served in the hospitals. Monitoring of this indicator will be carried out through **catering company records**. For this indicator a yearly monitoring frequency has been assumed.

3.2.3. Waste

Indicator: Waste reduction program (e.g.: reuse bags, organics recycling, training, compost food waste, etc.) and consequent financial saving

This indicator aims at identifying the reduction of waste that can be reached through virtuous actions such as recycling, reuse and reduction of waste. Reduction should be evaluated in percentage of "evolution" compared to an initial state. Monitoring of this indicator will be carried out through **survey/questionnaires** and the results will be archived in a record book/a spreadsheet. For this indicator a yearly monitoring frequency has been assumed.

Indicator: Quantity of waste reduction during the project according to waste reduction program, detailed for waste category (hazardous, non hazardous)

This indicator shows the waste reduction quantity (evaluated in "ton" of waste) reached during the project according to the waste reduction program. Monitoring of this indicator will be carried out through **survey/questionnaires** and the results will be archived in a record book/a spreadsheet. For this indicator a yearly monitoring frequency has been assumed.

3.3 Social, Political and Economic Performance, Market Uptake, Replication

3.3.1 Employment

Indicator: New jobs created (full time employee)

This indicator depicts the new jobs created (i.e.: full time employee) during the project. It is based on the staff to be hired in the project. Monitoring of this indicator will be carried out through **record book** where the HR Department will include the new FT employee. For this indicator a six months frequency has been assumed.

3.3.2 New infrastructure

Indicator: Investments in blue-green and grey infrastructures

This indicator is aimed at calculating the investment done in the green, blue and grey infrastructures. Monitoring of this indicator will be carried out through a dedicated **business plan.** For this indicator a six months frequency has been assumed.

3.3.3 Project Results' Replication / Transfer

Indicator: Hospital (health system) using Upscaling Adaptation Starting Package (UASP) in the country

This indicator is related to the UASP (i.e.: an "open access exploitable result") for the replication and transfer of the project results. This indicator will be constituted at the end of the project.

3.3.4 Guidance and tools

Indicator: Training/capacity building activities about: system-approach developed, capacity building programs designed, avoided economic losses, investments in climate adaptation, description and number of EU policy initiatives aimed at integrating health and climate policy

This indicator deals with training and capacity building activities to carry out during the execution of the project. Monitoring of this indicator will be carried out through **attendance registers** used during training activities/courses. The monitoring frequency depends on the single hospital usual plan for training activities, but can be assumed yearly.

3.4 Communication, dissemination, awareness rising

3.4.1 Awareness raising

Indicator: Stakeholders engaged

This indicator concerns the stakeholders that will be engaged during the project. Monitoring of this indicator will be carried out through **webinar and interviews**. For this indicator a six months frequency has been assumed.

Indicator: Entities/individuals reached/ made aware

This indicator concerns the entities/people that will be made aware during the project. Monitoring of this indicator will be carried out through **webinar and interviews**. For this indicator a six months frequency has been assumed.

Indicator: People trained to modules 1 to 6 of A3.1 “Design of the local toolbox” (Proposal- Part C, page 49)

This indicator deals with training activities to module 1 to 6 to carry out during the project. Monitoring of this indicator will be carried out through **attendance registers** used during training activities/courses. The monitoring frequency depends on the single hospital usual plan for training activities, but can be assumed yearly.

Indicator: People trained to module 7 of A3.1 “Design of the local toolbox” (Proposal- Part C, page 49)

This indicator deals with training activities to module 7 to carry out during the project. Monitoring of this indicator will be carried out through **attendance registers** used during training activities/courses. The monitoring frequency depends on the single hospital usual plan for training activities, but can be assumed yearly.

Indicator: Articles produced

This indicator concerns the articles produced during the project. Monitoring of this indicator will be carried out through an **excel file** where articles will be recorded.

The monitoring frequency depends on the single hospital usual plan for articles publications, but can be assumed yearly.

Indicator: Workshops and events organized

This indicator concerns the Workshops and the events that will be organized during the project. Monitoring of this indicator will be carried out through an **excel file** where Workshops and the events will be recorded.
For this indicator a three months frequency has been assumed.

3.4.2 Website

Indicator: Visitors per month

This indicator concerns visitors that will visit the website of the project, or that will post on social (LinkedIn, Twitter, or Facebook). Monitoring of this indicator will be carried out through **webinar click software**. For this indicator a monthly frequency has been assumed.

3.4.3 Behavioural change

Indicator: Entities/individuals changing behaviour as a result of their engagement in the project

This indicator concerns entities and people that will change their behaviour as a result of their engagement in LIFE RESYSTAL project. Monitoring of this indicator will be carried out through **webinar, interviews and survey.** For this indicator a three months frequency has been assumed.

4. Conclusions

This deliverable is included in the Action D.1 "*Development of a common monitoring methodology*" which is aimed at developing a common monitoring pilot scale methodology to allow proper evaluation of the project actions and their expected results along the project duration and beyond for the 7 pilot hospitals.

The scope of this deliverable is to provide an overview of the measurement equipment (i.e.: sensors, monitoring stations, data acquisition system) to use for the monitoring of the Key Performance Indicators (KPIs), identified in deliverable DD1.1. In particular, measurements equipment are indicated for KPIs related to the improved environmental and climate performance (i.e.: air temperature sensors, air relative humidity sensors, pyranometer, anemometer, pollutant analyzers, etc.).
It is worth mentioning that, as regards KPIs related to social, economic, political aspects, communication and dissemination on awareness raising, monitoring devices are not physical equipment (i.e.: sensors, meters or analyzers) but other kind of "devices" such as attendance registers, excel files, webinar, surveys/questionnaires, etc.

In this deliverable *type* of measurement instruments/sensors to use for monitoring purposes, frequency of parameter monitoring, how parameters will be monitored (i.e.: manually or automatically) and how monitored parameters will be recorded and stored (i.e.: by means of a data logger) are shown.
It is pointed out that additional information, in particular regarding *number* and *position* of the measurement instruments/sensors, will be given later during the execution of the project, once more details are available.

For example, as regards the green infrastructure, it is needed to know:

- ✓ type of green infrastructure that will be realized (i.e.: a green facade or a living wall), if they will be directly attached to the building facades/the interior walls, or if they will be placed on support structures such as wire, mesh, trellis, located to a certain distance to the building facades, or on a free-standing system, such as fence or column;
- ✓ the surface (m^2) and height (m) of the green infrastructures that will be installed on building facades/interior walls;
- ✓ the orientation of the green infrastructures (if they will be oriented to south, west, south-west, east, south-east).

Moreover, a draft design, including drawings (e.g.: front, section) of the green infrastructures that will be installed on the building facades and on the interior walls would be helpful.

As regards the air pollution removal (PM_{10}/$PM_{2.5}$ and O_3) it will be needed to define which kind of monitoring stations will be used in each of the seven pilot hospitals (i.e.: fixed monitoring stations or mobile stations/laboratories).

5. References

[2] M. Canditelli, C. Cellamare, M. Ferraris, A. Giuliano, P. G. Landolfo, L. Luccarini, D. Mattioli, F. Musmeci, L. Petta, G. Sabia, ENEA (2017), Report RDS/PAR2017/069 "Sviluppo di sistemi e metodologie per la gestione efficiente della risorsa idrica e del rifiuto organico in una smart city", https://www.enea.it/it/Ricerca_sviluppo/documenti/ricerca-di-sistema-elettrico/adp-mise-enea-2015-2017/smart-district-urbano/report-2017/rds-par2017-069.pdf

[2] F. Ariaudo, S.P. Corgnati, D. Raimondo, G.V. Fracastoro, Conference paper, 2015, "Cooling load reduction by green walls: results from an experimental campaign", https://www.researchgate.net/publication/273131709_Cooling_load_reduction_by_green_walls_results_from_an_experimental_campaign

[3] L.P. Urrestarazu, R.F. Canero, A.F. Salas, G. Egea, Journal of Urban Technology, 2016, "Vertical greening systems and sustainable cities", https://www.researchgate.net/publication/292150884_Vertical_Greening_Systems_and_Sustainable_Cities

[4] G. Vox, I. Blanco, E. Schettini, Department of Agricultural and Environmental Science DISAAT, University of Bari, Italy, 2017, "Green facades to control wall surface temperature in buildings", https://www.sciencedirect.com/science/article/abs/pii/S0360132317305607

[5] T-4 Green Roof, "Urban Drainage and Flood Control District", Nov. 2010, https://mhfd.org/wp-content/uploads/2019/12/T-04-Green-Roof.pdf

[6] L.P. Urrestarazu, R.F. Canero, A.Franco, G. Egea, Urban Greening and Biosystems Engineering Research Group, University of Seville ETSIA, 2016,"Influence of an active living wall on indoor temperature and humidity conditions", https://www.sciencedirect.com/science/article/abs/pii/S0925857416300507

[7] M. Ali Khan, N. Amin, A. Khan, M. Imtiaz, F. Khan, I. Ahmad, A. Ali, B. Islam, 2016, "Plant Therapy: a Nonpharmacological and Noninvasive Treatment Approach Medically Beneficial to the Wellbeing of Hospital Patients" https://www.researchgate.net/publication/309696045_Plant_Therapy_a_Nonpharmacological_and_Noninvasive_Treatment_Approach_Medically_Beneficial_to_the_Wellbeing_of_Hospital_Patients

[8] S. Marinello, M. Andretta, P. Lucialli, E. Pollini, S. Righi "A Methodology for Designing Short-Term Stationary Air Quality Campaigns with Mobile Laboratories Using Different Possible Allocation Criteria", MDPI, 2021, https://www.mdpi.com/2071-1050/13/13/7481