Algae Façade Integrated Envelope
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The proposed system is called AL.F.I.E, Algae Façade Integrated Envolope; it is technological element to be integrated on double skin external building envelopes that is able to purify rain water and grey water produced at building level in order to reduce the use of freshwater in dwellings.
The system is patent pending and has a technology readiness level between 2 and 3 (design concept level but not prototyped yet).
The façade system is made up of an aluminium frame that holds a series of modular photobioreactors designed for allowing the growth of microalgae at correct environmental requirements (light and temperature mainly). Microalgae are mixed with wastewater to absorb its pollutant used as major nutrients for their own growth. The purification process lead to the production of valuable biomass that can be used for several byproducts, such as biofuel, chemical and pharmaceutical compounds production.

This new technology of water treatment is presented on the international scene as an environmental friendly solution to improve sustainability of existing buildings and reduce water resources exploitation. With the use of this new purification system, the wastewater will be recovered and re-entered the building installation and the subsequent sale of biomass produced, it will be possible to amortize the cost of installation.
Micro-algae need an environment full of nutrients to increase their growth: in order to allow cell reproduction they need of precisely those organic compounds which usually they want to eliminate when it comes to wastewater treatment. In fact, nutrients, which usually are inoculated into a photo-bioreactor, consist of all those elements such as nitrogen, phosphorus and carbon dioxide, that could be found in grey water and rainwater.
In general terms the possibility of recycling wastewater depends on its chemical composition. At building level the water recycling issue focuses on the composition of domestic wastewater and rainwater. Domestic wastewater includes toilet wastewater and grey water, the latter indicating dwelling's sinks and showers fluxes. Total gray wastewater is estimated around 75% of the total volume. The main issue related to grey-water treatment is its large volume produced daily at building level. Grey water may contain several components: suspended solids, nitrogen (even if in lower concentration than domestic wastewater), phosphates in small quantities, sodium, relatively small amounts of heavy metals, xenobiotic organic compounds and microrganisms.
The design of the shape of AL.F.I.E. started from the search for a pattern easy to replicate horizontally and vertically without a continuous repetition of the same geometry. Six different shapes of bags are chosen and connected with a frame made up of six basic elements to be repeated on the façade structure. With the combination of these twelve basic elements it has been possible to seamless cover, partially or totally, the external façade of a chosen building. Oblique tubular steal bars connected to load bearing mullions through branched connection elements support the second skin modules. Steel mullions are anchored to the building envelope and have a dedicated foundation to be self-bearing.
A basic module of AL.F.I.E consists of an opaque section, the anodized aluminum frame, containing some of the mechanical elements necessary for the operation, and a transparent part. This last one is formed by two pillows of ETFE double layers which create a cavity that contains the micro-algal culture medium. Through exposure to solar radiation the photosynthetic process is started and consequent reproduction of micro-algae, through which the microorganisms absorb the pollutants present in the compound (water + microalgae).
The water is thus cleaned and can be re-placed in the water system for all those applications which do not specifically require the use of white water (discharges WC, washing machines, irrigation).

Attached technological details show the composition of a basic ALFIE module.

The technological system has to satisfy certain requirements to ensure a correct operation of the component and to achieve maximum growth of the micro-algae.
This core technology is capable of:
• Maximizing the surface exposed to sunlight;
• Maximizing the volume of waste water to be purified in daily cycles;
• Reduce the overall weight of the technology facade;
• To facilitate the handling of the compound;
• Adjust the internal temperature of the photobioreactor, to maintain the temperature range suitable for the micro-algal growth.
The choice of building materials is based on both technological and environmental requirements. All materials are chosen for their high recyclability in the attempt of reducing the environmental impact of the building element. Hot dip-galvanized steel is chosen for mullions and connection elements (tree-shaped anchors and tubular elements), being corrosion resistant and suitable for load bearing structures. Steel is among the most recycled construction materials in the world, in fact its reuse is estimated around 87%. An aluminium frame connects PBRs on the outer layer of the façade. Aluminium can be recycled without losing its specific features. In Italy more than 30% of aluminium derives from recycled components. The Ethylene Tetrafluoroethylene (ETFE) is chosen for bag-shaped PBR because it is transparent, flexible and thanks to laser cut technology it can assume a wide variety of shapes. It is strongly resistant to traction force and can be fixed in case of perforation.
Wastewater and rainwater are collected in a special tank placed in the basement of the building, inside which the initial microalgae strain is added as well. The mixture is pumped on the second skin façade from above. Inside PBRs microorganisms are fed by nutrients and CO_2 present in the water and, with exposure to solar radiation, photosynthesis starts together with microalgae growth. AL.F.I.E. façade is connected to the water collection systems of the building in order to control the flow of incoming liquid and, at the end of the process, its extraction; in this way it is possible to keep constantly under control the development of the compound and the levels of water inside PBRs.
Reached the point of maximum microalgae growth, the compound product (biomass + purified water) is withdrawn from the bottom of the facade and sent to the collection tank, located in the basement. Here the biomass is divided from the liquid part. The purified water can enter again the water system of the building to be used for all those applications that do not require the essential use of drinking water, such as toilet flushing, laundry machines, external irrigation. The biomass is sold to specialized industries to be converted into products of high economic value.

The attached technological section explains the process of wastewater recycling at building scale.

Because of the natural growth of microalgae during time, AL.F.I.E. becomes a dynamic component on the building envelope, characterised by a green texture that changes with hours, days and seasons.
A dynamic simulation of façade parameters is needed to further investigate the behavior of the designed PBR during the year and in different climatic regions. Potential applications of the system are very high. The façade is modular, light, self-bearing and highly industrialized; therefore it doesn't affect the supporting building envelope, it is fast and easy to install and it is designed to easy maintenance works. By first estimations the production cost of the façade system is about 1200 €/m^2, a figure highly comparable to other innovative technologies for the building envelope such as living wall systems and active curtain walls. One module of AL.F.I.E. has a surface area of about 23 m^2 and can load 1,16 m^3 of liquid mix. Considering the Italian average pro-capita consumption of freshwater for domestic use, 200 lt/p/d, one module of AL.F.I.E. would be sufficient for purifying wastewater produced by 5.8 dwellers, assuming 24 hours as total duration of the process. A further advantage of the integration of this system is the opportunity to sensitively reduce the payback time of the investment by the sell of the precious micro-algal biomass to transformation plants. The installation of AL.F.I.E. on several buildings at district scale would offer the opportunity to set up a distribution, collection and treatment service, to create local economies and to finance installation and maintenance costs of the technology. Finally the dynamic behavior of the façade characterizes its appearance throughout the year according to the growth of micro-organisms, providing a remarkable attractive value to the building and its surrounding.

AL.F.I.E. was presented at the APAC innovation summit on Smart Cities under the topic of sustainable buildings. Presented documents are available on the website for free download.