ACTIVE VERTICAL GARDEN SYSTEM FOR WATER TREATMENT AND ENERGY EFFICIENCY

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ABSTRACT

The **Structural Testing, Simulation and Modelling Research Group (GRESMES)** at the University of Alicante, in collaboration with the UNESCO Chair in Sustainability at the Polytechnic University of Catalonia, has developed an innovative **green façade** composed of hydroponic cartridges designed to integrate vegetation into urban environments, providing multiple benefits.

Thanks to a hybrid flow system (vertical and horizontal), these cartridges replicate the behaviour of a constructed wetland, enabling the **treatment and reuse of urban or grey wastewater**. Additionally, the system improves building energy efficiency, reduces thermal loads, contributes to improving air quality, and enhances both the aesthetic and environmental value of façades. Its modular design facilitates installation and maintenance, adapting to different architectural typologies.

This technology targets sectors such as sustainable construction, urban water management, landscaping, and energy efficiency. The research team is seeking companies interested in validating and commercially exploiting the solution.

INTRODUCTION

Green façades, also known as vertical gardens, have gained increasing popularity in recent years. Beyond their aesthetic value, they provide significant environmental benefits. These structures, combining support systems with vegetation adapted to urban environments, have proven effective in improving air quality, mainly through phytoremediation processes — the natural capacity of plants to remove airborne pollutants.

In addition to their decorative function, some vertical gardens have begun to explore new functional applications, such as partial water filtration. This line of development has opened new possibilities for designing sustainable buildings integrated with their surroundings, where constructive elements contribute not only structurally or visually, but also environmentally and energetically.

However, existing solutions face major limitations. None of the available technologies have effectively integrated a system capable of functioning as a true wastewater treatment ecosystem. While some façades can partially filter water, they do not replicate the complex and sustainable processes of natural wetlands. This represents an untapped opportunity to transform façades into multifunctional green infrastructures.

The integration of vertical gardens into actual water treatment systems remains scarce. Existing cases are often experimental, difficult to replicate, or rely on complex and costly structures, limiting their urban applicability.

In this context, there is an urgent need for a scalable and integrated solution that goes beyond ornamental purposes to deliver environmental and energy performance directly through the building envelope. Such innovation must not only improve air

quality but also enable efficient water management (particularly greywater) while contributing to building energy efficiency, all through an industrially scalable approach.

This is the foundation of the present invention: an innovative solution that reproduces the behaviour of a constructed wetland through a modular hybrid-flow system, optimised for real urban building applications.

TECHNICAL DESCRIPTION

GRESMES (University of Alicante) and the UNESCO Chair in Sustainability (Polytechnic University of Catalonia) have developed a novel system for integrating vegetation into buildings, specifically their façades. The technology consists of a **vegetated façade** made of **special hydroponic cartridges**.

The key innovation lies in combining the concept of constructed **wetlands** with vegetated façades. Thus, the system not only functions as a green wall but also imitates the natural process of wetland-based water purification.

The invention addresses a key challenge in urban green infrastructures: integrating a **hydroponic water treatment system** into a vertical, modular, efficient, and replicable structure, enabling real application in buildings.

Each cartridge contains one or more pots with plants through which water circulates internally. This **hybrid flow** moves both vertically and horizontally across the substrate and plant roots, enabling the treatment of urban wastewater such as greywater from homes, offices, or public facilities. Treated water can then be reused for non-potable purposes.

The **cartridges** are lightweight, designed for easy handling by one person, and can be easily replaced or repaired during maintenance. **Pots** are arranged in a staggered layout to maximise plant coverage and visual appeal. The **cartridge geometry** is **optimised** to cover façades while preventing direct solar exposure, which improves building thermal regulation.

ADVANTAGES AND INNOVATIVE ASPECTS

MAIN ADVANTAGES

The main advantages of installing this green façade are:

- **Efficient treatment of urban wastewater**, enabled by hybrid flow that mimics natural wetlands.
- **Reduced thermal load on buildings**, improving energy efficiency and lowering cooling demands.
- **Improved environmental quality**, through air purification and green surface creation.
- **Modular and scalable design**, ensuring simple installation, easy maintenance, and adaptability to different architectural typologies.
- **Enhanced aesthetic and functional value of façades**, adding vertical green spaces and increasing property value.
- **Multifunctional green infrastructure**, aligned with sustainability policies, circular economy, and urban regeneration.
- **Industrial scalability**, with strong market potential in vertical gardening, energy efficiency, and water management, especially in dense urban settings or green renovation projects.

INNOVATIVE ASPECTS

The main innovative aspect of this technology lies in the combination of two nature-based solutions: **constructed wetlands and green facades**.

More specifically, the key innovation lies in the **design of the hydroponic cartridge**, which reproduces a **'hybrid flow' of water**. This flow, which alternates between vertical and horizontal movements through the plants and their substrate, mimics the functioning of a wetland ecosystem to treat and purify urban wastewater, such as greywater generated in buildings.

This flow configuration ensures optimal contact between the water and the plant roots, maximising treatment efficiency. It also guarantees different redox conditions, which improves the removal of organic matter and the nitrification and denitrification processes.

Currently, **there are no commercial solutions** that integrate a modular hydroponic system with real wastewater treatment capacity using biological processes similar to those of a functional wetland within an architectural envelope.

The technology developed is also **scalable and replicable**, allowing it to be integrated into different types of buildings and facilitating its transfer to the market through industrial manufacturing and installation processes.

CURRENT STATE OF DEVELOPMENT

The technology has been developed at **laboratory scale**, with the construction of a 1:2 prototype.

The next stage will involve 3D-printing a set of 15 full-scale modules to be connected to a simulated greywater installation on a building façade.

MARKET APPLICATIONS

This invention lies at the intersection of **building technology** and **water treatment**. The hydroponic cartridge functions both as a modular living wall (LW) and a constructed wetland (CW) for **urban wastewater treatment**.

Potential **application** sectors include:

- *Architecture & Construction*: integration into new or retrofitted building façades, enhancing sustainability and efficiency.
- *Greywater treatment & reuse*: decentralised purification systems for homes, public buildings, or urban infrastructure.
- *Energy efficiency*: reducing building thermal loads via shading and passive cooling.
- *Urban landscaping & green infrastructure*: creating vertical green spaces with functional value beyond aesthetics.

Potential stakeholders:

- Manufacturers of construction materials and façade systems.
- Producers or distributors of hydroponic systems and vertical gardens.
- Engineering and construction firms.
- Water treatment and resource management companies.
- Urban landscaping and green infrastructure firms.
- Energy efficiency and smart building solution providers.

COLLABORATION SOUGHT

The University of Alicante seeks partners interested in **validating, applying, or commercially exploiting** this multifunctional green façade solution.

Collaboration options include:

- **Patent licensing** for industrial development and commercialisation.
- **Joint demonstration** or adaptation projects in real urban buildings and infrastructures.
- **Participation in public funding programmes** on sustainability, energy efficiency, or nature-based solutions.

The research team offers scientific and technical support and can adapt the solution to different sectors or contexts.

Preferred collaborators include:

- Companies in sustainable construction, energy efficiency, and urban green solutions.
- Manufacturers of vertical gardens or modular systems seeking to expand their portfolio.
- Firms specialised in greywater treatment and urban water reuse.
- Environmental consultancies, engineering firms, or landscape designers.
- Public entities responsible for urban planning, housing, or environmental management.

INTELLECTUAL PROPERTY RIGHTS

This technology is protected by **patent application**:

- *Patent Title: "Hydroponic Cartridge and Green Façade"*
- *Application Number: P202530520*
- *Application Date: 11 June 2025*

MARKET APPLICATION (1)

Construction and Architecture