Executive Summary

BlueLoop: Integrating Aquatic Plant Systems in Architecture and Interior Design

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1. Introduction & Context:

Rapid urbanization and climate change are placing unprecedented stress on water resources and built environments. Traditional mechanical systems for water treatment and climate control are energy-intensive and often divorced from the ecosystems they impact. BlueLoop proposes a novel, biomimetic approach: embedding living aquatic plant systems directly into architectural elements to deliver passive water purification, microclimate regulation, and biophilic benefits. Drawing on the structure–function relationships of emergent reeds, floating wetlands, and lotus leaves, BlueLoop modules will be fabricated as integrated façade panels, interior partitions, and freestanding installations. This research aligns with Horizon Europe's objectives for sustainable, nature-based solutions in the built environment and advances the Marie Skłodowska-Curie Actions' goal of fostering interdisciplinary innovation.

2. Objectives

- O1: Ecosystem Service Integration
  Demonstrate the capacity of living aquatic assemblies to filter greywater and stormwater at source, reducing pollutant loads (nutrients, heavy metals, pathogens) by ≥60% under controlled flow regimes.
- O2: Microclimate Regulation
  Quantify transpiration-driven cooling effects, targeting a ≥3 °C reduction in peak surface temperatures in a temperate test chamber and a 15% decrease in HVAC energy demand.
- O3: Biomimetic Structural Synthesis
  Translate aquatic plant morphologies into parametric form-finding algorithms that yield structurally robust, lightweight, and modular "BlueLoop" prototype geometries.

3. Research Methodology

The research unfolds in three integrated work packages:

3.1. WP1: Biomimetic Design Translation

Building on Prof. Gönenç Sorguç's biomimetic frameworks, we will analyze stem and leaf microstructures (e.g., reed aerenchyma, lotus superhydrophobic surfaces) via SEM imaging and computational morphometrics. These data will inform parametric scripts (Grasshopper/Python) that generate module geometries optimizing surface area, structural stiffness, and hydraulic retention time.

3.2. WP2: Prototype Fabrication & Hydraulic Testing

Using digital fabrication (CNC-cut recycled HDPE frames, 3D-printed connectors) and locally sourced substrates (gravel, biochar, inert foam), we will construct three module typologies:

- **Floating Wetland Panel** (500×500×100 mm) for still water basins
- **Vertical Reed Screen** (500×2000×200 mm) for façade integration
- **Lotus Leaf Canopy** (1000×1000×200 mm) for interior partitions

Each module's hydraulic performance will be evaluated in a flow channel (flow rates 0.5–2 L/min), measuring pollutant removal (COD, NO_3^-, Pb) and head loss.

3.3. WP3: Environmental & Biophilic Performance Assessment

Modules will be installed in a climate chamber to monitor surface temperatures, relative humidity, and user comfort metrics (PMV/PPD indices). Concurrently, user studies (n=30) will assess psychological responses (stress reduction, perceived air quality) via standard questionnaires (PSS, SBQ).

4. Expected Outcomes & Impact

Scientific Contributions:

- A validated biomimetic design methodology for living façade and interior systems.
- Quantitative datasets on phytoremediation efficacy and thermal performance in built prototypes.

5. Societal & Environmental Impact:

- Nature-based design tools enabling architects to meet EU Water Framework Directive targets at building scale.
- Enhanced occupant wellbeing through direct engagement with living systems.

6. Policy & Industry Integration:

- Policy brief for EU DG ENV on integrating BlueLoop into urban water-management guidelines.
- Open-source parametric scripts and fabrication protocols for design practitioners.

7. Alignment with MSCA & ZRC SAZU

BlueLoop embodies MSCA's emphasis on excellence, impact, and implementation by merging advanced biomimetic research with tangible societal benefits. Hosted at ZRC SAZU, the project will leverage cross-institute expertise in environmental anthropology and heritage studies to contextualize local plant species (e.g., *Phragmites australis*, *Nelumbo nucifera*) within regional building traditions. The fellowship will foster EU–Egypt research synergies and contribute to SDGs 6 (Clean Water), 11 (Sustainable Cities), and 13 (Climate Action).