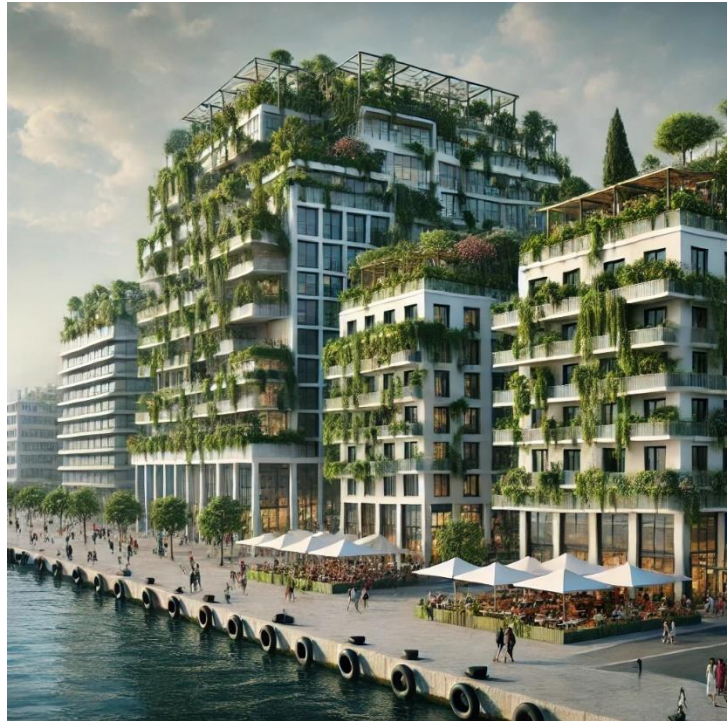




Resilient Vertical Forest Renovation of Reinforced Concrete Structures in Seismic prone areas



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Project background

The 2-year project GREENERGY project is carried out within the framework of the National Recovery and Resilience Plan Greece 2.0, funded by the European Union – NextGenerationEU (Implementation body: HFRI)

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The GREENERGY vision

GREENERGY envisions forest diffusion to alleviate extreme weather conditions impacts in coastal seismic urban regions and to optimize inclusive people-centric social engagement towards habitant comfort and satisfaction through high-density urban forestation. GREENERGY goes beyond the leading state of the art concepts in the area that aim mainly to produce nearly zero energy consumption and neutral carbon footprint within built environment in urban areas in order to promote the “green deal” while the real green nature itself is suppressed.

The GREENERGY team

The Host of Organization for GREENERGY Democritus University of Thrace (DUTH), while a collaborating organization is Aristotle University of Thessaloniki (AUTH).



The GREENERGY approach

GREENERGY conducts basic research at building level in order to review barriers in existing renovation approaches that lead to exclusion of forests from cities and detrimental incompatibility with built environment and revolutionize vertical forest (VF) concepts. It gathers and coordinates approaches and develops the fundamental structural and energy related drivers in order to allow for harmonic VF growth inside smart cities and interconnection of urban forests in a unified high-quality living environment for citizens. It defines critical parameters and suitable concepts in order to optimize resilient and safe ecosystem that combines existing concrete buildings/infrastructure and VF. A physical model structure is tested in lab to set proof of a) innovative concept as well as real time data collection to interact with digital twin (hybrid), b) suitable carbon neutral contributing structure renovation with green materials and c) suitable green-corrosion-resistant building envelopes to act as a compatible structural interface with VF and allow its growth and advanced energy savings and high quality micro-climate.



Recent highlights

Vanian, V.; Rousakis, T.;
Fanaradelli, T.; Voutetaki, M.;
Macha, M.; Zapis, A.;
Theodoridou, I.; Stefanidou,
M.; Vatitsi, K.; Mallinis, G.;
Kytinou, V.; & Chalioris, C.;
Performance-Based Damage
Quantification and Hazard
Intensity Measures for Vertical
Forest Systems on RC
Buildings. Buildings 2025, 15,
769.

The GREENERGY Digital Twin

Digital twin model is developed to incorporate and enable real time assessment from a combined structural-energy-human 'health monitoring' aspect and allow for future optimization scenarios. The tested GREENERGY building is designed in detail and evaluates parameters and concepts in terms of structural (corrosion, seismic strengthening and joints, monitoring), energy as well as management and mitigation of the associated risks. It will achieve increased share of green reusable and /or recyclable and/or biosourced construction materials / products used in building renovation to contribute to circular economy.



The GREENERGY achievements (1)

DESIGNS, DETAILING AND INSTRUMENTATION OF CONSTRUCTED AS-BUILT 3D STRUCTURE

The one-bay, one-story 3D structure consists of a slab, four columns, four foundation beams, and four brick infill walls. It is scaled down to the capacity of the seismic table of DUTH that can perform with a maximum mass of tested structure of 8 tons and $8\text{tn}\cdot\text{m}$ maximum overturning moment. It refers to old generation design codes for reinforced concrete buildings, especially columns having sparse and inadequate steel stirrups and in general poor steel detailing. Further, low strength brick wall infills with horizontal holes and with relatively low strength brick-joint mortar, cover the two opposite RC frames subjected to out of plane dynamic excitation. Finally, the two opposite RC frames subjected to in plane dynamic excitation include two partial brick wall infills of identical mechanical characteristics. The instrumentation of the structure involves advanced embedded a) innovative PZT sensors inside the concrete mass (columns, slab, and beams hidden in the slabs) and externally bonded on the infill walls, as well as b) strain gauges, glued on the longitudinal bars of the four columns. Further, 3d accelerometers are attached to the slab, on the foundation beam, and on the infill wall subjected to out-of-plane dynamic excitation. Finally, draw wire displacement meters are attached on the slab, on the foundation beams and along the diagonals of the partial infill walls subjected to in-plane dynamic excitations. In total, more than 80 different sensors are installed. The successive dynamic excitations of the seismic table follow a dynamic pushover scheme and are based on the dynamic characteristics and severity of the well-known disastrous Thessaloniki (Volvi) 1978 earthquake. Further, experimental resonance dynamic tests are included. With the as-built reinforced concrete brick-infilled structure, GREENERGY aims to assess the dynamic performance of old-type deficient structures enabled by innovative and resilient structural health monitoring. Next, the innovative and resilient renovation will follow including Vertical Forest constructions.



The GREENERGY achievements (2)

We are excited to announce the publication of our latest research article, "Performance-Based Damage Quantification and Hazard Intensity Measures for Vertical Forest Systems on RC Buildings," in the journal *Buildings*. The research identifies key damage indicators and evaluates their applicability to VF-integrated structures, highlighting the need for specialized design codes and integrated monitoring systems to ensure structural stability and environmental efficiency. For a comprehensive understanding of our findings and methodologies, we invite you to read the full article at the following link: <https://doi.org/10.3390/buildings15050769>.

