

ADVANCING SUSTAINABLE DEVELOPMENT THROUGH GREEN CONSTRUCTION MATERIALS: A CASE STUDY OF SÂNTANDREI VILLAGE, BIHOR COUNTY

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ABSTRACT:

The harmonization between nature and construction, in the context of the development of human society, is a desideratum for protecting the environment; the advantages of a sustainable construction industry are reflected economically by increasing energy efficiency, reducing pollutants, and the consumption of natural resources while respecting the legislation and norms in the field. Climate change is mainly determined by the increase in the concentration of greenhouse gases released into the atmosphere, as a result of human activities in all fields, with particular emphasis on the construction sector. On the other hand, the construction sector is one of the most important pillars of economic growth in Romania. According to provisional data from the I.N.S., the construction sector represents almost 8% of GDP (Agerpres, 2025), being the largest share in the European Union (according to Eurostat data). The locality of Sântandrei in Bihor County is located in a strategic peri-urban development area, in the west of Oradea municipality, being one of the most dynamic communes in Bihor County. The development of the locality and its favorable location have attracted real estate investors in rapid and dynamic urban development. In order to become a model of sustainable and intelligent economic development, for Sântandrei the issue of renewable energies, sustainability and environmental protection represents a central point of urban development. The rapid population growth requires the application of a coherent strategic vision in accordance with Romanian and European norms regarding the construction of new, sustainable, ecological and efficient housing.

1. INTRODUCTION

The trend of population growth and its concentration in urban settlements is a specific reality of current societies, with profound effects at the spatial level (Herman et al., 2025a). In this context, identifying opportunities for sustainable development is essential for the factors involved, central and local public authorities and, finally, for the local population, as the main beneficiary of a healthy living environment. One of the major desiderata of current society is sustainable development, with reference to economic development, social inclusion and environmental sustainability (Singh, 2016, United Nations General Assembly Report of the Secretary General, 2013; Zhou et al., 2026).

The concept of sustainable development has been widely debated in the literature through the lens of climate change (Kaur and Sharma, 2026; Sohn, 2026; Zhang et al., 2026), renewable energy (Işık et al., 2026; Rusydiana et al., 2026; Xie and Lin, 2026), circular economy (Albu et al., 2021; Hoang et al., 2026; Joensuu et al., 2020; Saravanan and Chandrasekar, 2026), spatial management (Dong et al., 2026; Kılış et al., 2026; Herman et al., 2025b), water management (Biswas et al., 2026; Herman et

al., 2019; Karri and al., 2026), artificial intelligence (AI) (Gohr et al., 2025; Nurjain et al., 2026; Pluskota et al., 2026), etc. Basically, sustainable development opportunities refer to the ways in which society can progress economically and socially without negatively affecting the environment and resources for future generations. One of these ways can also be represented by the need to innovate and use more environmentally friendly construction materials.

In the European Union, the construction sector - buildings - consumes about 40% of total energy and emits 36% of total greenhouse gases. With the adoption of the European Green Deal (2019) and the Energy Performance of Buildings Directive (2014), sustainable constructions become a "key" element for the decarbonization of the built stock and the transition to new, more efficient and sustainable construction practices. In Romania, according to data from the INS and the Ministry of Development, over 70% of residential buildings were built before 1990. The materials used at that time: reinforced concrete, cement, classic masonry, met the needs for structural resistance, functionality and low execution costs; they involved high consumption of raw materials, energy and significant emissions (according to the

National Energy Agency - IEA, 2022). Constructions with traditional materials and technologies have begun to be replaced, amid climate change, rising prices for raw materials and energy; European Union legislation on sustainable construction at all stages from design to execution, operation and demolition, if necessary, aims to reduce environmental impact, increase energy efficiency and reduce the consumption of natural resources (World Green Building Council, 2021). Mineral aggregates, water, land, energy and carbon dioxide emissions contribute to the intensification of climate change (Efficient Romania, 2023).

2. RESEARCH METHODOLOGY

The purpose of this research is to identify and highlight the opportunities for sustainable urban development in the town of Sântandrei, Bihor County, through the integration of sustainable construction materials, to reduce the impact on the environment and increase the quality of life of the inhabitants (Herman et al., 2022).

The research hypothesis of the present study aims to ensure that the integration of sustainable construction materials in the urban development process in the town of Sântandrei, Bihor County, contributes to reducing the impact on the environment and increasing the quality of life of the inhabitants.

The research is of an applied and descriptive-explanatory type, aiming to analyze the opportunities for sustainable urban development in the town of Sântandrei, Bihor County, through the use of sustainable construction materials.

The main research methods used in carrying out this approach aimed at documentary analysis to identify the current development framework and existing sustainable directions. Thus, innovative and sustainable construction materials that could be used in the development of the town of Sântandrei, Bihor County, Romania were highlighted. The analysis of the studied area was based on direct observation of newly built residential areas and their dynamics and the materials from which they were made. The justification for this approach is derived from the proximity of the town of Sântandrei in relation to the municipality of Oradea and from the accentuated dynamics of the urbanization process amid the increase in population.

The present approach can be continued with other studies and research aimed at the perception and motivation of local public authorities, residents and real estate developers regarding the use of sustainable construction materials.

3. CLASSIFICATION OF CONSTRUCTION MATERIALS FOR SUSTAINABLE CONSTRUCTION

Sustainable construction is no longer a luxury; it is a technical and ethical necessity. In the not-too-distant future, buildings will consume less, but will produce energy and regenerate the environment. The concept of "sustainable construction" with ecological materials is defined by the ecological impact starting from the choice of location, design - with the choice of the constructive solution and construction materials -, execution, to

the completion and release of waste. According to statistical data, the consumption of natural resources in construction, globally is:

- raw materials, 30%,
- electricity, 40%,
- water, 12%,
- CO2 emissions, 39%.

Building materials are testimonies of the technical and technological level reached by human society in a certain place at a given time (Herman et al., 2020). Thus, from archaeological research, historical testimonies and information provided by some historical monuments, man over time has used numerous materials (earth, stone, wood, plant and animal remains, etc.) to build shelters and settlements. With the passage of time, man has learned to process what nature has made available to him, innovating and obtaining other types of materials as a result of processing. Among these, ceramics, bronze, iron, cement, etc. stand out. The accumulation of technological and scientific advances has facilitated and will facilitate the obtaining of new building materials with special characteristics and qualities, whose role is to support the sustainable development of human settlements.

Thus, a classification of construction materials carried out by PlanRadar in 2022 refers to the existence of several innovative, efficient and sustainable, but also ecological materials, some of which are still in the experimental phase. These are:

*Carbon fiber, 75% lighter than iron and 30% lighter than aluminium. This material reinforces traditional materials by increasing their resistance, reduces thickness and weight; offers high thermal insulation, but has high production costs.

*Self-healing concrete - is a product in the experimental phase, but it can become an effective solution for cracked concrete that has lost its properties.

*Liquid granite made of 70% marble chips and 30% additives. It is sprayed on various surfaces and is an ecological material.

*Flexible concrete, which is 30 times more resistant than traditional concrete or metal. It is ecological because it also contains waste from coal-fired power plants.

*Canvas concrete is a flexible roll-on concrete material. Installation is 10 times faster than classic materials.

*Laminate wood is a wood pressed into panels and laminated, very resistant.

*Cabkoma - hydrocarbon fibers. It was developed in Japan, being very resistant to earthquakes, but has a high price.

Sustainable constructions are based on modern technologies that combine energy efficiency, sustainability and comfort of beneficiaries. Urban studies involve modernization in design, execution and materials used, taking into account climate changes. The European Environment Agency (EEA) has prepared a report on climate change in Europe, summer temperatures and the increase of these values (fig.1):

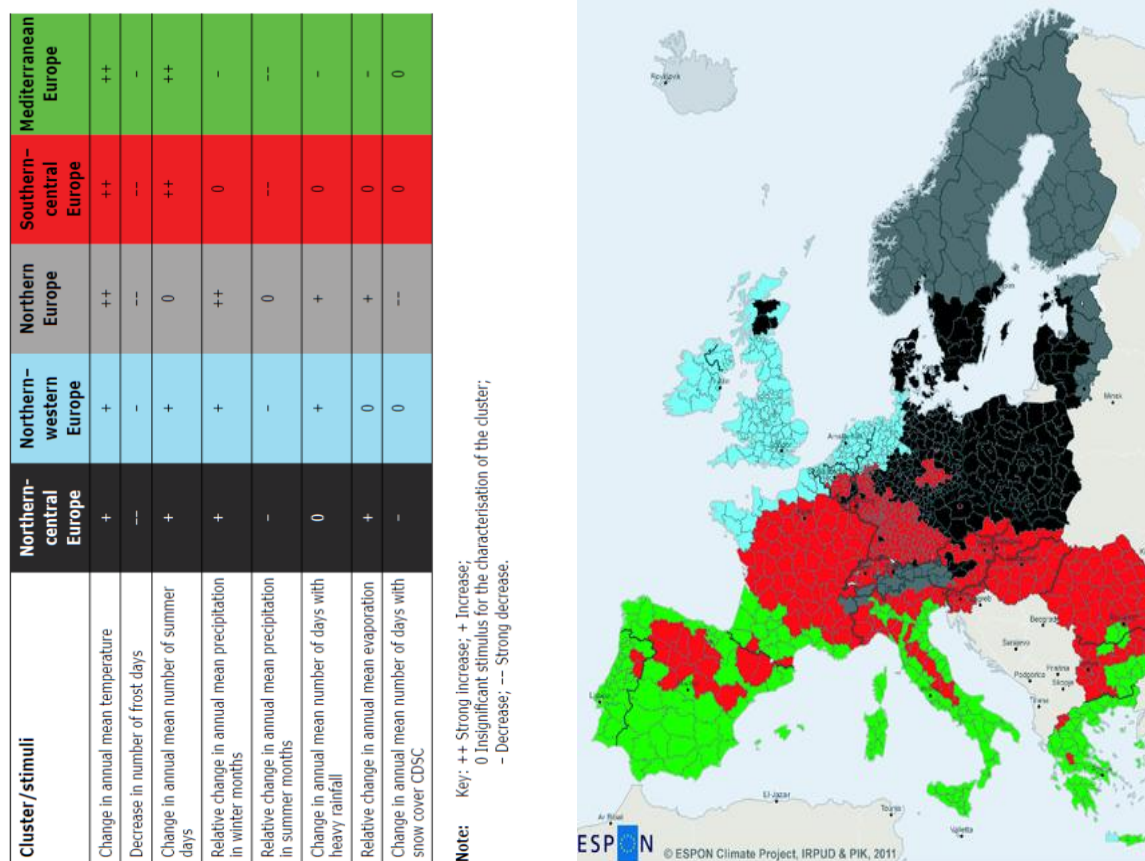


Figure 1. Climate change in Europe – European Environment Agency (EEA) Report No. 2 (2012) (origin of data after Lautenschlager et.al., 2009)

Romania is one of the countries most exposed to climate change, according to this report. Adapting constructions using sustainable materials and technologies that are as low as possible is necessary but faces obstacles:

- the cost of green buildings is increasingly higher than that of classic ones, by percentages between 10-20%, depending on materials and technologies;
- lack of specialized labor;
- lack of specialized infrastructure and technology;
- resistance to change among citizens;
- adaptation to climate change;

- specialized maintenance of buildings.

An example of a locality that has experienced dynamic growth in recent years is the locality of Sântandrei, Bihor County.

The constant population growth (fig.2), the expansion of new residential areas, economic development based on services and light industry, as well as the modernization of infrastructure have transformed the profile of the locality: from a predominantly rural and agricultural economy, the locality is economically integrated with Oradea and is in full expansion.

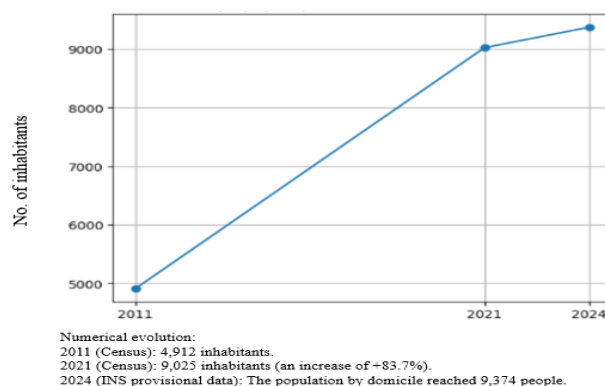


Figure 2. Population evolution in Sântandrei

Sântandrei has recorded the highest percentage increase in population in Bihor County in the last decade. Sântandrei has become the most populous rural locality in the Oradea Metropolitan Area, with over 200 inhabitants/km² in 2025. The area of the Sântandrei is 28.01 km² (0.4% of the county), being one of the smallest in size, but the most densely built. The expansion is done through numerous Zonal Urban Plans (PUZ) that introduce extra-urban lands into the built-up area, especially in the south and east of the locality. The development was accelerated by the connection road with Cazaban Street (completed in 2018) and the proximity to the new Oradea-A3 connection road. The expansion of its zone is visible through the rapid transformation of agricultural lands into residential areas.

The profound transformations of the Sântandrei locality are due to the growth of the population, most of which works in Oradea. Easy access, infrastructure, metropolitan public mobility networks are elements that have attracted investors to the locality. According to the National Institute of Statistics, the housing stock, in 2020, was 3063 homes. The increase compared to 2013 was 1032 units, or 50.81%. If in 2011 the population was 4912 inhabitants, in 2024 according to provisional data from the INS the population of the commune was 9374 people.

An accelerated development of the area is noted, especially in the south and east of the locality. The development was also accelerated by the connection road with Cazaban Street in Oradea - completed in 2018, but also the new Oradea-A3 connection road.

In 2025, the locality became the densest rural area in Bihor with 200 inhabitants/km². At the level of the locality of Sântandrei, the average living area increased from 64 sq m in 2013 to 66.18 sq m in 2019 (+2.18 sq m), according to data taken from the "Strategy for sustainable development of the commune of Sântandrei 2021-2027. Oradea metropolitan area".

The locality of Sântandrei has a very high development potential that creates the premises for economic growth; with a positive demographic dynamic it can create the premises for a model economic development in the area.

The share of the active population aged between 20 and 64 has increased, stimulating the demand for housing and jobs, services and adequate infrastructure.

In recent years, Sântandrei has become predominantly a destination point, not a migration point from the village to the city. The integrated urban vision of the Sântandrei locality means the development of a well-organized polycentric structure, without spatial fragmentation of poorly connected areas.

The fundamental benchmarks are functional coherence, fluent mobility and spatial equity. Urban planning will avoid the development of isolated or insufficiently equipped neighbourhoods. The sustainable and balanced development of residential areas, services, educational, commercial and health spaces is achieved by promoting local identity by providing coherence in urban expansions.

Residential development must be carried out responsibly to avoid urban dysfunctions. Sustainability in housing is achieved by promoting/designing energy-efficient homes, integrating solar panels, sustainable and ecological building materials (Grădinaru & Șerbănoiu, 2019).

By using high-performance materials and new technologies, the result is:

- reduction of energy consumption and CO₂ emissions,
- reduction of air and water pollution,
- energy independence through the integration of renewable sources: solar panels, heat pumps,
- use of non-toxic materials for beneficiaries,
- sustainable buildings in extreme weather events,
- reduced long-term maintenance,
- contributes to reducing climate change.

The European Union aims to become a global leader in the field of sustainable development, influencing international policies and promoting high standards of environmental protection. Through international cooperation, the EU has the potential to transform current challenges into opportunities for sustainable economic growth and social well-being.

4. CONCLUSIONS

The construction sector has a considerable impact on climate change. Sustainability and increased construction efficiency mean saving natural resources and energy, but also the ability of buildings to respond effectively to future challenges. Energy simulations allow for a behavioral prediction of constructions in the present and future: efficient construction solutions can be adopted, with durable, less polluting materials, correctly sized: the risk of subsequent major interventions is reduced and resilient buildings with a high degree of comfort are obtained.

Efficient buildings represent an integrated process that includes high-efficiency construction solutions and installations, less polluting but which meet quality standards, ensure constant comfort, respecting the legislation in force.

Climate change significantly affects the built environment. Extreme temperatures can cause degradation of constructions, such as: expansion or degradation of embedded materials; heavy rainfall and storms can degrade foundations, utility networks and, in general, structural integrity. In addition to the design adapted to these needs, it is necessary to use sustainable solutions and materials: renewable energy, ecological materials, green spaces and green infrastructure.

The costs of sustainable construction with ecological materials and technologies are higher, and the investment recovery time is longer. The locality of Sântandrei in Bihor County is located in a strategic development area, to the west of Oradea municipality. In the last 20 years, the local population has grown rapidly; housing construction has radically transformed Sântandrei functionally and economically.

The development has been facilitated by public mobility networks, proximity to Oradea, and the expansion of public infrastructure. The development dynamics raise challenges in maintaining the balance between sustainability and economic development, with the management of urban expansion, increasing the quality of life, and protecting the environment. The interest of real estate developers is constantly growing.

In the development of the locality, renewable energies and sustainable growth occupy a central position; in urban development strategies, the transition to a sustainable energy model is a practical necessity (Badea et.al, 2024).

The local administration encourages the implementation of green solutions, with the transition from a system based on fossil fuels to one based on renewable resources, energy efficiency and ecological materials. The expansion of residential neighborhoods, the increase in energy consumption and the need for adaptation offer the opportunity to implement green, clean and climate resilient solutions in construction, in the long term.

The village of Sântandrei is in economic and urban expansion. Sustainable and durable development is an integrated process in which urban development, construction, water, technology, the environment and the community are harmoniously intertwined. The goal is to transform the village with a change in behavior, collective involvement and awareness for a balanced, modern and sustainable living environment. The village has all the conditions to become a model of sustainable and intelligent urban development.

References

- Badea G., Naghiu G., Albici O., 2024. *Energetica localităţii în tranziţia spre neutralitatea climatică*, Conferinţa „Barierile energiei în energetica localităţilor” Cluj Napoca (Local energy in the transition to climate neutrality, Conference "Energy Barriers in Local Energy" Cluj Napoca).
- Grădinaru Cătălina, Şerbănoiu A., 2019. *Managementul materialelor ecologice de construcţii* (Management of ecological building materials), Ed. Bioflux Cluj Napoca.
- Emisiile de carbon „ascunse” ale clădirilor: cât contribuie la poluare şi cum pot fi reduse, în *România Eficientă*, 31.ian.2023 ("Hidden" carbon emissions of buildings: how much they contribute to pollution and how they can be reduced, in *Efficient Romania*, January 31, 2023).
- Agerpres, 30.10.2025. Sectorul construcţiilor din România reprezintă aproape 8% din PIB (Agerpres, 10/30/2025. The construction sector in Romania represents almost 8% of GDP).
- I.N.S. *Date statistice anuale – Anuare statistice în construcţii şi mediu* (I.N.S. Annual statistical data – Statistical yearbooks in construction and environment).
- Eurostat. *Date statistice* (Eurostat. Statistical data).
- ONU, 2015. Agenda de Dezvoltare Durabilă 2030 (UN, 2015. 2030 Agenda for Sustainable Development).
- Uniunea Europeană, 2019. Pactul verde European (European Union, 2019. European Green Deal).
- Directiva UE 2024/1275 privind performanţa energetică a clădirilor (EU Directive 2024/1275 on the energy performance of buildings).
- P. Marian, 13.09.2022. Plan Radar: 17 materiale de construcţii inovatoare care reinventează modul în care construim (Planradar: 17 innovative building materials that are reinventing the way we build).
- Raportul European Environment Agency (EEA), 2013 (European Environment Agency report).
- Agenţia Internaţională a Energiei (IEA), 2022 (International Energy Agency).
- Zona Metropolitană Oradea (ZMO), Strategia de dezvoltare durabilă a comunei Sântandrei 2021-2027, zona metropolitană Oradea (Sustainable development strategy of the commune of Sântandrei 2021-2027, Oradea metropolitan area).
- MDLPA, 2018. Strategia naţională de dezvoltare durabilă a României 2030 (Romania's National Sustainable Development Strategy 2030).
- Ghid pentru clădiri verzi şi eficiente energetic în România, Bucureşti, 2022 (Guide to green and energy efficient buildings in Romania, Bucharest).
- Agenţia Naţională de Meteorologie, 2020. Schimbări climatice în România – tendinţe şi scenarii, Bucureşti (National Meteorological Agency, 2020. Climate change in Romania – trends and scenarios, Bucharest).
- World Green Building Council (WGBC), 2021.
- Ministerul Dezvoltării Regionale, 2013. *Plan de creştere al numărului de clădiri al căror consum de energie este aproape egal cu zero*. Nearby zero energy buildings (NZEB) Romania (Ministry of Regional Development, 2013. Plan to increase the number of buildings whose energy consumption is almost zero).
- Herman, G. V., Caciara, T., Herman, M. L., Şandra, M., & Bulz, G. C. (2025a). Exploration of the relationship between the population and football stadiums in Romania. *Urban Science*, 9(1), 19. <https://doi.org/10.3390/urbansci9010019>.
- Herman, G. V., Bucur, L., Filimon, C. A., Herman, M. L., Nistor, S., Tofan, G. B., ... & Caciara, T. (2025b). Exploring the Relationships Between Bicycle Paths and Urban Services in Oradea, Romania. *Urban Science*, 9(9), 373. <https://doi.org/10.3390/urbansci9090373>.
- Singh, Z. (2016). Sustainable development goals: Challenges and opportunities. *Indian Journal of Public Health*, 60(4), 247-250. United Nations General Assembly Report of the Secretary General 26th July, 2013. Last accessed on 2016 Oct 17 Available from: http://www.un.org/en/ga/search/view_doc.asp?symbol=S/2013/444.
- Zhou, T., Huang, C., Zhong, F., Song, X., Hou, J., & Zhang, Y. (2026). Unveiling the challenges and opportunities of sustainable development goals in China: Untangling the main causal relationships. *Environmental Impact Assessment Review*, 117, 108246.
- Sohn, W. S. (2026). Towards a sustainable future: addressing climate change and promoting sustainable development. *Sustainable Development*, 34, 226-247.
- Kaur, A., & Sharma, V. (2026). Nexus between climate change and mitigation approaches for sustainable development: a bibliometric review. *Global Knowledge, Memory and Communication*, 75(1-2), 477-509.

- Zhang, Q., Grassi, A., & Vallati, M. (2026). Gamification and sustainability: A review of approaches for urban mobility and climate change resilience. *Sustainable Futures*, 11, 101589.
- Işık, C., Ongan, S., Islam, H., & Segota, T. (2026). Exploring the commitment to sustainable development goals (SDGs)—the renewable energy and tourism demand nexus. *Tourism Economics*, 32(2), 342-366.
- Rusydiana, A. S., Rosadhillah, V. K., & Riani, R. (2026). Efficiency of renewable energy for sustainable development: empirical evidence in OIC countries. *International Journal of Energy Sector Management*, 20(2), 386-404.
- Xie, Y., & Lin, B. (2026). Driving urban sustainable development: The role of renewable energy technology innovation in enhancing urban environmental efficiency. *Renewable and Sustainable Energy Reviews*, 226, 116228.
- Saravanan, K., & Chandrasekar, T. (2026). Circular Economy Practices and Its Role Towards Sustainable Development in the Textile Industry. *Journal of The Institution of Engineers (India): Series E*, 1-11.
- Joensuu, T., Edelman, H., & Saari, A. (2020). Circular economy practices in the built environment. *Journal of cleaner production*, 276, 124215.
- Hoang, V. H., Dong, V. C., & Tran, T. M. T. (2026). Determinants of transforming to a circular economy: evidence from a developing country. *Sustainable Futures*, 11, 101665.
- Albu, A.V., Caciora, T., Berdenov, Z., Ilies, D.C., Sturzu, B., Sopota, D., Herman, G.V., Ilies, A., Kecse, G., Ghergeles, C.G. (2021). Digitalization of garment in the context of circular economy Ind. Textila, 72, 102-107.
- Dong, X., Jiang, G., Qu, Y., Yang, Y., Ma, W., & Tian, Y. (2026). Path dependency and differentiated driving mechanism: Revisiting the spatio-temporal evolution of rural settlement sustainable development for future policy insights. *Environmental Impact Assessment Review*, 117, 108156.
- Kılış, Ş., Krajačić, G., & Duić, N. (2026). Integrating solutions for enabling the sustainable development of energy, water and environment systems. *Energy conversion and management*, 347, 120492.
- Karri, R. R., Ravindran, G., Pingili, V., Mubarak, N. M., Ruslan, K. N., & Tan, Y. H. (2026). Integrating the Food-Energy-Water Nexus: Strategies for climate change mitigation with SDG alignment. *Environmental Impact Assessment Review*, 116, 108070.
- Biswas, K., Kumar, A., Girigoswami, A., & Girigoswami, K. (2026). Evaluating the role of functionalized graphene systems in achieving wastewater treatment: A paradigm for sustainable development. *Next Materials*, 10, 101397.
- Herman, G. V., Gaceu, O., Mester, C., Baias, S., Caciora, T., & Wendt, J. A. (2019). Spatial analysis of water quality in natura 2000 Sites Bihor, Romania. *Journal of Environmental Protection and Ecology*, 20(4), 2121-2129.
- Nurjain, A., Nurjain, L. R., Fajriah, Y. N., Nurjain, A. K., & Firdaus, H. A. (2026). Integrating generative artificial intelligence (AI)-based multimodal learning in education to enhance literacy aligned with Sustainable Development Goals (SDGs). *ASEAN Journal of Educational Research and Technology*, 5(1), 71-88.
- Pluskota, P., Słupińska, K., Wawrzyniak, A., & Wąsikowska, B. (2026). The Application of Artificial Intelligence (AI) in the Implementation of ESG-Oriented Sustainable Development Strategies in the Banking Sector: A Case Study. *Sustainability*, 18(2), 732.
- Gohr, C., Rodríguez, G., Belomestnykh, S., Berg-Moelleken, D., Chauhan, N., Engler, J. O., ... & von Wehrden, H. (2025). Artificial intelligence in sustainable development research. *Nature Sustainability*, 8(8), 970-978.
- Herman, G. V., Caciora, T., Ilies, D. C., Ilies, A., Deac, A., Sturza, A., ... & Nistor, S. (2020). 3D Modeling of the cultural heritage: Between opportunity and necessity. *Journal of Applied Engineering Sciences*, 10(1), 27-30.
- Herman, G.V., Matlovičová, K., Kostilníková, K., Pantea, L., Gozner, M., Demkova, M., & Zemanová, L. (2022). The relationship between the degree of knowledge and the perception of the importance of the route of tourist routes. Case study: tourist Destination Arieseni, Romania. *GeoJournal of Tourism and Geosites*, 45(4spl), 1610–1617. <https://doi.org/10.30892/gtg.454spl10-981>.