

Article

Not peer-reviewed version

Maximizing Green Building Efficiency: Innovations for Sustainable Constructions

[Luigi Abruzzese](#)*, Massimo Bilotta, Michela Carzaniga, Arianna Ciriello, Danilo D'Ambrosio, Manuela Di Santo, Federica Giorgione, Paquale Leo, Antonietta Maiello, Patrizia Mainiero, Raffaele Melito, [Annamaria Vicari](#)

Posted Date: 24 June 2024

doi: 10.20944/preprints202406.1636.v1

Keywords: sustainability; green buildings; energy; PVGIS



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article

Maximizing Green Building Efficiency: Innovations for Sustainable Constructions

Luigi Abruzzese ^{1,*}, Massimo Bilotta ¹, Michela Carzaniga ², Arianna Ciriello ¹, Danilo D'Ambrosio ³, Manuela Di Santo ², Federica Giorgione ¹, Pasquale Leo ³, Antonietta Maiello ¹, Patrizia Mainiero ³, Raffaele Melito ¹ and Annamaria Vicari ¹

¹ Istituto Nazionale di Geofisica e Vulcanologia, Sezione Irpinia, Italy

² Istituto Nazionale di Geofisica e Vulcanologia, Amministrazione Centrale, Italy

³ Independent Contractor- Grottaminarda, Italy

* Correspondence: pmo@ingv.it

Abstract: The construction sector is a paradigm shift into the sustainable era to solve environmental issues, combat global warming. And the reflection of this is on Green Buildings where energy savings, cost savings, occupant comfort takes priority. The idea of green building efficiency merges sophisticated technologies, creative architectural design templates, and reusable materials into the whole life cycle of a building process in order to render minimum environmental impact. The pilot project of The National Institute of Geophysics and Volcanology (INGV) - Irpinia headquarters, illustrates in this context, innovative technologies of energy transition with a photovoltaic parking with geothermal piles. The project is consistent with the concepts of Nearly Zero Energy Buildings (NZEBS), directed to a high energy performance and very low environmental impact. Incorporating geothermal piles is a major area of advancement in sustainable building ideas that use the Earth's natural heat to create an energy efficient solution in heating and cooling. Project Goals – The project aims to install emission free renewable cleaning energy cost-effective clean production and increase energy efficiency, reduce CO2 emissions and energy security. For this purpose this paper, using as a support the PVGIS software, evaluates the potential produced with the photovoltaic system installed in the canopies. With the help of this analysis, it is feasible to determine the amount of electricity produced as well as the system's amortization based on the excess energy sent to the public grid. The project is regarded as creative from the standpoints of energy given the use of geothermal and photovoltaic systems, as well as from an architectural and design perspective due to the use of novel materials. This all-encompassing strategy establishes INGV as a pioneer in the promotion of environmentally friendly technologies and shows a dedication to sustainability and energy efficiency.

Keywords: sustainability; green buildings; energy; PVGIS

1. Introduction

As environmental concerns grow and the need to slow down climate change becomes more urgent, the building sector is changing dramatically to become more sustainable. As a result of this paradigm change, green buildings have become symbols of optimism since they demonstrate a real commitment to lowering carbon footprints and encouraging resource-efficient behavior. The need to optimize these buildings' energy efficiency is at the core of this movement, as it guarantees that these constructions not only adhere to strict environmental regulations but also provide measurable advantages in terms of cost savings, energy conservation, and occupant comfort. The notion of green building efficiency is a complex process that goes beyond simply adhering to legal obligations. It symbolizes an all-encompassing vision of construction that reduces environmental effects over a building's lifetime by integrating state-of-the-art technologies, creative design ideas, and sustainable building materials. Every phase of a green building, from planning and design to construction, operation, and eventual decommissioning, is carefully coordinated to maximize resource efficiency, improve energy performance, and foster environmental stewardship. Furthermore, green building

efficiency extends beyond individual structures to include larger factors like urban planning, community resilience, and global sustainability. As cities cope with the difficulties of rapid urbanization and rising energy demands [6], the need to build sustainable built environments is more essential. Green buildings act as catalysts for urban redevelopment, promoting innovation in infrastructure, transportation, and energy systems while cultivating dynamic, living communities that coexist with nature. In this situation, achieving green building efficiency is not only a question of environmental responsibility but also a social and economic need. Green buildings have numerous advantages that go well beyond the immediate benefits of their occupants, such as decreased energy usage, minimized waste, and improved indoor environmental quality. They generate significant benefits in terms of energy savings, operational efficiencies, and increased property values, and they represent prudent investments in long-term resilience, economic competitiveness, and public health. In conclusion, the pursuit of green building efficiency embodies a revolutionary idea of sustainable development, according to which buildings are essential to social cohesion, economic growth, and environmental stewardship. We can fully realize the potential of green buildings as change-catalysts and move toward a more sustainable and prosperous future for future generations by utilizing innovation, teamwork, and forward-thinking design. In this contest, we introduce the INGV - Irpinia headquarters project, in terms of innovative technologies applied to the energy transition. The project, that we realized, consists of building a photovoltaic parking with geothermal pillars incorporated. This project is therefore based on two key concepts:

1. The energy retrofit of buildings as a crucial theme for the energy and environmental future of our country, dictated by the Paris Climate Agreement, which, in summary, aims to limit global warming to below 2°C and to continue efforts to contain it to 1.5°C in order to avoid the catastrophic consequences of climate change [1].
2. The INGV, as a leading national institution in the field of geophysics and volcanology, could derive significant benefits from the implementation of energy systems based on geothermal and photovoltaic technologies. This transition would not only promote overall environmental sustainability but also consolidate the institute's position as a promoter of the adoption of cutting-edge and environmentally friendly technologies.

In a study by Osorio et al. [15] it has been demonstrated that open car parks have enormous technological, environmental and financial advantages. Malek et al. [8] presented a project for a covered car park with a power of 3kWp, composed of 12 photovoltaic modules with the aim of charging urban vehicles, thus reducing CO₂ emissions. Merten et al. [9] has studied the synergy between electric vehicles, photovoltaic power plants and the electricity grid to allow a substantial market share of electric vehicles while also reducing greenhouse gas (GHG) emissions. Car parks occupy significant surfaces in cities and are generally used as single-use spaces, but they represent a great untapped opportunity for the implementation of photovoltaic modules and consequent production of clean, electrical energy [2].

2. Materials and Methods

2.1. The New Project of INGV - Irpinia Headquarters

The project directly fits into one of the most discussed topics in energy transition and innovation: Nearly Zero Energy Buildings (NZEBS). These are buildings designed and constructed with a very high energy performance, so that the amount of energy required for their operation is nearly zero or very low. This means that the building is extremely energy-efficient, using technologies and materials that minimize energy consumption for heating, cooling, lighting, and other energy needs. The main objectives of NZEBs include reducing energy demand and improving energy efficiency, with an emphasis on adopting renewable technologies and sustainable construction practices [10]. However, there are challenges associated with defining and implementing NZEBs, which vary based on climatic conditions, construction traditions, and local objectives of each country. In summary, widespread adoption of the NZEB model represents a significant step towards decarbonization and energy efficiency within European policies to address climate change and promote sustainability in

the construction sector. The National Institute of Geophysics and Volcanology (INGV), as part of the energy retrofitting project of the Irpinia Headquarters into a Near Zero Energy Building (NZEB), installed 2 galvanized steel canopies and a photovoltaic system with a total estimated power of 73 KWp connected to the electrical grid (Figure 1). Additionally, 6 columns for recharging electric vehicles were installed. This photovoltaic system was installed on the metal structure, designated as a parking area for vehicles. Thanks to this intervention, useful also as a covering for cars and vehicles in general, the surface of the canopy can be used for clean energy production. Among the interventions already implemented by the INGV to improve energy efficiency at its headquarters, the important innovation is represented by the provision, within the foundation poles of the photovoltaic canopies, of an installation of a low enthalpy geothermal system with vertical probes. These energy poles are connected to a heat pump and a water/water conditioning system of the headquarters, in order to exchange energy with the ground continuously and naturally. The main benefits, compared to traditional heating solutions, are numerous: obtaining thermal energy at a lower cost, as the return on investment of this type of system will be shorter than less efficient traditional systems; use of a single heat distribution system, both for heating and cooling; absence of substantial maintenance interventions for about 20 years.



Figure 1. Energy car parks with solar panels INGV - Irpinia headquarters.

2.2. Objectives and Expectations

To guarantee that the actions conducted result in observable and consistent outcomes with the established expectations, the project objectives have been properly stated. Among these goals are:

- **Production of clean energy:** The initiative intends to provide a direct contribution to the decrease of emissions that cause pollution, especially those that result from the burning of fossil fuels. This not only contributes to environmental preservation but also improves the implicated institution's energy reputation. In order to lessen the influence on the environment and encourage sustainable practices, clean and renewable energy must be produced.
- **Lowering energy expenses at the Grottaminarda (AV) headquarters** through self-production of clean and renewable energy is one of the main goals. This helps ensure the institution's financial stability and may also free up funds for investments in other vital areas.
- **Energy efficiency:** Installing renewable energy systems at the INGV headquarters reduces environmental effect while simultaneously boosting facility efficiency and energy effectiveness.

Investing in energy-efficient techniques and renewable energy technology is crucial to maximizing resource utilization and minimizing waste.

- Emissions reduction: Measuring the project's environmental advantages, especially in terms of energy savings and CO2 emissions reduction, is another crucial goal. This can help achieve both national and international emission reduction targets in addition to giving a precise assessment of the project's beneficial environmental effects.
- Energy independence: Increasing energy independence and security for the INGV, especially for infrastructure of great importance, is a crucial objective. Relying on renewable energy sources can help reduce dependence on volatile fossil fuel markets and improve resilience to disruptions in energy supplies. This enhances the overall reliability and sustainability of the institution's energy infrastructure.

2.3. Innovation in All Aspects

The work that INGV is doing is an all-encompassing structural and energy innovation. From a structural point of view, the innovative approach is clearly visible in the architectural layout and the use of cutting-edge materials that not only guarantee the stability and longevity of the structure but also optimize resource and energy efficiency. Innovation in energy is demonstrated by the use of state-of-the-art technologies for energy generation and use. A major divergence from conventional methods is made possible by the installation of solar and geothermal systems, which enable the production of clean, renewable energy right on the construction site. This lowers reliance on traditional energy sources while simultaneously lowering greenhouse gas emissions and raising the building's overall efficiency. In conclusion, the structure is an example of holistic innovation since it addresses both structural and energy issues, making it a more efficient and sustainable building.

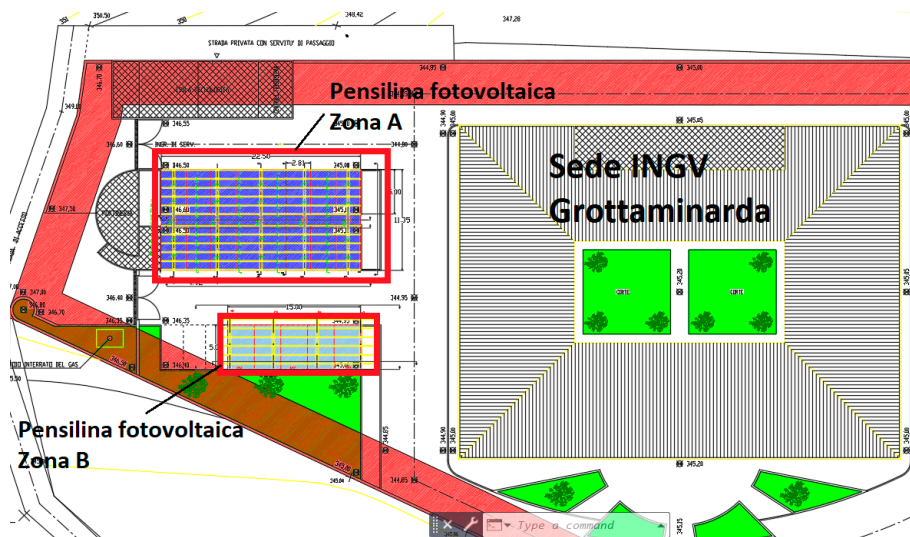


Figure 2. General plan and layout of the canopies.

2.3.1. Innovation Structure

The two structures (canopy zone A, canopy zone B) consists of a series of identical flat frames spaced equidistantly, 4.92 meters apart, characterized by a single vertical column flanked by one or two structural arches (rolled tubular), depending on whether the canopy is made up of two or a single slope, which provide support to the main roof beams (Figure 3).

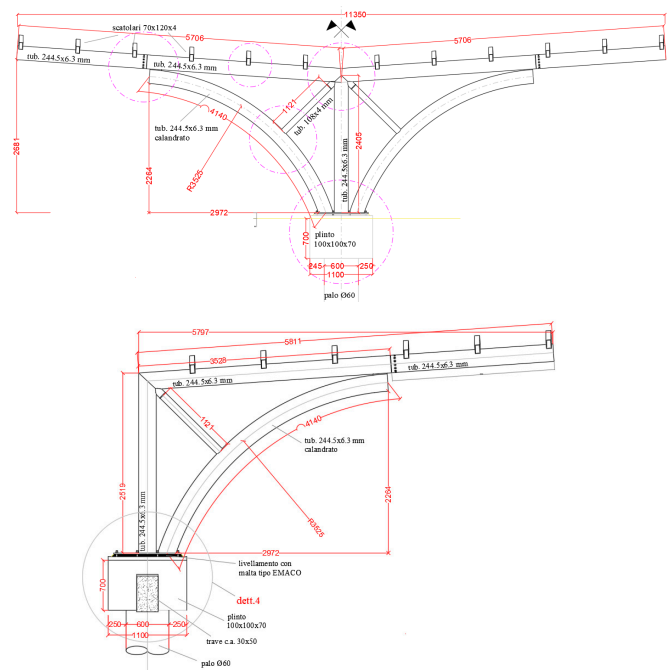


Figure 3. Canopies frame.

The rolled tubular columns, arches, and mains beams are made of S355 steel tubes with a section of 244.5*6.3, and there are also bracing elements made of S355 steel tubes with a section of 108.0*4 is woven, to which the photovoltaic panels are anchored. The foundation consists structure consists, for each canopy, of a battery of pile caps on piles, with a diameter of 60 centimeter and a depth of 6.0 meters, connected by beams with a section of 30*50, made of normal reinforced concrete of class 25/30 and B450C steel. The use of deep foundation, considering the modest magnitude of gravitational loads acting on the structures in question, pursues mainly two objectives; reducing the planimetric footprint of the foundations by reaching the layer of medium consistency soil beyond the superficial altered layer, ad serving as ballast capable of resisting the significant bearing action exerted on the wide canopy surfaces by the incident wind (Figure 4).

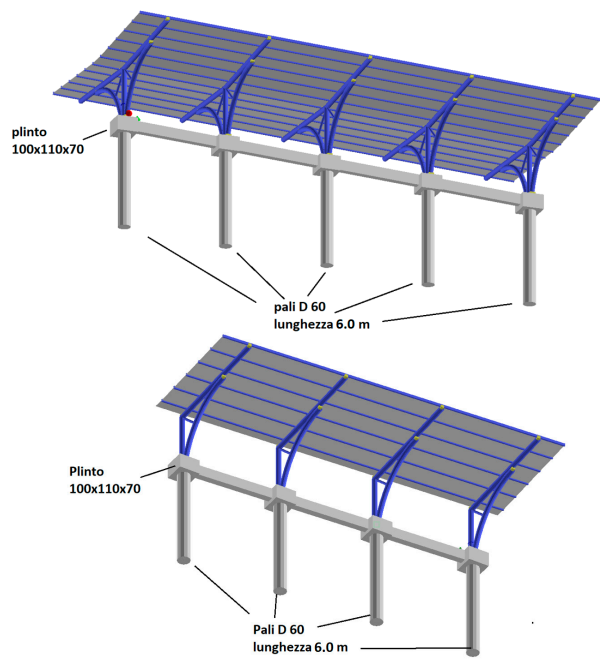


Figure 4. Canopies foundation.

Another innovation in terms of design and utility structure is relative to the geothermal pillars. This innovation represents a significant breakthrough in sustainable construction and energy efficiency. These geothermal piles (Figure 5), also known as energy piles, are designed to harness the natural heat of the ground to heat and cool buildings in a highly efficient manner. One of the most interesting features of this technology is its ability to utilize the constant temperatures of the underlying ground, which remain relatively stable throughout the year. The geothermal piles are connected to a system of heat pumps that utilize this intrinsic heat to heat the spaces during colder months and cool them during warmer months. This approach significantly reduces dependence on non-renewable energy sources such as natural gas or coal, thereby contributing to the reduction of greenhouse gas emissions and the fight against climate change. Additionally, since geothermal heat is a constantly available and free energy source, operational costs associated with heating and cooling buildings can decrease significantly over time. In terms of environmental impact, the use of geothermal piles also reduces the need for heating and cooling systems that may result in polluting emissions and high energy consumption. This not only improves indoor air quality but also reduces the overall environmental impact.

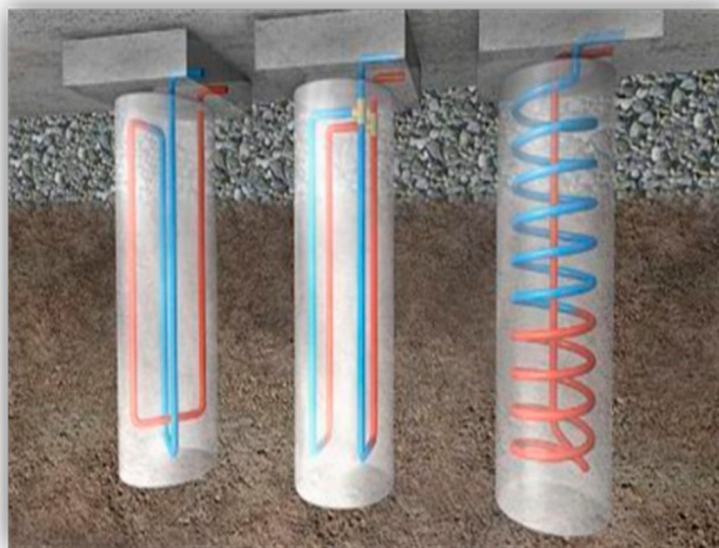
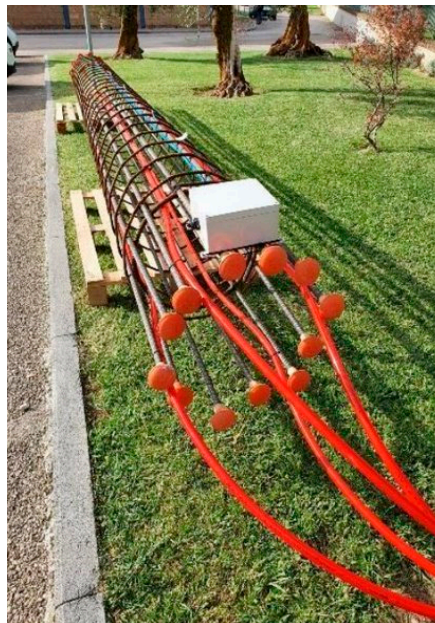


Figure 5. Geothermal piles.

2.3.2. Innovation Energy

The initiative proposed by the National Institute of Geophysics and Volcanology (INGV) reflects a modern and future - oriented approach to resource management and energy use. In addition to providing practical solutions for the institute's parking needs, the installation of steel canopies with sloped roofs presents a unique opportunity to harness natural resources and reduce environmental impact. The integration of photovoltaic modules (Figure 6), for a total system of 73 KWp, on the canopies will not only help to reduce long - term energy costs for the INGV but also demonstrates a tangible commitment to transitioning to cleaner and more sustainable energy sources. Furthermore, the use of LED lighting with motion sensors will not only improve the energy efficiency of the area but also enhance user safety, providing a modern and adaptable solution to needs a modern infrastructure.

The charging stations for electric vehicles represent a further step towards promoting sustainable mobility, in fact the INGV has decided to introduce a fleet of electric cars for its employees. This decision represents a significant step towards reducing greenhouse gas emissions and improving air quality, thus contributing to the fight against climate change.



Figure 6. Finished canopies with the photovoltaic system.

In addition, the above-mentioned geothermal piles are used to the heating and cooling system exploiting the intrinsic heat of the earth. Before we discuss the advantages of this system, it is essential to first talk about geothermal energy and the Energy Geo Structures (EGS).

2.3.2.1. Methodology for Solar Potential Estimation

Geographic information systems (GIS) such as ArcGis or QGis, together with the PVGIS tool, are most often used. Singh [14] estimates the rooftop solar PV potential of cities using the methodology applied to 13 Indian cities. Ren et al. [13] developed a novel 3D- geographic information system and

a deep learning integrated approach for high-accuracy building rooftop solar energy potential characterization of high-density cities. Roofs are the main location for the installation of solar panels for several reasons, i.e., the simplicity of installation. In addition to roofs, other elements can also be used to collect solar energy in buildings [12]. Fakour et al. [4] evaluated the solar photovoltaic carport canopy with electric vehicle charging.

For this project we used the PVGIS web tool to estimate the solar radiation and the potential of the photovoltaic system. This web tool has a very simple interface that includes shadows in the estimation, allowing the user to incorporate a horizon profile for more accurate results. For the research presented, the input parameters for the computation of solar radiation were:

- Solar radiation database PVGIS-SARAH2 is used as a source of solar radiation data because it presents a current temporal range of years 2005-2020. This is a database produced by the Satellite Application Facility on Climate Monitoring (CMSAF). It covers Europe, Africa, Asia and parts of South America;
- PV technology: crystalline silicon is the technology most used to estimate the losses due to temperature and irradiance effects;
- Installed peak PV power (kWh): the photovoltaic system on the canopies has a PV power of 73 kWh;
- System Losses (%): the estimated system losses are all the losses in the system that cause the power actually delivered to the electricity grid to be lower than the power produced by the PV modules. There are several causes for this loss, such as losses in cables or inverters. In general, it is considered that the losses of the system are between 10 and 20% for the estimation of solar production, so in this case, the average value (14%) has been considered as the value;
- Mounting position: for fixed systems the way the modules are mounted will have an influence on the temperature of the module, affecting their efficiency. Experiments have shown that if the movement of air behind the modules is restricted, the modules can increase their temperature up to 15°C at 1000 W/m² of sunlight. In the application, there are two possibilities: free-standing, meaning that the modules are mounted on a rack with air flowing freely behind the modules; and building-integrated, which means that the modules are completely built into the structure of the wall or roof of the building with no air movement behind the modules. In this case, the free-standing option was chosen because the modules are directly installed on the canopies.
- Slope: the tilt angle of the sloped roof. For the simulation we set it at 10°;
- Azimuth or Orientation: it is the angle of the photovoltaic modules in relation to the direction. We set it at 45° because the modules are faced southwest;

Based on these parameters, the PVGIS tool provides all input and output data in different ways: (i) csv format; (ii) json format; (iii) web format. The last option allows the direct results through dynamic graphs and tables that show the estimated average amount of irradiation (Figure 7) and the average amount of production (Figure 8) expected for each month based on the input data.

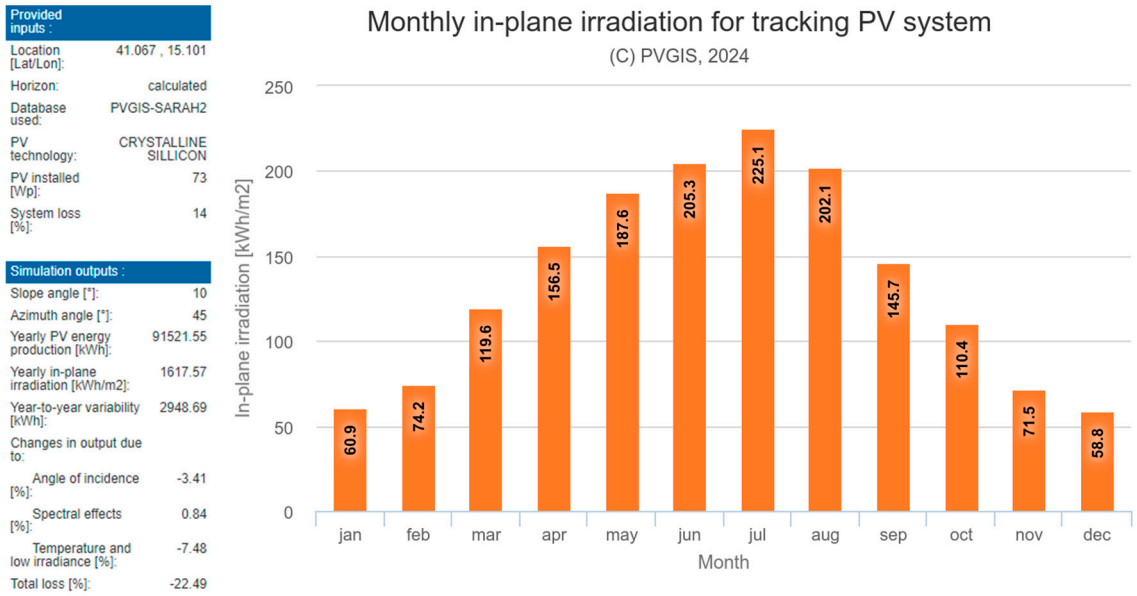


Figure 7. Dynamic graphs of monthly irradiation (kWh/m²).

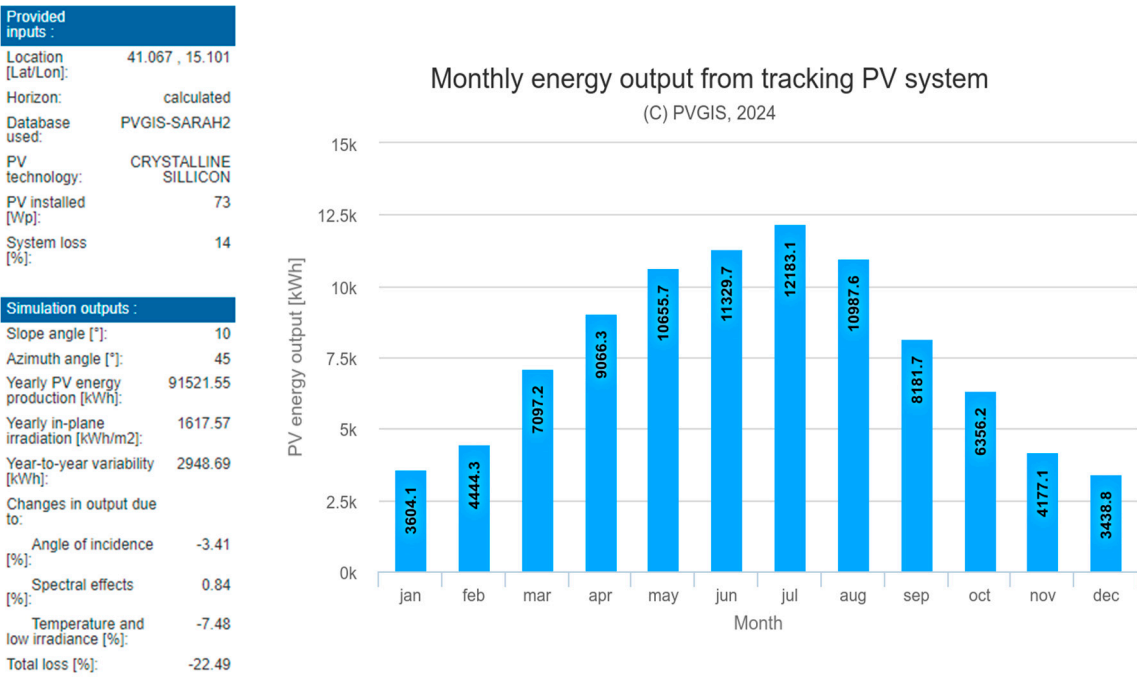


Figure 8. Dynamic graphs of monthly energy output (kWh).

2.3.2.2. The Geothermal Energy and the Energy GeoStructures (EGS)

Geothermal energy is the branch of geophysics that studies the distribution and origin of heat within the Earth. It belongs to the category of renewable energies and arouses considerable interest, both for the favorable prospects presented by some systems for exploiting the Earth’s internal heat, and for the development potential offered based on the availability of unused resources [5]. As reported on the institutional website of Enea, although the contribution of direct use of terrestrial heat to the global consumption of renewable heat remains limited, an increase of over 40% (+0.3 EJ) is expected in the period 2019-2024, thanks to the contributions from China, the United States, and the EU. Direct use of geothermal heat satisfies only 0.3% (0.13 EJ) of the global heat demand; therefore, although increasing, it is currently the least utilized renewable source [16]. Low-enthalpy geothermal

energy is a form of clean, renewable, and long-term safe and environmentally friendly heat. A geothermal heat pump is a refrigeration machine that performs a type of heat exchange, transferring heat from a cooler source to a warmer one. In the case of geothermal heat pumps, the energy source is the heat contained in the ground, which is “collected” through geothermal probes installed in the ground and connected to the heat pump. Inside the probes flows a heat transfer fluid, responsible for carrying the accumulated energy to the heat pump, powered by electricity. From the heat pump, the heat is then distributed throughout the building, for example through radiant floor panels [3]. The Earth’s temperature increases gradually as you go deeper, following the average geothermal gradient (3°C for every 100 meters of depth). There are various system configurations to harness low-enthalpy geothermal heat:

- Systems utilizing a heat exchanger to transfer heat from the geothermal fluid to a secondary circuit connected to the user;
- Systems directly using the geothermal fluid;
- Geothermal heat pump (GHP) systems.

This category of systems can be further divided based on the type of geothermal exchange used for coupling with the ground, namely open-loop or closed-loop configuration.

Closed-loop systems can be further subdivided into:

- Vertical borehole systems (one or more pairs of “U-tubes” housed in wells, through which the heat transfer fluid, usually water flows) (Figure 9a);
- Horizontal loop systems (loops consisting of coil of tubing variously configured and housed in trenches in the ground, typically 1 to 5 meters deep) (Figure 9b);
- Energy GeoStructures (EGS) e.g., foundation piles (embedding the loops directly within the building’s foundation piles) (Figure 9c).

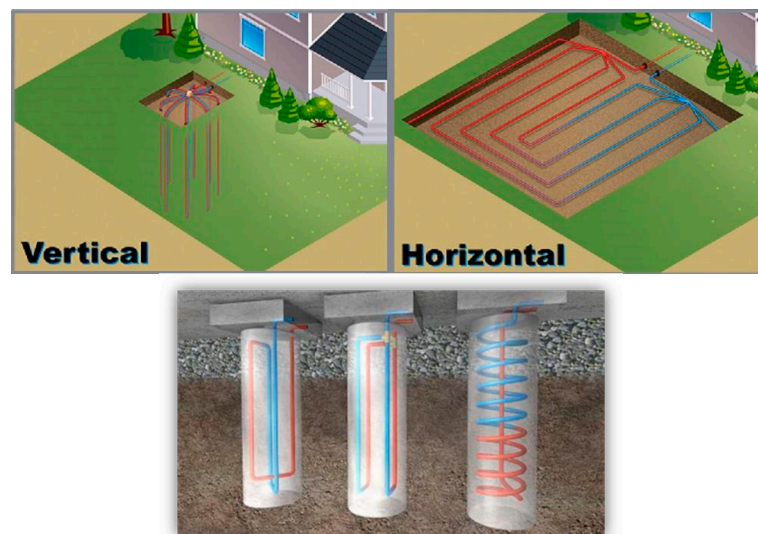


Figure 9. a) Vertical borehole systems; b) Horizontal borehole systems; c) Foundation piles (EGS).

The number of loops and the depth of installation depend on the intended heat usage and thermal loads required by the user. To enhance the performance of a low-enthalpy system, efforts are made to optimize the contribution of geothermal heat energy by employing a combination of utilization types connected to the same extraction system.

The Energy GeoStructures (EGS), such as energy piles, walls and tunnels (Figure 10) are innovative engineering solutions that integrate the primary heat exchanges of ground-source heat pump (GSHP) systems into foundation elements or tunnel linings.



Figure 10. a) pile; b) wall; c) tunnel.

Concrete is a great medium for heat exchange with the earth because of its high thermal conductivity and thermal storage capacity. This integration is made possible by its use. Geostructures with energy properties serve purposes other than only supporting mechanical loads. They also function as efficient heat exchangers, drawing heat from the ground's geothermal energy reserves by passing a heat-transfer fluid—either warmer or colder—through the concrete components. Among Energy GeoStructures' main benefits are:

- **Effective Heat Exchange:** The heat transfer fluid running within the geostructures and the ground may transmit heat efficiently thanks to the high thermal conductivity of concrete;
- **Thermal storage:** By absorbing and storing thermal energy from the earth, concrete's thermal storage capacity enhances the functionality of the GSHP system;
- **Dual Functionality:** EGS serve as both a structural load support system and a building thermal management component;
- **Space optimization:** EGS maximizes land usage efficiency by reducing the need for extra space-consuming heat exchangers by incorporating heat exchange capabilities into tunnel linings or basic elements;
- **Environmental benefits:** Ground-source heat pump systems paired with energy geostructures offer significant energy savings and reduce greenhouse gas emissions compared to traditional heating and cooling systems, contributing to sustainability goals.

Energy GeoStructures (EGS) are a great way to combine sustainability with engineering, providing creative answers to today's pressing environmental and energy problems [7]. Investing in the creation and application of EGS can guarantee increased resilience and lessen the environmental impact of our infrastructure, all of which can help to promote a more effective and sustainable built environment. Investing in the creation and application of EGS can guarantee increased resilience and lessen the environmental impact of our infrastructure, all of which can help to promote a more effective and sustainable built environment.

3. Discussions

We can now talk about the advantages of installing these cutting-edge structures after presenting and outlining geothermal energy and Energy GeoStructures (EGS). There are numerous benefits, which can be summed up as follows:

- **Energy Efficiency:** By taking advantage of the soil's consistent temperature at deeper depths, geothermal piles enable effective thermal exchange with the ground underneath them. This

- lowers energy usage by enabling the structure to be heated or cooled more effectively than with traditional systems.
- **Cost savings:** Geothermal piles lessen reliance on traditional energy sources like electricity or natural gas for building heating and cooling because they can collect and release heat to the ground. In the long run, this results in significant cost savings.
 - **Environmental Sustainability:** By employing geothermal energy as a sustainable source for heating and cooling buildings, geothermal piles help to reduce greenhouse gas emissions and the overall environmental effect of the structure.
 - **Lower Maintenance:** Once installed, geothermal piles require less maintenance than standard heating and cooling systems. This decreases the expenses and inconveniences involved with regular maintenance.
 - **Durability:** After being placed properly, geothermal piles may withstand the test of time and last for decades before requiring major repairs or improvements.
 - **Space Optimization:** Geothermal piles integrate thermal exchange directly into the load-bearing structure of the building, eliminating the need for additional space for the installation of external units or separate heat exchangers. This maximizes the use of available space.

All this proves how the installation of geothermal piles offers an efficient, sustainable and long-term solution for heating and cooling needs of buildings with significant benefits in terms of energy costs, environmental impact and performance efficiency. In addition, the photovoltaic system is a great solution because the energy produced through the system is used to meet the entire headquarter’s demand and any surplus is fed into the public grid. For this reason, if we analyze the headquarters consumption for the year 2023 (Figure 11) and compare it with the expected production according to the PVGIS tool (Figure 8), we observe that the production far exceeds the consumption (Figure 12). Since the system is connected to the public grid, from an economic standpoint, it is possible to estimate the average time (15 years) for the amortization of the entire system solely through annual energy production, considering: (i) the installation and construction cost of the entire project; (ii) the average energy price in 2023 was 0.16 Eur/kWh [11].

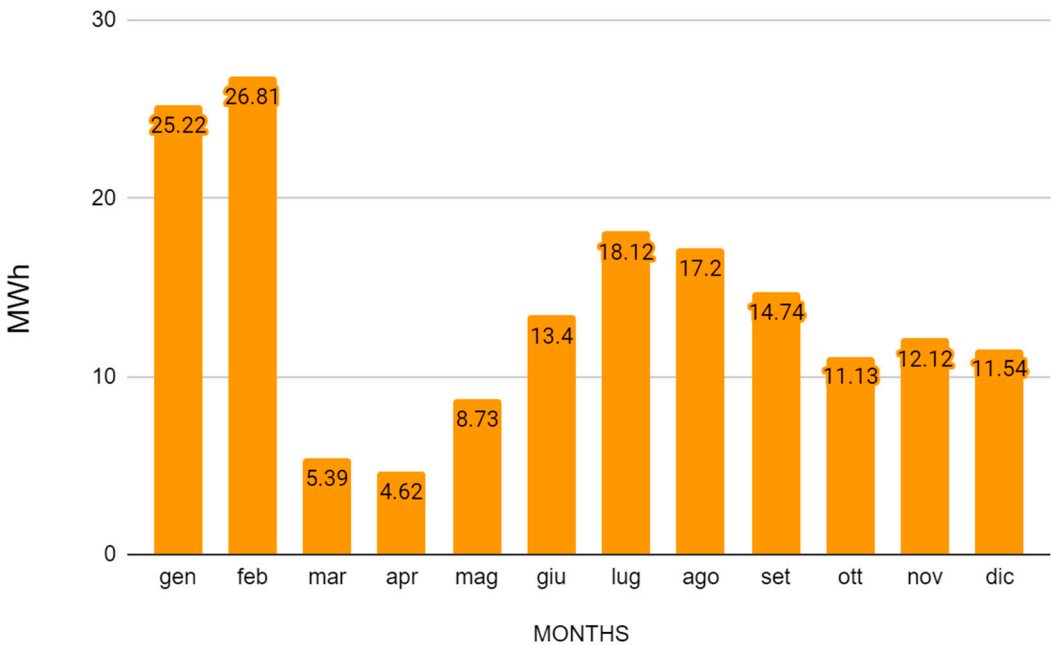


Figure 11. Dynamic graphs of monthly energy used (MWh) in 2023.

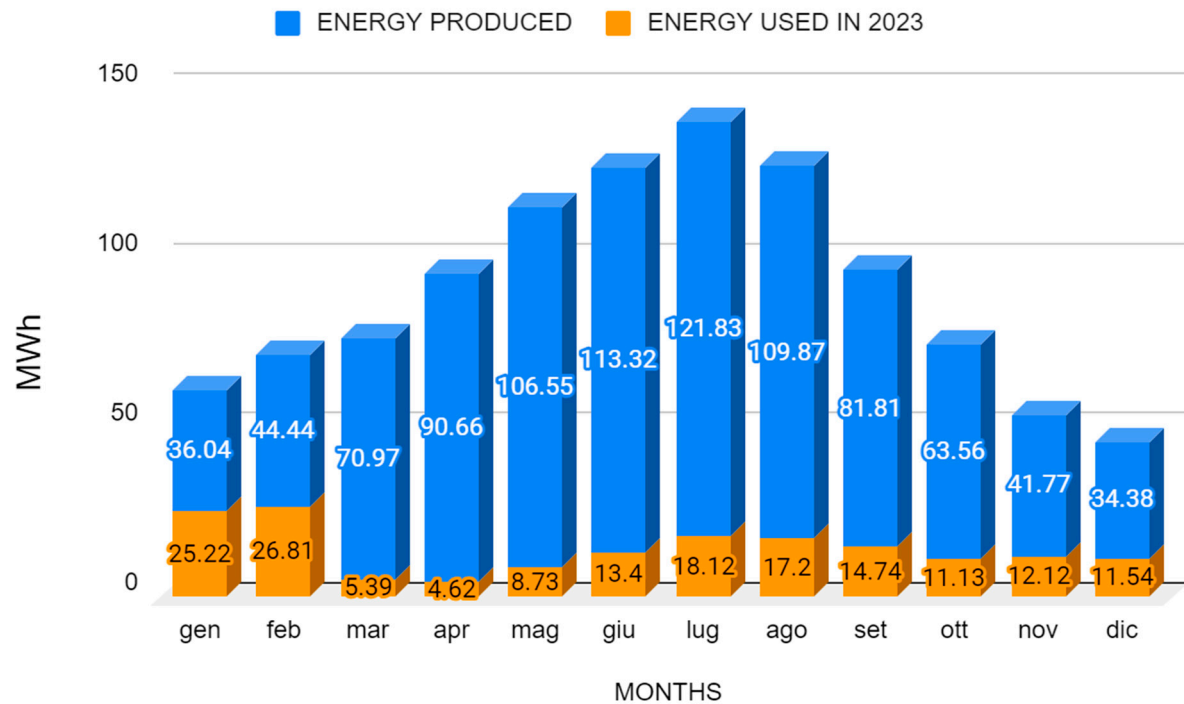


Figure 12 Dynamic graphs of monthly energy used (MWh) and energy produced.

4. Conclusions

The project implemented by INGV - Irpinia headquarters is examined in the study, which concludes that it is a daring venture into the fields of energy and structural innovation. The canopies' innovative design and structure not only showcase a concrete dedication to environmental sustainability, but also represent a trailblazing idea in the building industry. This combination of cutting-edge structural design and cutting-edge technologies not only promises to significantly lessen the building's overall environmental effect, but it also opens the door for a new paradigm in construction where sustainability and energy efficiency are prioritized in design. By implementing these cutting-edge solutions, INGV - Irpinia Headquarters shows its dedication to a more sustainable and brighter future, acting as a role model for other organizations and companies hoping to undergo a comparable shift in how they handle energy and construction.

Funding: This research received no external funding.
Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Montini, M. (2015). L'Accordo di Parigi sui cambiamenti climatici. RIVISTA GIURIDICA DELL'AMBIENTE, 30(4), 517-528.
2. Khoso, Awais Ali, et al. The Development of Solar Powered Carport Canopies for the Charging Infrastructure of Electric Vehicles. Dec. 2022, doi:10.1109/icetec56662.2022.10069060.
3. Kumar, Laveet, et al. "Technological Advancements and Challenges of Geothermal Energy Systems: A Comprehensive Review." Energies, vol. 15, no. 23, Nov. 2022, p. 9058, doi:10.3390/en15239058.
4. Fakour, Hoda, et al. "Evaluation of solar photovoltaic carport canopy with electric vehicle charging potential." Scientific Reports, vol. 13, no. 1, Feb. 2023, doi:10.1038/s41598-023-29223-6.
5. Barbier, Enrico. "Geothermal energy technology and current status: an overview." Renewable & Sustainable Energy Reviews, vol. 6, no. 1-2, Jan. 2002, pp. 3-65, doi:10.1016/s1364-0321(02)00002-3.
6. Kabeyi, Moses Jeremiah Barasa, and Oludolapo Akanni Olanrewaju. "Sustainable Energy Transition for Renewable and Low Carbon Grid Electricity Generation and Supply." Frontiers in Energy Research, vol. 9, Mar. 2022, doi:10.3389/fenrg.2021.743114.

7. Meibodi, Saleh S., and Fleur Loveridge. "The future role of energy geostructures in fifth generation district heating and cooling networks." *Energy*, vol. 240, Feb. 2022, p. 122481, doi:10.1016/j.energy.2021.122481.
8. Małek, Arkadiusz, et al. "Charging Electric Vehicles from Photovoltaic Systems—Statistical Analyses of the Small Photovoltaic Farm Operation." *Energies*, vol. 15, no. 6, Mar. 2022, p. 2137, doi:10.3390/en15062137.
9. Merten, Jens, et al. "Solar mobility: Two years of practical experience charging ten cars with solar energy." *5th International Conference on Integration of Renewable and Distributed Energy Resources* Dec. 2012.
10. D'Agostino, Delia, and Livio Mazzarella. "What is a Nearly zero energy building? Overview, implementation and comparison of definitions." *Journal of Building Engineering*, vol. 21, Jan. 2019, pp. 200–12, doi:10.1016/j.jobe.2018.10.019.
11. Schiavone, Matteo Paolo. *Comunità dell'Energia Rinnovabile: Individuazione della Dimensione Ottimale a Scala Territoriale*. Diss. Politecnico di Torino, 2021.
12. Panagiotidou, Maria, et al. "Prospects of photovoltaic rooftops, walls and windows at a city to building scale." *Solar Energy*, vol. 230, Dec. 2021, pp. 675–87, doi:10.1016/j.solener.2021.10.060.
13. Ren, Haoshan, et al. "A novel 3D-geographic information system and deep learning integrated approach for high-accuracy building rooftop solar energy potential characterization of high-density cities." *Applied Energy*, vol. 306, Jan. 2022, p. 117985, doi:10.1016/j.apenergy.2021.117985.
14. Singh, Rhythm. "Approximate rooftop solar PV potential of Indian cities for high-level renewable power scenario planning." *Sustainable Energy Technologies and Assessments*, vol. 42, Dec. 2020, p. 100850, doi:10.1016/j.seta.2020.100850.
15. "Osório, Gerardo J., et al. "Rooftop photovoltaic parking lots to support electric vehicles charging: A comprehensive survey." *International Journal of Electrical Power & Energy Systems*, vol. 133, Dec. 2021, p. 107274, doi:10.1016/j.ijepes.2021.107274.
16. Cerutti, Paolo. "[Renewable Resources, High to Low Enthalpy Geothermal, opportunities and perspectives]." *Acque Sotterranee*, vol. 11, no. 3, Sept. 2022, pp. 77–78, doi:10.7343/as-2022-593.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.