DECARBONISING THE TOURISM INDUSTRY POST COVID-19 SUPPORT – DETOCS

JOINT THEMATIC GUIDEBOOK

Decarbonising European tourism entities – Technical considerations

PROJECT ID: 01C0020

Task coordinator: Mediterranean Agronomic Institute of Chania (PP2)

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Summary

An extensive overview of the adoption and application of sustainable energy technologies within the European tourism sector has been implemented in the framework of DETOCS project. Recognising tourism as one of Europe's most energy-intensive economic activities, the report highlights the urgent need to transition towards renewable energy sources and energy-efficient solutions to mitigate the tourism sector's carbon footprint and align with the European Green Deal and the 2030 Agenda for Sustainable Development. **The Joint Thematic Guidebook is a joint effort of all the organisations participating in the implementation of DETOCS project while the task was coordinated by MAICH**. The analysis identifies a variety of sustainable energy technologies currently in use across tourism entities. Among the most common are solar photovoltaic systems, solar thermal collectors, heat pumps, LED lighting, insulation of the building envelope and biomass heating systems. In hospitality, these technologies are applied to power lighting, heating, ventilation, air-conditioning, and water heating systems. The report also explores the integration of smart energy management systems which optimise consumption patterns and enhance operational efficiency. Examples from various European destinations illustrate successful implementation and measurable reductions in energy consumption and greenhouse gas emissions. Beyond technological solutions, the report emphasises the importance of soft measures that complement technical innovations. These include energy monitoring, energy auditing, energy benchmarking, behavioural changes of tourists and employees, carbon offsetting, linking hotels with local food suppliers and promotion of virtual tourism.

The findings also address the challenges tourism entities face in adopting sustainable energy technologies. These include high initial investment costs, regulatory complexity and seasonal variability in energy demand. By investing in these sustainable energy solutions, tourism enterprises not only lower their environmental impact but also strengthen their market position. Eco-conscious travellers increasingly prefer accommodations that demonstrate environmental responsibility. Therefore, sustainable energy adoption enhances

competitiveness, improves brand image, and contributes to long-term profitability. Ultimately, the transition to renewable energy in tourism is not just a moral imperative but a strategic opportunity to align economic success with environmental stewardship. Overall, the present report provides evidence that sustainable energy technologies, when integrated with effective management practices and supported by enabling policies, can substantially reduce the tourism sector's dependence on fossil fuels. By fostering innovation, collaboration, and knowledge sharing among European tourism stakeholders, these technologies contribute to a more resilient, competitive, and environmentally responsible tourism industry.

Table of Contents

The aim of the Joint Thematic Guidebook

The aim of the Joint Thematic Guidebook is to provide real-life and successful examples (case studies) of energy efficiency measures implemented in tourism enterprises in the participating regions. It was realised during the final two semesters of the core phase of DETOCS project.

It is desirable that the real-life examples in each region will comprise successful green energy investments in different types of enterprises in tourism industry – preferably financially supported by EU structural funds, e.g., hotels, campsites, restaurants, etc.

The Joint Thematic Guidebook will be translated in national languages by each partner. It will be used by tourism enterprises and policy makers. Tourism enterprises will be informed about successful applications of sustainable energy technologies that can be transferred to their own enterprises. Policy makers can develop policies supporting the use of sustainable energy technologies in tourism enterprises.

1. Introduction

The Impact of Tourism Enterprises on Climate Change

Tourism is one of the largest and fastest-growing industries worldwide, but it is also a significant contributor to climate change. Tourism enterprises—including hotels, resorts, restaurants, transport services, and recreational facilities—rely heavily on energy, water, and land resources, resulting in substantial greenhouse gas emissions. Their impact extends across operational activities, supply chains, and tourist behaviours. One of the main contributors is energy consumption. Accommodation facilities require electricity for air conditioning, heating, lighting, and water heating, often relying on fossil fuel-based grids. Large resorts and hotels, particularly in tropical or urban areas, consume vast amounts of energy, leading to high carbon footprints. In addition, many enterprises depend on diesel generators in remote destinations, further intensifying emissions. Transportation services connected to tourism also play a critical role. While airlines and cruise ships are often highlighted, local tourism enterprises contribute through shuttle services, rental vehicles, and maritime activities. The integration of these services creates a network of emissions that collectively accelerates global warming. Tourism enterprises also influence climate change indirectly through resource use and waste generation. High water demand for pools, golf courses, and landscaping in water-scarce regions exacerbates climate stress. Moreover, food waste and single-use plastics increase methane emissions and environmental degradation. The cumulative effect of these activities positions tourism as a significant driver of climate change, responsible for an estimated 8–10% of global emissions. However, tourism enterprises also hold the potential to mitigate their impact by adopting renewable energy, improving energy efficiency, and promoting sustainable practices. By rethinking operations and embracing sustainability, tourism enterprises can reduce their carbon footprint while contributing to global climate goals.

Using Sustainable Energies in Tourism Enterprises

The tourism sector is one of the fastest-growing industries globally, yet it is also energy-intensive, contributing significantly to greenhouse gas emissions through accommodation, transportation, and recreational activities. As pressure mounts to decarbonise economies, tourism enterprises—such as hotels, resorts, tour operators, and attractions—are increasingly exploring the adoption of sustainable energy sources. Assessing the technical, economic, and environmental feasibility of these energies is crucial to determine their potential for widespread integration in the sector.

Technical Feasibility

Advancements in renewable energy technologies have significantly enhanced their applicability to tourism enterprises. Solar photovoltaic (PV) panels, for example, are well-suited to resorts and hotels in sunny destinations, providing reliable electricity for lighting, cooling, and water heating. Similarly, small-scale wind turbines and micro-hydro systems can power remote lodges or eco-parks where grid access is limited. Energy storage systems, such as lithium-ion batteries, further improve reliability by addressing intermittency issues. Biomass and biogas technologies can also be deployed in rural or agricultural tourism enterprises, converting organic waste into usable energy. While these technologies are increasingly efficient and adaptable, technical challenges remain, including the need for skilled maintenance, system integration with existing infrastructure, and site-specific limitations such as terrain or weather patterns. Nevertheless, from a technical perspective, sustainable energy solutions are increasingly viable and scalable in diverse tourism settings.

Economic Feasibility

The economic case for sustainable energies in tourism enterprises is complex, balancing high upfront costs with long-term savings. Installing solar panels or geothermal systems requires significant initial investment, which can be a barrier for small and medium-sized enterprises (SMEs) that dominate the tourism sector. However, declining costs of renewable technologies, combined with government incentives, subsidies, and financing mechanisms, are making adoption more accessible. Over time, operational savings from reduced fossil fuel consumption, lower electricity bills, and resilience against fluctuating energy prices enhance financial feasibility. Furthermore, adopting sustainable energy can provide a marketing advantage, as eco-conscious travellers increasingly favour businesses demonstrating environmental responsibility. For large resorts and global hotel chains, economies of scale can further improve cost-effectiveness, making the transition not only possible but strategically beneficial.

Environmental Feasibility

From an environmental standpoint, the adoption of sustainable energy in tourism enterprises is highly desirable. Renewable energy systems reduce carbon emissions, air pollution, and reliance on non-renewable resources, directly supporting global climate mitigation goals. They also minimise the ecological footprint of tourism, which is particularly important in environmentally sensitive destinations such as islands, coastal zones, and protected areas. For example, replacing diesel generators with solar or wind systems in island resorts reduces both emissions and risks of oil spills. Additionally, integrating renewables supports sustainable community development by reducing strain on local energy resources. While some renewable projects may have localized impacts—such as land use changes or visual intrusion from wind turbines—the environmental benefits far outweigh the drawbacks when projects are carefully planned. The technical, economic, and environmental feasibility of sustainable energies in tourism enterprises demonstrates strong potential for their broader adoption. Technological advancements are addressing reliability concerns, while falling costs and supportive policies are improving financial accessibility. Environmentally, the transition to sustainable energy aligns with the sector's responsibility to preserve the natural and cultural resources upon which tourism depends. Although challenges remain in terms of financing, training, and infrastructure adaptation, sustainable energies represent not just a feasible option, but a necessary pathway for the long-term viability and competitiveness of tourism enterprises.

2. Presentation of successful examples in several regions

2.1 Hotel Murat - SLOVENIA

Hotel Murat (pictured above) is a welcoming family-run hotel, built in 2007. It is located in Hajdina, right next to the Podravje motorway and close to the border with Croatia. The hotel is just 4 km from Ptuj, Slovenia's oldest town, 20 km from the Pohorje ski slopes, and a little over an hour's drive from the capital, Ljubljana. The hotel combines a modern design with stylish interiors, air-conditioned rooms, and conference facilities. While it may not boast a long historical tradition, it is fully dedicated to the comfort and needs of today's traveller. Guests can also take advantage of a conference and event hall with a capacity of up to 60 people. The property has undergone energy renovation to meet high standards of living comfort while ensuring sustainable operation. Its location was carefully chosen as well—when the hotel was being built, the final section of the motorway connecting Slovenia and Croatia through the Spodnje Podravje region was also under construction. Guests consistently rate the hotel highly, particularly for cleanliness, comfort, and the friendliness of the staff. With an overall score of 8.4, it ranks above average in the region. In the summer season, the hotel is often fully booked with travellers on their way to the Adriatic coast. For many, it serves as a convenient stopover to rest before completing the final leg of their journey, giving the hotel a distinct transit role during this time of year. At the same time, Hotel Murat is an excellent starting point for active visitors. The surrounding area offers countless opportunities for recreation and year-round experiences, including:

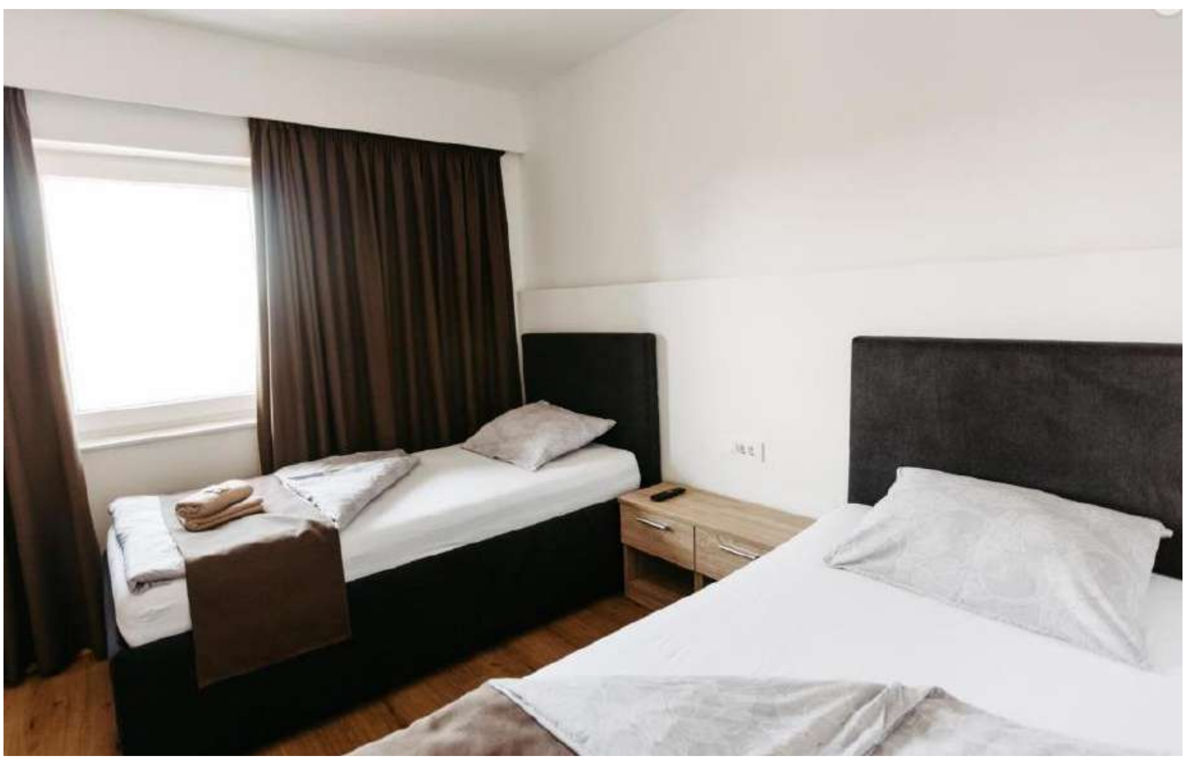
- golfing at the Ptuj Golf Course,
- skiing on nearby Pohorje in winter,
- numerous scenic hiking trails,
- exploring the rich cultural heritage of Ptuj, Slovenia's oldest town.

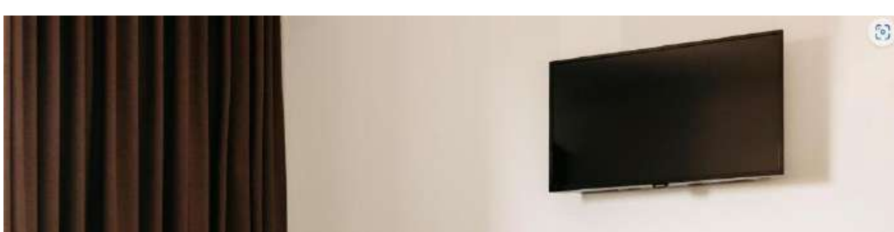
Characteristics of the region

Spodnje Podravje is a region in northeastern Slovenia covering 860 km² and home to around 85,000 residents. It is known for its picturesque landscapes and rich cultural heritage. Tourism in the region is moderate, with 182,887 overnight stays recorded annually allowing for balanced development without excessive crowds. Tourist density stands at 212.66 overnight stays per km², while the intensity is 2.15 overnight stays per resident. The region is renowned for its historical and religious landmarks that reflect its long and diverse past. One of the most striking sites is the **Basilica (Marije Zavetnice)** on Ptujska Gora in the Municipality of Majšperk. Built in the 14^{th} century, this Gothic church rises above the surrounding hills and has been a popular pilgrimage destination for centuries. It impresses visitors with its spiritual significance as well as panoramic views. At the heart of the region stands **Ptuj Castle**, whose origins date back to the 11th century. In the 17th century, it was transformed into a Baroque residence with a distinctive triangular layout. Today it houses a museum, where visitors can explore lavishly furnished rooms, an impressive armoury and a gallery of Gothic and Baroque artworks that bring history vividly to life. Nearby lies **Dornava Manor**, a site with medieval roots. Originally built as a fortified castle, it was later remodelled into a Renaissance residence and enriched with Baroque elements. Surrounded by a landscaped park, it is recognised as a cultural monument of national importance and remains a symbol of the region's rich architectural and historical heritage. Another remarkable site is the **Orpheus Monument** in Ptuj, a marble tombstone from the 2nd century dedicated to Marcus Valerius, a former city councillor, judge and mayor. This ancient Roman monument has become an enduring symbol of Slovenia's oldest town, inviting visitors to step into its Roman past. Adding to the city's historic charm is the **Dominican Monastery**, founded in the 13th century and dedicated to St. Dominic. Alongside its church, the monastery served as an important centre of Christianity and education, a role that continues to highlight its cultural and spiritual significance today. The area of Hajdina reveals further layers of history through archaeological remains of a Roman aqueduct and **Mithras** shrines (shrines dedicated to the god Mithraeum) which testify to the religious practices of the Roman era. Beyond its cultural wealth, Spodnje Podravje is also a natural treasure. Around 100 km^2 of the region is part of the **Natura 2000** network, protecting fragile ecosystems along the Drava River. Conservation efforts focus on preserving habitats for fish and bird species typical of flood plains, as well as safeguarding river channels and natural flood dynamics. A notable achievement in this regard is the **LIFEDRAVA project**, which restored riverbeds, gravel banks, nesting islands and sand walls, while also establishing natural reserves that enhance biodiversity and landscape preservation.

Characteristics of the Hotel Murat

The hotel covers a total floor area of 1,060 m², of which 840 m² is built. The hotel offers 34 beds and a conference hall with a capacity of up to 60 people. In 2024, it recorded 2,280 overnight stays. Even before construction, the owners recognised the economic potential of this geostrategic location, situated right next to the motorway corridor leading toward Croatia. With a vision of greater guest comfort and sustainable business practices, the owners later decided to carry out an energy renovation, incorporating renewable energy sources. Energy-efficient systems were introduced to reduce operating costs, minimise the environmental footprint and increase the hotel's appeal to eco conscious travellers. Despite challenges such as financing, coordination of work and limited expert guidance, the renovation has brought long term economic and environmental benefits. Looking ahead, the vision of hotels to further strengthen its sustainability focus. Planned investments include additional renewable energy sources, such as a solar power plant, energy storage systems and charging stations for electric vehicles and bicycles. These initiatives aim to further reduce the hotel's carbon footprint while offering guests an eco-friendly experience in harmony with both nature and the local community.





Local climate characteristics

The region receives about 1,200 kWh/m² of solar radiation and around 1,000 mm of precipitation per year, while the average annual air temperature is shown below.

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Description of energy systems used in Hotel Murat

Hotel Murat is designed around the principles of environmental sustainability and long-term resilience. As part of its energy renovation, sustainable and energy-efficient solutions were introduced to reduce environmental impacts and ensure lower operating costs over time. The building features a well-insulated external envelope, while inside it is equipped with several modern energy systems. The hotel remains connected to the grid, yet using sustainable technologies, it can achieve net-zero carbon emissions.

a) High-efficiency heat pump

For heating in winter and cooling in summer, the hotel uses a highly efficient water-to-water heat pump. The primary energy source is groundwater, which maintains a stable temperature throughout the year. This renewable resource ensures high energy efficiency even during the colder months, while directly contributing to the reduction of greenhouse gas emissions and enhancing the hotel's energy self-sufficiency. Instead of generating heat from fossil fuels, the heat pump transfers energy from the natural environment (groundwater), significantly reducing the hotel's environmental footprint. The total annual energy consumption of the hotel amounts to 54,000 kWh, with a specific consumption of 64.29 kWh/m^2, confirming the buildings above average energy performance.

b) LED lighting

Replacing conventional lighting with LED technology has delivered both environmental and financial benefits. Each year, the hotel saves 6,935 kWh of electricity, which also prevents 2,774 kg of CO_2 emissions. This measure accounts for the largest share of energy savings (89%) and forms part of a broader sustainability strategy, which also includes raising guest awareness of green practices and encouraging responsible energy use.

c) Resource optimisation systems

The energy renovation also included the introduction of smart heating sensors and upgraded sanitary equipment: sensor operated faucets, showers with flow restrictors, and dual-flush toilet systems. These measures contribute to more efficient energy and water use, enabling precise temperature control, reduced consumption and fewer energy losses. Water use in this area has been reduced by as much as 35%.

d) Paper, cardboard, and packaging compactor

The hotel also invested in a compactor for paper, cardboard and returnable packaging, which plays an important role in its commitment to lowering its carbon footprint. This measure reduces disposal and labour costs by compressing packaging volume by up to 80%. It also indirectly cuts CO_2 emissions from transport and helps prevent methane emissions from the anaerobic decomposition of waste a gas with 80 times the greenhouse effect of CO_2.

Characteristics of the energy systems used in hotel Murat

Sustainable energy systems used at Hotel Murat include several technologies:

Building envelope insulation: The insulation covers all major areas of heat loss, such as the roof, eaves, exterior walls, doors and windows. According to the latest energy performance certificate, the hotel building is classified in category A. The exterior envelope is well insulated, while high-quality double-glazed windows reduce heat transfer and limit condensation. By combining various energy efficiency measures, the hotel has achieved a significant reduction in energy demand. This integrated approach not only lowers utility costs but also creates a more comfortable and sustainable indoor environment.

LED lighting: Awareness of reducing the environmental footprint has led to the adoption of LED lighting, which consumes 75% less electricity compared to the previous type. LED lights have replaced incandescent bulbs, offering a significantly longer lifespan and much lower maintenance costs, as bulb replacement is virtually unnecessary. This energy-efficient lighting is part of the hotel's low carbon systems, helping optimise energy use and reduce its carbon footprint.

Automated systems: Smart thermostats and energy management systems (such as automatic lighting and temperature) enable precise temperature control and optimisation of energy consumption. Smart thermostats allow accurate temperature regulation in individual rooms, thereby reducing energy use for heating. Sensor faucets activate water flow only when needed, with a limited operating time, while showers are equipped with flow restrictors and smart controls.

High-efficiency water-to-water heat pump (44 kW): The low-temperature underfloor heating system operates at lower temperatures, increasing efficiency and reducing energy use. The main source of energy for heating the building and producing domestic hot water is groundwater, utilised through a water-to-water heat pump. This renewable energy source ensures high efficiency throughout the year, as groundwater maintains a stable temperature, helping reduce greenhouse gas emissions and strengthening energy self-sufficiency. Water-to-water heat pumps are highly efficient, as about 75–80% of the energy is sourced from the environment, with only 20–25% coming from the electricity grid.

Recyclable packaging system: A packaging press minimises the storage space needed for temporary waste and returnable packaging collection. The system allows fast and easy tearing and pressing of packaging, producing small, clean bales that are easy to handle manually. Baled recycled waste reduces collection costs and significantly lowers the risk of fire.

Environmental analysis

The estimated annual savings in grid electricity amount to 6,935 kWh, corresponding to an annual reduction of 2,774 kg of CO_2 emissions. The calculation is based on the latest emission factor for grid electricity, provided by the national electricity utility, which is 0.4 kg CO_2/kWh.

Economic analysis

The total investment in sustainable energy at Hotel Murat is estimated at € 146,000, of which 75% (€ 110,000) is covered by nonrepayable funds, while the remaining 25% (€ 36,000) represents the hotel's own contribution. The annual savings from reduced grid electricity consumption are estimated at approximately € 3,523. The payback period for the investment is around 10 years, with an expected lifetime of 15 years. While the project is not designed to deliver high financial returns, it represents a sustainable choice aimed primarily at reducing environmental impacts and ensuring long-term stability. No repayable funds play a key role in making the investment economically viable.

Cost estimations of sustainable energy systems installed in Hotel Murat

Energy system	Value
Installation cost of sustainable energy systems	€ 173.80 per m^2
Installation cost of sustainable energy systems	€ 4,294 per bed
Installation cost of sustainable energy systems per kWh used	€ 2.7 per kWh used annually
Installation cost of sustainable energy systems per annual CO_2 emission savings due to grid electricity use	€ 52.63 per kg of annual CO_2 emission savings

Simplified cost-benefit analysis of the sustainable energy investments

The total annual economic benefits of the energy investments include cost savings and other advantages generated by the project. These benefits can be summarised as follows:

- Energy cost savings resulting from lower electricity consumption due to more efficient systems.
- Reduced pressure on natural water resources thanks to more efficient equipment. Annual water consumption has decreased by 290 m^3, representing a 35% reduction.
- A subsidy of € 110,000, which has been essential in ensuring the economic viability of the investment.
- Increased property value: the energy renovation has raised the property's value by 33%, estimated at approximately € 900,000.
- A reduction of 2.7 tons of CO_2 emissions per year.
- Operational benefits through lower maintenance costs (e.g., LED lighting eliminates frequent bulb replacements; the heat pump system requires longer, and more cost-effective service intervals compared to fossil fuel-based heating).

The hotel's energy renovation delivers a wide range of environmental benefits, including:

- a reduced carbon footprint,
- greater energy independence,
- a contribution to a cleaner environment and
- improved guest comfort and quality of stay.

The transition from a fossil fuel–based heating system (natural gas) to a renewable energy solution (heat pump), combined with enhanced building efficiency, has significantly reduced CO_2 emissions, helping to mitigate climate change. By phasing out fossil fuels, the renovation has also reduced emissions of particulate matter, nitrogen oxides, noise, and other local pollutants typically associated with outdated heating systems. Lower heat losses and the switch to renewable energy have decreased overall energy consumption while improving the operational efficiency of the hotel. The use of a heat pump taps into a renewable and sustainable natural heat source (water), reducing dependence on non-renewable resources. Moreover, a growing number of guests actively seek accommodation that follows environmentally friendly principles. The energy investments are part of a comprehensive sustainability strategy that also focuses on raising guest awareness, including:

- informing guests about green practices,
- encouraging reduced electricity and water consumption,
- promoting waste separation and reduction.

Financial sources used for the sustainable energy investments

For the sustainable energy investments, 25% of the funds were provided from own capital, while the remaining 75% came from a public subsidy.

Hotel Murat – Key characteristics

Location	Hajdina, Ptuj, Slovenia
Capacity	34 beds, seasonal operation, 7 months
Covered area	840 m^2
Energy intensity	64.29 kWh/m^2 year
Carbon emissions	Negative emissions hotel
Building envelope	Well insulated
Energy sources used	Grid electricity, heat from the environment
Sustainable energy technologies used	Heat pump, smart sanitation systems, LED lighting
Installation cost of sustainable energy systems	€ 146,650
Payback time of the sustainable energy investments	10 years

Installation cost of sustainable energy systems	€ 173.80 per m^2

2.2 Dominican Monastery Ptuj - SLOVENIA

Dominican Monastery Ptuj (Cultural Heritage)

The Dominican Monastery in Ptuj is a cultural jewel with a history spanning more than eight centuries. It was founded in 1230 by Matilda, the widow of Frederick III of Ptuj, and remained under the stewardship of the Dominicans until 1785, when the monastery was dissolved and converted into military barracks. In the early 20th century, its most distinguished spaces were dedicated to museum activities, while today the monastery thrives as one of the city's most important cultural centre. The complex is situated on the western edge of the historic town centre, on a terrace above the left bank of the Drava River, offering panoramic views of the river valley and surrounding hills. Its wings converge around a spacious inner courtyard with a central well, conceived as a place of peace and contemplation. Entry into the monastery leads through a Baroque portal adorned with a depiction of St. Dominic, guiding visitors into the cloister (the central nexus of the entire complex). This cloister is considered one of the best-preserved in Central Europe. It is distinguished by tall Gothic windows opening toward the courtyard, as well as numerous details such as sculpted consoles, frescoes, and keystones featuring saints and patrons. Alongside the cloister lie a series of ancillary spaces, most notably the chapter hall and the summer refectory. The chapter hall, with its triumphal arch and Romanesque-Gothic architectural elements, radiates dignity, while the refectory captivates with its Baroque stuccowork and biblical wall paintings. A special feature of the monastery is the former Church ("Marijinovnebovzetje"), which today serves as the main events hall. Its architecture is distinguished by a double triumphal arch, decorated with coats of arms, and richly designed details combining Romanesque, Gothic, and Baroque characteristics. The Dominican Monastery is a multi-layered architectural and artistic ensemble where monumental spaces, richly decorated interiors and harmoniously designed exterior settings come together. As a vibrant cultural venue, it unites spiritual, artistic and spatial dimensions and today stands as one of Ptuj's most prominent landmarks.

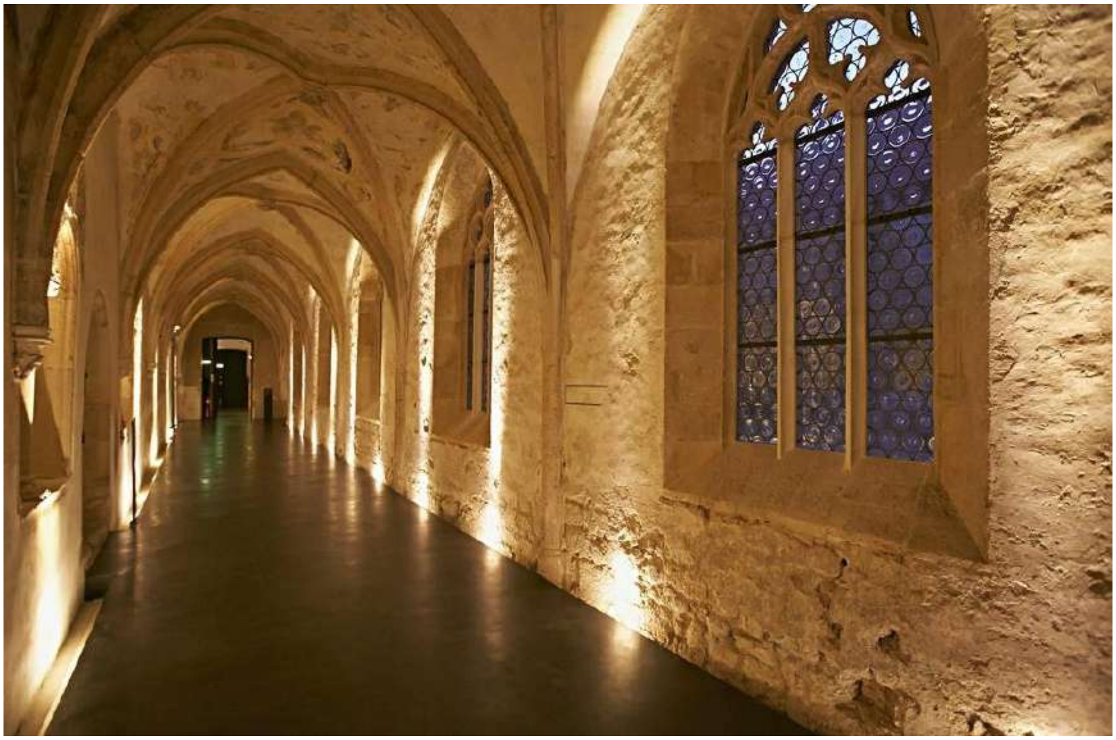
Characteristics of the region

The “Spodnje Podravje” region located in northeastern Slovenia, covers an area of 860 km^2 and is home to around 85,000 inhabitants. Despite its relatively small size, it plays an important role in the cultural, economic and tourism landscape of the country. Tourism here is developing at a moderate pace, as reflected in the annual statistics of 182,887 overnight stays and a density of 212 overnight stays per km^2. This level of tourist intensity is significantly lower than that of Slovenia’s most visited destinations, such as Piran or Bled, which allows the region to maintain a balance between residents’ quality of life, spatial protection and tourism development. Tourism intensity, measured at 2.15 overnight stays per resident, indicates that tourism in Spodnje Podravje currently functions mainly as a complementary economic activity. This means that visitors do not overburden local communities but instead contribute to their economic development. Cultural heritage plays a particularly important role in this context, as it provides the region with a unique identity and opens opportunities for niche tourism development. The Dominican Monastery in Ptuj, revitalized as a cultural centre, offers possibilities for creating diverse tourism products ranging from guided tours and exhibitions to concerts, conferences and connections with local gastronomy and winemaking traditions. Spodnje Podravje is an area where rich cultural heritage coexists with exceptional natural assets. Ptuj and its surroundings boast numerous historical and religious monuments that mark over two millennia of development. Among them, **Ptuj Castle** holds a central place. This mighty fortress, which served as a noble residence from the 12th century onward, today houses the Ptuj Regional Museum with extensive collections of weapons, artworks and ethnographic objects. Its Baroque halls preserve valuable art, while the Knight’s Hall offers a unique glimpse into aristocratic culture. A distinctive feature of the castle is the exhibition of traditional carnival masks, which ties the site to the vibrant tradition of “Kurentovanje” (one of Slovenia’s most recognisable intangible cultural heritage elements, inscribed on UNESCO’s Representative List). In the immediate vicinity stands the **Minorite Monastery**, founded in the 13th century, which embodies Ptuj's spiritual and cultural legacy. Its valuable library, containing thousands of historical volumes and its preserved architecture with Romanesque, Gothic and Baroque elements bear witness to the order's importance in the city. Today, the monastery functions as a venue for exhibitions and concerts, remaining an active part of Ptuj's cultural life. Other notable monuments include the **Orpheus Monument**, a tall Roman tombstone from the 2nd century, considered the largest of its kind in Slovenia. Over time, its role has shifted (from a Roman funerary monument to a medieval pillory), today it stands as the central symbol of ancient Poetovio, the predecessor of Ptuj. Another defining feature of the city's skyline is the 16th-century **Town Tower**, whose clock and embedded Roman reliefs link Ptuj's medieval and Roman history, making it one of the city's most recognisable landmarks. Beyond cultural heritage, the natural environment plays a crucial role, particularly the Drava River, which forms one of Slovenia's largest protected ecosystems. The Drava is part of the **Natura 2000** network, providing habitat for numerous endangered bird species, plants and habitats. Its dynamic flow creates diverse environments such as side channels, oxbow lakes, gravel bars and wetlands, which are constantly evolving. However, this sensitive ecosystem is heavily affected by human interventions, including river regulation, hydropower projects and gravel extraction. The consequences are visible in the gradual drying of side channels and a reduced capacity to retain floodwaters. To counter these effects, nature conservation projects focus on wetland restoration, habitat improvement and raising local awareness, while also enhancing opportunities for nature-based tourism. The connection between cultural heritage and the natural environment is particularly strong in Spodnje Podravje. Castles, monasteries and ancient remains give the area historical depth, while the Drava River adds ecological value through its biodiversity. Together, they form the foundation for the development of sustainable tourism, based on respect for both heritage and nature.

Characteristics of the Dominican Monastery in Ptuj

The Dominican Monastery in Ptuj is one of the region's central cultural and historical landmarks. The complex covers 1,426 m^2 of built-up floor space, with an additional 290 m^2 of adjoining green areas. Its location on the edge of the old town centre and its architectural character make it an important part of the city's identity. In recent years, the number of visitors has grown significantly. In 2021 the monastery welcomed 5,409 visitors, rising to 10,460 in 2022, 8,846 in 2023, and as many as 13,985 in 2024. Visitor numbers were notably influenced by the COVID-19 pandemic, as restrictions on public life in 2021 and part of 2022 reduced opportunities for cultural and tourist visits. Nevertheless, the data shows that once restrictions were lifted, the monastery quickly regained visibility and popularity, re-establishing itself as a cultural destination attracting both domestic and international visitors. The motivation for introducing sustainable practices within the monastery arises from the need to reconcile the building's historical value with its modern-day use. One key factor is economic efficiency: heating all spaces would be unreasonable, as different areas serve different purposes (corridors function merely as passageways, while conference halls require consistent comfort levels). This highlights the need for functional adaptability, ensuring that energy is consumed only where it is truly needed. Another important aspect is environmental sustainability: the use of a water-to-water heat pump significantly reduces reliance on fossil fuels and lowers greenhouse gas emissions. Implementing these solutions has not been without challenges. The most important is the preservation of cultural heritage, which requires that modern systems do not compromise the historic architecture. Technical implementation is also demanding due to irregular structural layouts and limited access for installations. Financial constraints further complicate the process, as initial investments exceed budgetary capacities, making public subsidies a crucial factor in project feasibility. Despite these limitations, the Dominican Monastery today stands as an example of good practice in managing cultural heritage. By combining modern energy solutions with strict conservation requirements, it demonstrates how historical value can be successfully aligned with efficiency, sustainability and the contemporary needs of its users.


DOMINIKANSKI SAMOSTAN
KONGRESNO KULTURNO SREDIŠČE PTUJ



Local climate characteristics

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Description of energy systems used in Dominican Monastery Ptuj

In recent years, the Dominican Monastery in Ptuj has introduced modern solutions that enable more efficient and sustainable energy management. From the outset, the energy renovation of the monastery was subject to restrictions set by the Institute for the Protection of Cultural Heritage. In practice, this meant that broader measures (such as insulating the building envelope or replacing historic windows and doors), could not be carried out. All energy solutions were therefore designed to respect conservation requirements while still achieving significant energy savings and emission reductions.

a) High-efficiency heat pump

A water-to-water heat pump serves as the primary source of heating for both space heating and domestic hot water. The system harnesses the stable year-round temperature of groundwater, ensuring a high level of efficiency. With minimal electricity consumption, the heat pump transfers a substantial amount of thermal energy into the heating system, significantly reducing the monastery's dependence on fossil fuels and lowering greenhouse gas emissions. This solution combines sustainability, energy efficiency and operational reliability.

b) Resource consumption optimisation system

An advanced resource optimisation system complements the heat pump, allowing precise regulation and control of heating. It operates through wireless sensors and control stations that measure temperature and humidity, coordinating the functioning of underfloor heating. The system is managed via a central application server with a user interface, enabling real-time monitoring and adjustments. This setup makes it possible to direct heating only to the areas where it is needed, delivering considerable energy savings. A particular advantage of the system is that it operates independently of the existing infrastructure, avoiding interventions in the monastery's protected architecture. The system is also designed with openness and flexibility, allowing for future upgrades such as monitoring electricity consumption, lighting and ventilation. This ensures that the monastery is prepared for further development and the integration of smart solutions, which will enhance energy efficiency and contribute to the long-term sustainability of the building. By implementing a heat pump and a resource optimisation system, the Dominican Monastery has taken an important step toward energy self-sufficiency and a reduced environmental footprint. It stands as a good practice example of how cultural heritage can be preserved while integrating modern energy solutions that deliver lower costs, reduced emissions and greater operational flexibility.

Characteristics of the energy systems used in Dominican Monastery Ptuj

In recent years, the Dominican Monastery in Ptuj has introduced several energy systems designed to reduce consumption, improve efficiency and ensure the sustainable operation of the building, all while respecting the restrictions imposed by cultural heritage protection. At the heart of the system is a 190-kW water-to-water heat pump, which provides space heating and domestic hot water. It operates by harnessing the stable year-round temperature of groundwater, ensuring a reliable and highly efficient transfer of heat into the system. This approach reduces dependence on fossil fuels and significantly contributes to lower CO_2 emissions. The efficiency of heating is further enhanced by a resource optimisation system, based on wireless sensors and control stations. These collect data on temperature and humidity in individual rooms, enabling precise regulation of underfloor heating. All operations are managed via a central application server, which allows monitoring, adjustments and easy maintenance. The system is designed independently of the existing infrastructure, preventing interventions in the monastery's protected architecture. Its main advantage lies in centralized management, which allows heating to be adapted to actual use of the spaces, thus achieving substantial energy savings. The system has an open design that allows for future upgrades, including the monitoring of electricity consumption, lighting control and ventilation management. By combining the heat pump, the optimisation system and readiness for further smart upgrades, the monastery has reached a high level of sustainability. This demonstrates that even in heritage protected buildings, modern energy solutions can be successfully implemented to reduce costs, cut the carbon footprint and increase functionality, without compromising the building's historical value.

Environmental analysis

The estimated annual savings in grid electricity amount to 51,887 kWh, corresponding to an annual reduction of 20,755 kg of CO_2 emissions. The calculation is based on the latest emission factor for grid electricity, provided by the national electricity utility, which is 0.4 kg CO_2/kWh.

Economic analysis

The total investment in sustainable energy is estimated at € 233,000, of which 35%, or € 81,000 is covered by non-repayable funds, while the remaining 65% or € 152,000 represents the own contribution. Annual savings from reduced electricity consumption from the grid amount to approximately € 10,000. The expected lifespan of the system is 25 years, which corresponds to the estimated payback period. The investment's payback doesn't generate additional value over its lifetime, indicating marginal profitability. Investments in the preservation of cultural heritage do not yield **direct** financial returns, but their value goes beyond purely economic considerations. Cultural heritage represents an important part of national and local identity, historical memory and social cohesion, contributing to the preservation of cultural diversity and collective awareness. Heritage buildings and elements serve as tangible links to our past, promoting education, tourism, social cohesion and the safeguarding of these values. Preserving cultural heritage also provides **indirect** economic benefits by attracting tourists, supporting the local economy, creating employment and strengthening connections with cultural activities.

Cost estimations of sustainable energy systems installed in Hotel Murat

Energy system	Value
Installation cost of sustainable energy systems	€ 163.39 per m^2
Installation cost of sustainable energy systems per kWh used	€ 2.4 per kWh used annually
Installation cost of sustainable energy systems per annual CO_2 emission savings due to grid electricity use	€ 11.23 per kg of annual CO_2 emission savings

Simplified cost-benefit analysis of the sustainable energy investments

Energy investments in the Dominican Monastery in Ptuj deliver clear economic and environmental benefits that confirm their long-term justification. The overall annual benefits are reflected primarily in cost savings and a reduced environmental impact. On the economic side, the key effects are:

- savings in electricity costs, as optimisation systems have enabled a reduction in consumption of around 34%,
- non-repayable funding of € 81,000, which provided the financial basis for the implementation of the investment,
- lower operating and maintenance costs, since the heat pump requires longer service intervals and incurs lower maintenance expenses compared to fossil fuel-based systems.

These are complemented by important environmental effects:

- a reduction of CO_2 emissions by 20.8 tons per year,

- a lower carbon footprint and increased energy independence,
- a contribution to a cleaner and healthier environment.

Heating with a water-to-water heat pump, which relies on a renewable natural heat source, represents a transition to sustainable and efficient energy use. This reduces dependence on non-renewable sources and ensures greater cost stability in the future. The energy investment is also part of the monastery’s broader sustainability strategy, which includes raising visitor awareness of sustainability, such as:

- guided tours highlighting sustainable solutions, where heritage is presented alongside modern energy practices,
- digital communication, with the monastery’s website providing access to regular reports on achieved environmental impacts (e.g., reduced CO_2 emissions). These reports are prepared by the Local Energy Agency of Spodnje Podravje (LEA Spodnje Podravje) as part of its energy accounting system.

In this way, the economic and environmental aspects of the investment are complemented by educational and promotional value, positioning the monastery as a good practice example in the sustainable management of cultural heritage.

Financial sources used for the sustainable energy investments

For the sustainable energy investments, 65% of the funds were provided from own capital, while the remaining 35% came from a public subsidy.

Dominican Monastery – Key Characteristics

Location	Ptuj, Slovenia
Covered area	1,426 m^2
Energy intensity	69.37 kWh/m^2year

Carbon emissions	Negative carbon emissions
Building envelope	The object is subject to the restrictions of the Institute for the Protection of Cultural Heritage of Slovenia regarding the implementation of energy related interventions.
Energy sources used	Grid electricity
Sustainable energy technologies used	Heat pump, smart control system for separate section heating
Installation cost of sustainable energy systems	€ 233,000
Payback time of the sustainable energy investments	25 years
Installation cost of sustainable energy systems	€ 163.39 per m^2

2.3 Mediterranean Dream hotel -GREECE

Hotel Mediterranean Dream is a boutique gem along Crete's southwest coast in Chania. This modern, family-run property blends minimalistic elegance with authentic Cretan warmth, offering an ideal base to explore the Libyan Sea coast. Mediterranean Dream hotel offers an exceptional blend of modern and authentic Cretan hospitality, with stunning views of the Libyan Sea. Designed with comfort and style, the hotel features modern rooms that combine simplicity with modern amenities. Enjoy spacious rooms, a welcoming atmosphere and high-quality services, all within walking distance of the picturesque beaches of Paleochora, Chania. Amenities are thoughtfully curated—rooms range from Deluxe Doubles to One-Bedroom Apartments and Suites—each equipped with features like kitchens or kitchenettes, Nespresso or espresso machines, air conditioning, flat-screen TVs, free Wi-Fi, and balconies with sea views. The property earns top marks across categories like cleanliness, comfort, and staff overall rating is around 9.5 out of 10, ranking it first of 16 hotels in the area. The hotel has electrified all its operations, it does not use fossil fuels while it is a net-zero emission hotel, due to energy use, allowing its guests to minimise their carbon footprint during their staying in Crete. Perfect for couples, families, or solo travellers, this hotel offers a sleek, tranquil haven—just steps from Paleochora's sandy beach, local bakery, supermarket, cafés, and charming village atmosphere.

Characteristics of the region

Mediterranean Dream hotel is located in the island of Crete, Greece. The area of Crete is 8,336 km^2. The population in the island is 617,360 inhabitants (according to the latest census) while the number of tourists' bed-nights is 6,327,366. The tourism density in the island is 4,000 overnight stays per km^2 while its tourism intensity 55.63 overnight stays per permanent resident. The Chania prefecture of Crete is a treasure trove of historical and religious monuments, reflecting the island's layered past and diverse cultural influences. One of the most significant sites is the **Monastery of Chrysoskalitissa**, perched on a cliff overlooking the Libyan Sea. According to tradition, one of its 98 steps is made of gold, visible only to the pure of heart. Equally remarkable is the **Monastery of Gouverneto**, founded in the 16th century, with impressive architecture and proximity to the cave of Saint John the Hermit. In Chania's Old Town, the **Cathedral of the Presentation of the Virgin Mary** stands as a symbol of the city's Christian devotion, built in the 19th century on the site of an earlier Venetian church. Venetian fortifications, such as **Frangokastello Castle** and the **Firka Fortress**, highlight the strategic importance of the region, while Ottoman-era mosques, like the **Yiali Tzami** in Chania's harbour, add to its multicultural character. Together, these monuments embody Chania's role as a crossroads of civilizations, where history and spirituality remain deeply intertwined. The prefecture of Chania in western Crete hosts some of Greece's most valuable and fragile natural ecosystems, many of which are protected under the **Natura 2000** network. Chania's Natura 2000 sites include the **Samaria Gorge National Park**, home to rare endemic species such as the Cretan wild goat (*Capra aegagrus cretica*), as well as hundreds of plant species found nowhere else in the world. The **Lefka Ori** (White Mountains) shelter high-altitude plateaus, caves, and rugged peaks that provide critical habitats for birds of prey, including the griffon vulture. Coastal zones like **Elafonissi** and **Falassarna** are equally sensitive, with sand dunes, sea lilies, and nesting grounds for the endangered loggerhead sea turtle (*Caretta caretta*). Wetlands such as **Lake Agia** support migratory birds and play a vital role in water regulation and biodiversity. These ecosystems are highly sensitive to human pressures—over-tourism, climate change, and pollution threaten their delicate balance. Sustainable tourism, environmental education, and strict protection measures are essential to maintain the biodiversity and natural beauty of these areas. Preserving Chania's Natura 2000 sites means safeguarding not only rare species but also the ecological heritage that defines the region's identity.

Characteristics of the hotel Mediterranean Dream

The total covered area of the hotels 660 m^2 while its green area is 150 m^2. The capacity of the hotel is 34 beds, the annual visitors 617 and the number of bed-nights spent 4,320 (2024).

The owners dreamed of creating something meaningful on this island, and they invested in a **small, net-zero carbon emission family hotel**. Their motivation comes from the belief that tourism should not only bring joy to visitors but also protect the land that hosts them. They saw this project as an economic opportunity. More and more travellers are looking for eco-friendly places to stay. By offering genuine sustainability, not just marketing promises, they can attract guests who value responsibility as much as comfort. A zero-carbon certification will set them apart and give them access to new markets and funding opportunities. Ultimately, their motivation is both personal and forward-looking. They wanted to build a business that our children can be proud of—one that proves tourism can be profitable, sustainable, and respectful. This hotel is their family's contribution to a greener future for Crete, and a promise to preserve its beauty for generations to come.

Local climate characteristics

The annual solar irradiance is 1,834 kWh/m^2 year, the annual precipitation 530 mm/year while the average annual air temperature is presented below.

Month	Average temperature
Jan	12°C
Feb	12°C
Mar	13.6°C
Apr	16.9°C
May	21.2°C
Jun	24.7°C

Month	Average temperature
Jul	27.5°C
Aug	27.8°C
Sep	24.8°C
Oct	20.8°C
Nov	16.9°C
Dec	13.9°C

Description of energy systems used in Mediterranean Dream hotel

The design and operation of Mediterranean dream hotel is based on the concept of environmental sustainability offering to its guest's net-zero carbon vacations in Crete. The envelope of the hotel is very well insulated while it has installed several zero-carbon emissions energy systems which utilise the abundant solar energy in the island. Mediterranean Dream is grid-connected while using sustainable energy systems achieves the elimination of its net carbon emissions.

a) <u>A solar thermal system installed on its roof terrace producing hot water,</u>

Solar thermal collectors are employed to harness the sun's heat for domestic hot water (DHW) production and space heating during the cooler months. Given Crete's high solar irradiance—averaging over 3,000 hours of sunshine annually—solar thermal systems are highly efficient and reliable. These collectors heat water stored in insulated tanks, significantly reducing the need for electric or fossil-fuel-based water heating.

b) <u>A solar photovoltaic system installed on its roof terrace generating electricity,</u>

The hotel's solar PV array is the centrepiece of its electrical energy strategy. Installed on the building's roof and other sun-facing surfaces, the PV system generates clean electricity throughout the year. Despite being a seasonal operation, the PV system continues to produce electricity even when the hotel is closed. This allows the hotel to feed surplus electricity into the local grid, effectively becoming a net electricity producer over the course of the year.

c) <u>Electric batteries storing excess electricity,</u>

Electric batteries are used to store electricity when the solar-PV system generates electricity while the power demand in the hotel is low.

d) <u>High efficiency heat pumps producing heat, cooling and hot water,</u>

To complement the installed solar systems, the hotel uses high-efficiency heat pumps for space cooling in summer and supplementary hot water in cloudy days when the solar thermal system does not produce the required hot water.

e) A battery charging point to charge the batteries of electric vehicles of the guests.

The charging point can be used for charging the batteries of the electric vehicles of hotel's guests. The hotel uses grid electricity, solar thermal energy, solar photovoltaic energy and ambient heat. It is fully electrified while it does not use fossil fuels. The total annual energy consumption in the hotel is 24,949 kWh/year (electricity 18,949 kWh_{el}/year, heat 6,000 kWh_{th}/year), and its specific annual energy consumption is 37.80 kWh/m^2 year (5.78 kWh/bed-night). The specific annual energy consumption in the hotel at 37.80 kWh/m^2 is considered very low.

Characteristics of the energy systems used in Mediterranean Dream hotel

The sustainable energy systems used in Mediterranean Dream hotel comprise several technologies such as:

Insulation of the building envelope including roof insulation, walls' insulation and insulation of the doors and windows.

LED lighting

Several automatic systems

It uses an off-site **solar photovoltaic system** with installed power 17 $kW_{p.}$ The solar photovoltaic system generates annually more electricity than the demand of the hotel. Its annual electricity generation is estimated at 21,700 kWh_{el}/year while the annual electricity surplus is estimated at 2,751 kWh. It also uses a **solar thermal system** for hot water production with installed heat power 14 $kW_{th.}$ The surface of the solar collectors is 20 m^2. Its annual heat generation is estimated at 6,000 kWh_{th}. It also uses a **heat pump** with power 15 kW. The heat pump is used for air-conditioning (mainly for space cooling in the summer) and for the production of hot water supplementing the hot water produced from the solar thermal system. It also has a **power storage system** with storage capacity 24 kWh. The battery can store electricity when the solar radiation is high while the demand is low.

Environmental analysis

The estimated annual saving in grid electricity is 18,949 kWh_{el}/year while the annual decrease of CO_2 emissions due to grid-electricity saving is estimated at 7,655kgCO_2/year (The CO_2 emission coefficient for grid electricity according to the latest data provided by Public Power Company is at 0.404 kgCO_2/kWh).

Economic analysis

The total investments in renewable electricity generation systems are estimated at € 15,450 (including the investments in the solar photovoltaic system and the electric batteries) while the total investments in renewable heat generation systems are estimated at € 45,200 (including the investments in the solar thermal system and the heat pump). The total sustainable energy investments in Mediterranean Dream hotel are estimated at € 60,650. The annual benefit due to lower use of grid electricity is estimated at € 8,732 per year. The payback period of the investments is estimated at 6.95 years.

Cost estimations of sustainable energy systems installed in Mediterranean Dream hotel

Energy system	Value
Installation cost of sustainable energy systems	€ 91.90 per m^2
Installation cost of sustainable energy systems	€ 1,784 per bed

Installation cost of sustainable energy systems per kWh used	€ 3.2 per kWh used annually
Installation cost of sustainable energy systems per annual CO_2 emission savings due to grid electricity use	€ 7.92 per kg of annual CO_2 emission savings

Simplified cost-benefit analysis of the sustainable energy investments

Total annual economic benefit of the energy investments in 5 years is estimated at € 43,660. The estimated payback time of the sustainable energy investments at 6.95 years is very attractive. The operating cost of the hotel will be reduced since grid electricity and fossil fuels will not be used. Additionally, the resilience of the hotel to climate crisis will be increased. Future increases in fuels and electricity prices will not affect the hotel. The value of the property will be also increased due to state subsidies that Mediterranean Dream hotel has received. The use of sustainable energy technologies in the hotel has several environmental benefits such as:

- reduction of atmospheric carbon emissions,
- increased energy independence,
- increased energy security,
- contribution to a cleaner environment and
- Improved air quality for guests.

Financial sources used for the sustainable energy investments

The sustainable energy investments have been financed by own capital (40%), bank loan (20%) and public subsidy (40%).

Mediterranean Dream– Key characteristics

Location	Paleochora, Western Crete, Greece
Capacity	34 beds, seasonal operation, 7 months
Covered area	660 m^2
Energy intensity	37.80 kWh/m^2 year
Carbon emissions	Negative emissions hotel
Building envelope	Well insulated
Energy sources used	Grid electricity, solar energy, ambient heat
Sustainable energy technologies used	Solar thermal, solar photovoltaic, heat pump, electric battery, LED lighting
Installation cost of sustainable energy systems	€ 60,650
Annual benefit	€ 8,732 per year
Payback time of the sustainable energy investments	6.95 years
Installation cost of sustainable energy systems	€ 91.90 per m^2
Annual benefit per bed	€ 256.8 per bed

2.4 Renieris hotel – GREECE

The **Renieris hotel** is a small-size family-owned hotel located in Stalos village around 7 km west of Chania (municipality of Chania) operating 7 months annually (10,721 bed-nights in 2023). Its capacity is 52 beds and its covered area around 1,000 m^2. Nestled in the sun-kissed landscape of West Crete, the small-scale hotel is redefining sustainable hospitality by striving to become carbon neutral through its energy practices. While many businesses in the tourism sector are only beginning to consider their environmental footprint, this hotel has already taken several commendable steps to minimise its impact on the planet. By integrating renewable energy systems, leveraging efficient technologies, and supplementing them with conventional energy sources in a responsible manner, the hotel exemplifies a practical and progressive model of environmental stewardship.

Characteristics of the region

Chania, the westernmost prefecture of Crete, is a region that combines rich history with stunning natural beauty. Known for its picturesque landscapes, traditional villages, and vibrant culture, Chania has become one of the most attractive destinations in Greece. Historically, the prefecture has been shaped by various civilizations, including the Minoans, Venetians, and Ottomans. Each has left its mark through unique monuments and architectural landmarks. The Old Town of Chania, with its Venetian harbour, lighthouse, and narrow streets, reflects this multicultural past. Important historical sites include the Venetian fortress of Frangokastello, the Archaeological Museum of Chania, and numerous Byzantine churches scattered throughout the region. These monuments stand as reminders of Chania's strategic importance in the Mediterranean. Equally impressive are the natural beauties of the prefecture. The White Mountains, or Lefka Ori, dominate the landscape and provide opportunities for hiking and exploration. The Samaria Gorge, one of Europe's longest canyons, attracts thousands of visitors each year with its dramatic scenery and rich biodiversity. Chania is also famous for its beaches, ranging from the exotic Balos lagoon and

Elafonissi with its pink sand to the more secluded shores of Falassarna. Olive groves, vineyards, and citrus orchards add to the prefecture's charm, offering a glimpse into traditional Cretan life. Overall, Chania prefecture is a place where history and nature coexist harmoniously. Its monuments tell stories of past civilizations, while its breathtaking landscapes highlight the timeless beauty of Crete. This unique combination makes Chania an unforgettable destination.

Characteristics of Renieris hotel

Renieris hotel is a small-size family-owned hotel operating 7 months annually from April until late October. Its capacity is 52 beds and its covered area around 1,000 m^2. During 2023 the hotel hosted 1,448 visitors staying 10,721 bed-nights.

Local climate characteristics

The annual solar irradiance is 1,834 kWh/m^2 year, the annual precipitation 530 mm/year while the average annual air temperature is presented below.

Month	Average temperature
Jan	12°C
Feb	12°C
Mar	13.6°C
Apr	16.9°C
May	21.2°C
Jun	24.7°C

Month	Average temperature
Jul	27.5°C
Aug	27.8°C
Sep	24.8°C
Oct	20.8°C
Nov	16.9°C
Dec	13.9°C

Description of energy systems used in Renieris hotel

At the heart of the hotel's sustainability strategy is its use of **solar energy**, a resource abundantly available in Crete's Mediterranean climate. The hotel uses solar thermal systems to provide hot water for guest rooms and operational needs. This significantly reduces reliance on fossil fuels for water heating, a major source of carbon emissions in hospitality operations. In addition, photovoltaic panels are installed to generate electricity from the sun. This on-site solar electricity reduces the hotel's dependence on grid power and helps offset carbon emissions associated with conventional electricity generation. Another integral component of the hotel's energy system is the use of **heat pumps**, which provide energy-efficient heating and cooling. Heat pumps operate by transferring heat rather than generating it, making them far more efficient than traditional heating systems. In a moderate climate like Crete's, heat pumps are especially effective, offering a low-carbon solution for maintaining guest comfort year-round. The integration of heat pumps into the hotel's infrastructure not only contributes to emissions reduction but also supports energy cost savings and operational efficiency. Despite the strong presence of renewable technologies, the hotel still uses **grid electricity**, **liquefied petroleum gas (LPG)** in the kitchen, and **diesel oil** for hot water production during periods when solar energy is insufficient. While these conventional energy sources do produce carbon emissions, the hotel uses them strategically and in moderation, often as backup systems or during peak demand. LPG is preferred over other fossil fuels for cooking due to its relatively lower emissions and high efficiency. Diesel oil, though a less sustainable choice, is used minimally and is being gradually phased out as renewable and low-emission alternatives become more viable.

Characteristics of the energy systems used in the Renieris hotel

The sustainable energy systems used in Mediterranean Dream hotel comprise several technologies such as:

A) A solar-PV system with nominal power at 10 KW_p installed on the terrace of the building. It generates around 15,000 KWh_{el} per year,
B) A solar thermal system producing domestic hot water installed on the terrace of the building. The surface of the solar thermal panels is 30 m^2 [12 panels, 2.5 m^2 each]. The total heat power is 21.72 KW_{th}. Diesel oil is additionally used for domestic hot water production.
C) The hotel uses efficient LED bulbs for lighting,
D) The building's envelope is well insulated while it has glazed windows and doors,
E) A modern energy system is used optimising the production and distribution of hot water,
F) The hotel has double glazed windows and well insulated walls to reduce thermal losses,
G) LPG is used in the kitchen with energy efficient apparatus.

What distinguishes this hotel from many others is its **commitment to achieving carbon neutrality despite the mixed energy portfolio**. Carbon neutrality refers to balancing the total emissions produced with an equivalent amount of carbon offset or removal, effectively bringing the net emissions to zero. The hotel plans to reach this goal by implementing a combination of strategies:

1. **Maximising energy efficiency**: Through regular audits, energy-efficient appliances, and smart building systems, the hotel continuously minimises waste and optimises consumption.
2. **Expanding renewable energy use**: Future plans include increasing photovoltaic capacity and improving solar thermal performance, further reducing the need for fossil fuels.
3. **Carbon offsetting**: For emissions that cannot be eliminated through renewable sources or efficiency measures, the hotel invests in certified carbon offset projects. These may

include reforestation efforts, renewable energy development in underserved regions, or methane capture programs.

4. **Staff training and guest engagement**: The hotel actively involves staff and guests in its sustainability mission. Information on energy-saving practices is shared with guests, while employees are trained in eco-friendly operations, ensuring that the commitment to carbon neutrality is embedded in the hotel's culture.

The hotel's path to carbon neutrality is not without challenges. Seasonal fluctuations in solar energy availability, the intermittency of renewable sources, and the initial investment required for clean energy infrastructure are all significant hurdles. However, the long-term benefits — environmental, economic, and reputational — outweigh these obstacles. By leading with a clear vision and a practical strategy, the hotel turns these challenges into opportunities for innovation and continuous improvement.

Energy balance in Renieris hotel (2023)

Fuel/energy source	Quantity (KWh)	%, of total
Grid electricity	34,913	47.18
Solar-PV electricity	15,000	20.27
Solar thermal energy	8,750	11.82
Diesel oil	11,000	14.86
LPG	4,347	5.87
TOTAL	74,010	100

Contribution of solar energy in the annual energy balance 20.27 % +11.82 % = 32.09%

a) Specific annual energy consumption = 74.01 KWh/ m^2

b) Specific annual energy consumption = 1,423.27 KWh/bed
c) Specific energy consumption = 6.90 KWh/bed-night

Environmental analysis

The carbon emissions in Renieris hotel in 2023 are presented below.

CO_2 emissions due to energy use (2023)

Fuel/energy source	CO_2 emissions ($kgCO_2$/year)	%, of total
Grid electricity	19,752	84.06
Solar-PV electricity	0	0
Solar thermal energy	0	0
Diesel oil	2,794	11.89
LPG	951	4.05
TOTAL	23,497	100

a) Annual CO_2 emissions 23.50 $kgCO_2/m^2$
b) Annual CO_2 emissions 451.87 $kgCO_2$/bed
c) CO_2 emissions 2.19 $kgCO_2$/bed-night

The estimated annual saving in grid electricity is 23,750 kWh_{el} while the annual decrease of CO_2 emissions due to grid-electricity saving is estimated at 9,595 $kgCO_2$ (The CO_2 emission coefficient for grid electricity according to the latest data provided by Public Power Company is at 0.404 $kgCO_2$/kWh).

Economic analysis

The cost of the solar photovoltaic system in the hotel is estimated at € 11,000 while the cost of the solar thermal system at € 10,500. The annual benefit from the generated solar electricity is estimated at € 3,000 while from the generated solar heat at € 1,100. The total installation cost of the solar energy investments is estimated at € 21,500 while the total annual economic benefit at € 4,100. The payback period of the solar photovoltaic system is calculated at 11,000/3,000 = 3.67 years while the payback period for the solar thermal system at 10,500/1,100 = 9.55 years. The combined payback period of both solar energy investments is estimated at (11,000+10,500)/ (3,000+1,100) = 5.24 years.

Simplified cost-benefit analysis of the sustainable energy investments

Total annual economic benefit of the energy investments in 5 years is estimated at € 20,500. The estimated payback time of the sustainable energy investments at 5.24 years is very attractive. The use of solar energy technologies instead of fossil fuels and grid electricity (which is mainly generated by fossil fuels in Crete) results in less carbon emissions contributing to climate change mitigation. Additionally, the resilience of the hotel to climate crisis will be increased. Future increases in fuels and electricity prices will not affect the hotel. The value of the property will be also increased due to installation of benign energy technologies. Therefore, the use of sustainable energy technologies in the hotel has several environmental benefits such as:

- Reduction of atmospheric carbon emissions,
- increased energy independence,
- increased energy security,
- contribution to a cleaner environment and
- Improved air quality for guests.

An increasing number of guests seek accommodations that operate under the principle of “environmental sustainability” The energy investment is part of a sustainability approach in Renieris hotel that emphasises raising environmental awareness among guests, including:

- Informing guests about the green technologies used in the hotel,
- encouraging them to reduce the electricity and water consumption,
- encouraging them to recycle their wastes.

Financial sources used for the sustainable energy investments

Hotel Renieris has financed the sustainable energy investments with its own resources. However, the high compensation for the solar-PV electricity injected into the grid consist of an indirect state financial support.

***T*he future plan of Renieris hotel to achieve carbon neutrality**

The hotel has a plan for the elimination of its carbon footprint in the future. Several options have been examined including:

a) The full electrification of its operation using electric machinery and appliances combined with the installation of an additional solar photovoltaic system generating (together with the existing solar-PV system) all the required electricity in the hotel.
b) The full electrification of its operation using electric machinery and appliances combined with its participation in a Cretan energy community generating all the required electricity in the hotel.
c) Provisional offsetting of its carbon emissions. The carbon offsetting cost is estimated at 23.5 tCO_2/year X € 6 per tCO_2 = € 141 per year.

Renieris hotel– Key characteristics

Location	Stalos, Western Crete, Greece

Capacity	52 beds, seasonal operation, 7 months annually
Covered area	1,000 m^2
Energy intensity	74.01 kWh/m^2year (6.90 KWh/bed-night)
Carbon emissions	23.50 kgCO_2/m^2 year (2.19 kgCO_2/bed-night)
Building envelope	Well insulated
Energy sources used	Grid electricity, solar energy, ambient heat, LPG, diesel oil
Sustainable energy technologies used	Solar thermal, solar photovoltaic, heat pump, LED lighting
Installation cost of sustainable energy systems (solar-PV and solar thermal)	€ 21,500
Annual benefit	€ 4,100
Payback time of the sustainable energy investments	5.24 years
Installation cost of sustainable energy systems	€ 21.5 per m^2 (€ 413.5 per bed)
Annual benefit per bed	€ 78.85 per bed

2.5 Milia agrotourism facility –GREECE

In the rugged landscapes of southwest Crete, where the Lefka Ori mountains descend into fertile valleys and the Aegean Sea whispers stories of millennia, lies a unique and inspiring destination—a small-scale agrotourism facility that seamlessly blends ecological sustainability with cultural authenticity. This off-grid retreat offers more than just accommodation; it offers a journey into a simpler time, inviting guests to live as the villagers once did, in harmony with the land, the seasons, and the rhythms of nature.

A Sustainable Vision Rooted in Tradition

Unlike conventional hotels and resorts that often place comfort above sustainability, this agrotourism facility was designed with a different vision. Its mission is to demonstrate that true hospitality can exist without sacrificing the environment. Entirely off grid, the facility operates with zero carbon emissions. Its power is derived from solar photovoltaic (solar-PV) systems that harness Crete's abundant sunlight. Solid biomass, sourced sustainably from local agricultural residues and pruning, is used for heating, circulated through a central heating system during the cooler months. This integrated energy approach not only eliminates fossil fuel dependence but also supports the local agro-economy. The design of the facility mirrors the architecture and layout of traditional Cretan homes. Thick stone walls offer natural insulation, keeping interiors cool in summer and warm in winter. The rooms are purposefully simple: no kitchens, no refrigerators, no air-conditioning units—amenities that have become commonplace yet are energy-intensive. Instead, guests experience a way of life that was standard just a few generations ago.

Rediscovering the Essence of Living

This deliberate absence of modern appliances is not a shortcoming but a profound part of the experience. Guests quickly find that without the distractions of screens and gadgets, their senses awaken to the environment around them. The sound of cicadas replaces the hum of air-conditioners, and the scent of wild herbs—thyme, oregano, and sage—wafts through open windows. Meals are communal and prepared using local ingredients, often harvested directly from the surrounding land or sourced from neighbouring farms. Fresh seasonal vegetables, olive oil pressed from nearby groves, cheeses made by local shepherds, and bread baked in wood-fired ovens form the basis of simple yet rich Cretan dishes. Guests can participate in cooking sessions, learning to make traditional recipes like *dakos*, *kalitsounia*, and slow-cooked lamb with wild greens. The lack of refrigeration encourages daily foraging and visits to village markets, reinforcing a closer relationship with food and a deeper appreciation for freshness and seasonality. Rather than isolating guests in self-sufficient rooms, the facility fosters interaction and shared experiences, just as in the village life of old.

A Model for Climate-Conscious Travel

The agrotourism facility exemplifies a low-impact, high-reward model of tourism—one that aligns with global efforts to combat climate change. In a world where tourism accounts for nearly 5-6% of global greenhouse gas emissions, such zero-carbon initiatives are not just admirable; they are essential. Energy efficiency is embedded in every aspect of the facility. The solar-PV system provides electricity for basic lighting and limited appliances, carefully balancing demand and supply. The use of biomass for heating and domestic hot water production not only leverages renewable resources but also supports forest management practices that reduce wildfire risk and improve biodiversity. Water conservation is another cornerstone. Rainwater harvesting systems and greywater recycling support the facility's water needs, while native and drought-resistant plants minimise irrigation requirements. Guests are encouraged to be mindful of their water usage—part of a broader philosophy of conscious consumption that defines the experience. Waste is managed through composting, recycling, and avoidance of plastic packaging. Organic waste nourishes the soil, feeding the garden that in turn feeds the guests. This circular approach mirrors natural ecosystems and demonstrates that sustainability is not a constraint but a creative challenge.

Cultural and Community Revival

Beyond its environmental virtues, the agrotourism facility plays a vital role in preserving the cultural heritage of the region. Many rural villages in Crete have suffered from depopulation as younger generations migrate to urban centres. By attracting visitors who appreciate authenticity and simplicity, this project helps breathe new life into local traditions.

Workshops on beekeeping, olive oil production, weaving, and herbal medicine are regularly organised, often in collaboration with older villagers who serve as cultural ambassadors. These exchanges not only enrich the guest experience but also restore value to traditional knowledge systems. Furthermore, the facility operates as part of the local economy rather than apart from it. It employs local residents, sources materials and services locally, and encourages guests to explore nearby villages, tavernas, and artisans. This economic integration ensures that tourism revenue remains within the community, contributing to its resilience and sustainability.

Personal Journey of Transformation

Many visitors arrive at the facility seeking rest and disconnection but leave with something deeper—a shift in perspective. Stripped of modern luxuries, they reconnect with the natural world and their own inner rhythms. They rediscover the joy of slow living, the richness of simplicity, and the meaning of sufficiency. The experience can be transformative. In contrast to the hurried pace of modern life, this immersion in traditional living prompts reflection: What do we truly need to live well? How can we reduce our footprint while enriching our lives? These are questions that linger long after the stay has ended.

A Blueprint for the Future

As climate challenges mount and the tourism industry grapples with its environmental impact, small-scale, off-grid initiatives like this agrotourism facility in southwest Crete offer a hopeful blueprint for the future. They remind us that sustainability is not merely about technologies and carbon accounting, but about reimagining our relationship with nature, community, and time. Milia facility is more than a place to stay—it is a living example of how the past can guide us toward a more balanced and resilient future. By reviving traditional ways of life and coupling them with ecological innovation, it shows that hospitality and sustainability can not only coexist but thrive together. For those seeking an authentic, meaningful, and carbon-free journey, this corner of Crete offers a rare and precious escape.

Milia agro-tourism facility opened up to its guests in the early 90s, after twelve years of exhaustive works of restoration on the remnants of a medieval settlement that was abandoned in the middle of the 20th century. The off-grid facility operates all over the year (in winter only during the weekends) and promotes a sustainable and long-term eco-friendly traveling model characterised by:

- Self-sufficiency of energy provision through solar-PV panels for electricity and wood (collected from the nearby trees) for space heating & domestic hot water production,
- Organic food production in the farms and yards of the property and the nearby area,
- Systematic natural composting of organic material, including the leaves of trees that surround the area,
- Biological treatment of wastewater,
- Natural spring water supply towards the eco-lodge and the farm,

- Natural conditioning and zero electronic devices in the rooms,
- Zero food waste, into the food chain of the property, and
- Natural reforestation of the area by minimising goat grazing.

The energy consumption in Milia facility in 2023 is presented in table 1.

Characteristics of Milia agro-tourism facility

Number of beds	41
Covered area	450 m^2
Bed-nights	7,420
Energy sources used	Solar-PV, solid biomass
Use of power storage system	Yes
Grid connection	No
Total annual energy consumption (approximate estimation)	54,000 kWh
Total annual electricity consumption (approximate estimation)	6,480 kWh
Total annual heat consumption (approximate estimation)	47,520 kWh
Total carbon emissions	0

Specific annual energy consumption (approximate estimation)	120 kWh//m^2
Specific annual energy consumption (approximate estimation)	1,317.07 kWh/bed
Specific energy consumption (approximate estimation)	1.28 kWh/bed-night

2.6 Corinthia hotel – MALTA

Corinthia Hotel St George's Bay, Malta originally opened in 1995, is a tranquil coastal resort with sea views. There are 250 beautiful rooms, five swimming pools and a private rocky beach. The resort is home to a variety of different dining options – from Mediterranean cuisine through to flavours from the East. The hotel has an Apollo Day Spa, water sports centre and state-of-the art fitness centre. The rooms consist of twin, queen-size, and king-size beds. Main features within the rooms include mini-bar, safe, trouser press, air-conditioning, central-heating, cable/satellite TV, bathroom with bath/shower facility and balcony and free Wi-Fi.

Characteristics of the region

Corinthia Hotel St. George's Bay is located in the touristic town of St. Julian's, Malta. The area of St. Julian's is 1.6 km^2. The permanent population in the town amounts to 15,208 residents (2024), while the number of bed-nights in St. Julian's is estimated at 1.36 million, which is around 12% of the total bed-nights of Malta (2024). The tourism density in the town of the hotel is approximately 849,000 bed-nights per km^2, while its tourism intensity amounts to 90 bed-nights per permanent resident. St Julian's, although best known for its vibrant nightlife and tourism, also preserves a number of historical and religious monuments that reflect its rich past. The **Parish Church of Our Lady of Mount Carmel**, with its striking Neo-Gothic architecture, stands prominently along Balluta Bay, serving as a spiritual landmark and a reminder of the area's deep Catholic roots. Nearby, the **Church of the Immaculate Conception** at Balluta suburb, originally built in the 19th century, adds further cultural value. St Julian's name itself derives from a chapel dedicated to **St Julian the Hospitaller**, patron saint of hunters, which once served as the village's focal point. Remnants of old farmhouses and coastal watchtowers also highlight the area's strategic maritime importance during the

Knights of St John. Together, these monuments provide a glimpse into St Julian's transformation from a small fishing village into a modern cultural hub. Near St Julian's, lies several fragile natural ecosystems that form part of the EU's Natura 2000 network, established to safeguard biodiversity. Among these is **Wied Għomor Valley**, a rare stretch of natural habitat running inland from St Julian's, where carob, olive, and Mediterranean maquis vegetation support diverse bird and insect species. The valley also plays an important role in water management, acting as a natural catchment. Along the coast, marine habitats and **Posidonia oceanica seagrass meadows** provide crucial breeding grounds for fish while helping prevent coastal erosion. These ecosystems are vulnerable to pressures from urbanization, tourism, and climate change, making conservation essential. Protection under Natura 2000 ensures that such areas are managed sustainably, balancing human activity with ecological preservation. For residents and visitors, these sites offer a chance to appreciate Malta's natural heritage while underscoring the importance of safeguarding fragile environments for future generations.

Characteristics of the Corinthia Hotel St. George's Bay

The total covered area of the hotels 32,000 m^2 while its green area is 3,500 m^2. The capacity of the hotel is 250 beds, the annual visitors 125,675 and the number of bed-nights spent 64,598 (2024). The hotel's Sustainability Strategy is structured around three core pillars all anchored by Corinthia's overarching purpose of "'Uplifting lives': People, Planet and Governance."

People: The core values are to promote wellbeing, learning, and fair labour practices by supporting communities through philanthropy whilst upholding human rights across all operations and partnerships.

Planet: The hotel focuses on reducing environmental impact through carbon reduction, water conservation, waste minimisation, energy efficiency, sustainable sourcing and circular renovation practices.

Governance: The hotel's policy is built on a strong commitment to good governance through accountability, transparency, compliance, stakeholder engagement, ethical conduct and integrating sustainability across our organisational structure.

New customer demands, market competition and lower carbon emission regulatory requirements push tourism operators to adopt a greener tourism industry. The main challenges are finding CAPEX for investment and low awareness level on sustainability of the workforce. The hotel views sustainable practices as both a moral obligation and a strategic necessity, ensuring Corinthia's continued ability to uplift lives into the future.


CORINTHIA
HOTEL

Local climate characteristics

The annual solar irradiance is 1,841 kWh/m^2 on the horizontal, the annual precipitation over the period 2015-2024 was 450 mm/year, while the average annual air temperature is 19.37 °C (1991-2020).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature (°C)	12.9	12.6	14.1	16.4	20.0	24.2	26.9	27.5	24.9	21.7	17.9	14.5
Average maximum temperature (°C)	15.7	15.7	17.4	20.1	24.3	28.8	31.7	32	28.6	25.0	20.8	17.1
Average minimum temperature (°C)	10.0	9.6	10.9	12.7	15.8	19.6	22.1	23.0	21.2	18.4	15.0	11.8

Description of energy systems used in the Corinthia Hotel St. George's Bay

The hotel's energy systems are designed to maximise efficiency and sustainability through an integrated approach. Grid electricity is used for all electrical equipment including chillers for cooling, lighting, elevators, besides others while light fuel oil for boilers to provide hot water and space heating and LPG for cooking in kitchens. The percentage grid electricity amounts to 71% of the total energy consumption, followed by 21% for diesel oil for water and space heating, 8% liquefied petroleum gas for cooking and 3% coming from rooftop solar photovoltaic systems. The total annual energy consumption in the hotel is 5,016,537 kWh, and its specific annual energy consumption is 179.5 kWh/m^2 (77.66 kWh/bed-night).

Characteristics of the energy systems used in the Corinthia Hotel St. George's Bay

The hotel operates a full Building Management System (BMS) for all energy systems. Projects are being implemented to convert all the fossil fuel boilers to heat pump water heaters and replace all chillers by high efficiency seawater cooled chillers for air conditioning. Moreover, all lighting will be converted to the latest LED technology, and a new occupancy and intelligent control systems will be added to the BMS. The total budget is € 5 million. Moreover, the hotel has invested in a rooftop solar photovoltaic system of 126 kWp capacity.

Environmental analysis

In line with the Hotel's policy, it focuses on three pillars, namely People, Planet and Governance. The tourism market is constantly evolving, and tourists are increasingly looking for accommodation that is environmentally friendly. Therefore, the Hotel needs to align its operations with this new green trend. Although the payback period of the measures is long-term, we forecast increased influx of tourists to the Hotel, which will boost revenue and in so doing indirectly contribute to the reduction of the payback period. We also promote wellbeing and therefore we must ensure that the hotel is operating at the highest efficiency and therefore promote a comfortable stay. Our contribution to climate change mitigation goes beyond cost effectiveness. We are committed to reducing the carbon footprint of the hotel looking beyond immediate fiscal benefits but long-term sustainable operation. In doing so, we implement an ethical business model with social governance taking a leading role in our operations. Following the planned investment of 5 million Euro in the next 5 years, the estimated annual saving in grid electricity is estimated to amount to 30%, while fossil fuel usage will be eliminated. The equivalent reduction in carbon dioxide emissions due to shifting from diesel oil to heat pump water heaters will amount to 270 tCO_2/year, while the estimated total CO_2 emission reduction due to electricity savings will amount to 524 tCO_2/year, bringing the overall savings to 794 tCO_2/year.

Economic analysis

The total investment of € 5 million is expected to yield an annual saving of € 139,000 from electrical consumption and € 61,000 from elimination of diesel oil, bringing the total savings to € 200,000 per year. Therefore, the payback period would be around 25 years, except for the photovoltaic system which has a payback period of 5 years.

Cost estimations of sustainable energy systems installed in Corinthia hotel

Energy system	Value
Installation cost of sustainable energy systems	€ 156 per m^2
Installation cost of sustainable energy systems	€ 20,000 per bed
Installation cost of sustainable energy systems per kWh used	€ 0.997 per kWh used annually
Installation cost of sustainable energy systems per annual CO_2 emission savings due to grid electricity use	€ 6.30 per kg of annual CO_2 emission savings

Simplified cost-benefit analysis of sustainable energy investments

Total annual economic benefit of the energy investments in 5 years is estimated at € 200,000. The estimated payback time of the sustainable energy investments is 25 years. Although this is long, it is expected that it will drop significantly when electricity tariffs increase in the future. The operating cost of the hotel will be reduced since grid electricity and fossil fuels will not be used. Additionally, the resilience of the hotel to climate crisis will be increased. Future increases in fuels and electricity prices will not affect the hotel. The use of sustainable energy technologies in the hotel has several environmental benefits such as:

- Reduction of atmospheric carbon emissions,
- increased energy independence,

- increased energy security,
- contribution to a cleaner environment and
- Improved air quality for guests.

Financial sources used for sustainable energy investments

The sustainable energy investments are fully financed by the hotel.

Corinthia hotel – Key characteristics

Location	St. Julian's, Malta
Capacity	250 beds, full-year operation.
Covered area	32,000 m^2
Energy intensity	156.77 kWh/m^2 year
Carbon emissions	1,951 tCO_2/year (60.98 $kgCO_2/m^2$ year)
Building envelope	Double-wall limestone
Energy sources used	Grid electricity, diesel oil, solar photovoltaics
Sustainable energy technologies used	Solar photovoltaic, LED lighting. Planning to add insulation, double-glazing, heat pumps within the next few years
Installation cost of sustainable energy systems	€ 5,000,000

Payback time of sustainable energy investments	25 years except for the solar photovoltaic system which is 5 years
Installation cost of sustainable energy systems	€ 156.25 per m^2

2.7 The Phoenicia Malta hotel - MALTA

The Phoenicia Malta Hotel, is a five-star hotel located at the entrance to Valletta, proudly standing on a site rich in Maltese heritage. Originally opened in 1947, the building is surrounded by 7.5 acres of historic gardens and bastion walls, overlooking the Grand Harbour and the fortifications of Valletta, a UNESCO World Heritage site. The infrastructure blends historic architecture with careful green investments to reduce the environmental footprint while preserving the charm and legacy of the property. The Hotel has upgraded the HVAC systems to more energy-efficient models and implemented a building management system to control lighting and air conditioning based on occupancy, reducing unnecessary energy use without compromising guest comfort. The landscaped gardens are maintained using a smart irrigation system that reduces water consumption by prioritizing reclaimed water sources where feasible. Phoenicia actively collaborates with local cultural sites and artisans, promoting slow travel experiences and local heritage tours, which align with low-impact tourism practices. The Hotel encourages guests to explore Valletta and its surroundings on foot or by bicycle, directly connecting them with the city's living heritage while reducing reliance on motor transport. The Hotel's commitment to sustainability is woven into the heritage of the building itself, as it continues to find practical ways to improve energy efficiency, water conservation, and waste reduction while preserving the historic integrity that makes The Phoenicia a landmark of Malta. Green tourism is not just about technology, but about respecting the layers of history, protecting and sharing with guests.

Characteristics of the region

The Phoenicia Malta Hotel is located in Floriana, a fortified town in the Southeastern/Port Region of Malta and adjacent to the capital city of Valletta. Floriana is a relatively small town of 0.94 km^2 and has a population of around 2,070 persons. There is no specific bed-night data for Floriana only, but one can reference national/regional data as a proxy. In 2024, Malta recorded ~11.32 million bed nights in collective accommodations[1]. Assuming Floriana (with a handful of hotels including The Phoenicia) accounts for ~0.5% of total Maltese hotel capacity (given its size and role compared to broader Valletta and Sliema), one can estimate ~56,600 bed nights annually, which translates to a tourism density of ~60,200 bed-nights per km^2 and a tourism intensity of 27.3 bed-nights per permanent resident. Floriana stands as a gateway of layered heritage—with fortifications, churches, monuments, and public gardens creating a rich urban tapestry. The Floriana Lines are an imposing line of bastioned fortifications surrounding Valletta, which started being constructed in 1636. Key components include the Portes des Bombes gate (1721), an ornamental baroque arch, and Batterie-style bastions like Msida and San Salvatore These defences, originally built by the Order of St. John and later adapted by the British, now form a living monument to Malta's military and architectural history. Within the town, there are numerous religious and civic landmarks: St. Publius Parish Church and Square, the historic Granaries (Il Fosos) used in sieges and later as gathering spaces, and verdant Argotti, Vilhena, and Jubilee Gardens, which blend natural and built heritage in public spaces. Although Floriana itself is an urban fortified area, it is positioned near Malta's Grand Harbour coastline, which influences adjacent marine and coastal ecosystems included in the NATURA 2000 network. Malta's NATURA 2000 areas protect fragile habitats such as coastal cliffs, saline marshlands, and submerged reefs, which are essential for biodiversity in an island nation with limited natural spaces. Areas like the nearby il-Gżejjer ta' San Pawl (St Paul's Islands) and Il-Magħluqtal-Baħar ta' Marsaskala

[1] *https://en.wikipedia.org+14nso.gov.mt+14nso.gov.mt+14*

safeguard endemic flora, migratory bird resting points, and marine life sensitive to pollution and human activity. In these zones, seagrass meadows help stabilize coastlines and support fish nurseries, while coastal garigue and steppe habitats shelter native plants adapted to harsh, dry conditions. NATURA 2000 areas around Malta represent a balance between development pressures and the need to protect ecosystems that contribute to the island's environmental health and cultural landscape.

Characteristics of the Phoenicia Malta Hotel

The total covered area of the hotels 30,350 m^2, while its green area is 15,350 m^2. The capacity of the hotel is 264 beds, and the annual number of bed-nights spent was 57,800 (2024).

Figure 1. The Phoenicia Hotel is strategically situated close to the Capital City Valletta – a UNESCO World Heritage Site

Figure 2. The Phoenicia Hotel operates an organic kitchen garden on site.

Figure 3. The Phoenicia Malta Hotel has been nominated by the World Travel Awards 2025 as one of Europe's Leading Landmark Hotel

Local climate characteristics

The annual global horizontal solar irradiance is 1,825 kWh/m^2, the annual precipitation 450 mm/year (average over the past 10 years), while the average annual air temperature is 20.6°C.

Summer: Temperatures are hot and humid, with average daily highs ranging from 28-34°C and lows from 20-24°C with some heat waves reaching up to 40°C at times.

Winter: Temperatures are moderately cool, with average daily maximums of 12-15°C and average daily minimums of 7-10°C.

Description of energy systems used in The Phoenicia Malta Hotel

The Hotel mainly uses electricity to power lighting, HVAC systems, kitchen equipment, lifts, and guest services. The hotel is also equipped with a BMS system that actively monitors and manages all plant equipment, giving live insights into energy use, temperatures, and fault alarms. This helps to react quickly if a pump is underperforming or if there is an abnormal draw somewhere, which, has been instrumental to avoid more than one potential outage. For heating, the Hotel uses LPG modular boilers. LPG is chosen over heavier fuels for cleaner combustion and efficiency, and the modular design allows quick adjustment to boiler operation according to occupancy and demand, instead of running at full capacity all the time. This makes it easier to manage fuel consumption, particularly during shoulder seasons when the load fluctuates. Water pressure systems are managed via electrical pumps that maintain consistent supply across the property, with pressure transducers feeding data into the BMS system to ensure stable delivery without unnecessary energy waste. The Hotel uses grid electricity, which forms the backbone of the overall energy operations. Based on 2024 data, grid electricity accounts for around 76% of the total energy consumption costs. This electricity powers the HVAC systems, lifts, lighting, kitchen equipment, and guest room services, all monitored through our BMS system, which helps manage faults and usage in real time. The remaining 24% of the energy profile is covered by LPG modular boilers for heating and hot water, and water consumption costs related to our water bowser and metering systems. This balance allows to adjust energy use efficiently according to occupancy, maintaining guest comfort while controlling operational costs throughout the year. The Hotel is certified by the Global Sustainable Tourism Council (GSTC), a recognition that reflects the Hotel's dedication to the highest international standards in responsible tourism. The commitment spans environmental care, community engagement, and cultural preservation, ensuring that its impact is both meaningful and lasting. Some of the sustainability measures include:

- Building management system
- Preventive equipment maintenance
- Daily energy and water monitoring
- Water-saving fixtures
- Linen and Towel Reuse Options
- Plastic-Free Room Amenities
- Wooden Key Cards & Do Not Disturb Signs
- Paperless Check-in
- Energy-Aware Welcome
- Plastic-Free Beverage Service
- Organic kitchen garden
- Seasonal and local food sourcing
- Vegan-friendly dining
- Certified beverages
- Biodegradable cleaning products
- Eco-conscious purchasing
- Full waste recycling
- Waste tracking and reduction

The total annual energy consumption in 2024 in the hotel was 1,920,000 kWh [electricity 1,286,400 kWh_{el} (67%), heat 633,600 kWh_{th} (33%)], and its specific annual energy consumption was 128 kWh/m^2 based on total built-up area (33.2 kWh/bed-night).

Characteristics of the energy systems used in the Phoenicia Malta Hotel

This hotel integrates advanced building technologies to reduce energy consumption while enhancing guest comfort. A central Building Management System (BMS) coordinates all key operations, including site-specific controls for bedroom air-conditioning, ensuring efficient demand-based use. Double-glazing with low-e coatings and optimised U-values, combined with roof insulation, limit heat gains and noise, reducing cooling demand. Climate regulation is achieved through VRF air-conditioning systems linked to CS-Net and inverter-driven fresh air ventilation, providing precise, energy-efficient control. Modular LPG boilers supply hot water with flexible, load-based operation, while inverter-driven pumps further optimise energy use across the site. Cold rooms for food preservation are designed for reduced energy losses, and the outdoor pool cooling system uses evaporative technology, lowering electrical demand compared to traditional chillers. This integrated approach demonstrates how luxury hospitality can achieve operational efficiency, resource savings, and lower environmental impact while maintaining high service standards.

- BMS which monitors and controls all key operations, including site specific controls for air conditioners in every bedroom.
- Double-glazing with low-e and U-values.
- Insulation of roofs against heat and sound.
- New VRF air-conditioners with full control through CS-Net.
- Fresh air mechanical ventilation using inverter-driven systems.
- Water heating using modular LPG boilers with direct control.
- All pumps are inverter-driven and fully controlled via the BMS.
- All new cold rooms for preservation of food and energy saving.
- Cooling system for outdoor pools using evaporative cooling systems.

The hotel holds an Energy Performance Certificates (EPC) indicating a low-carbon emission system. The Building Primary Energy Use benchmark was calculated based on the actual operational energy performance for the year 2024 as 128 kWh/m^2, which reflects the total annual energy consumed for heating, cooling, lighting, and other building services per square metre of built-up area (15,000 m^2) only. This is well below the EPC certificate value of 427 kWh/m^2 year, as well as below the minimum energy requirements for hotels with renewable energy installations of 480 kWh/m^2 year, as set by the 2024 Minimum Energy

Performance Requirements Technical Document F for Malta. Nevertheless, the hotel continues to invest to improve this energy performance even further. Between 2015 and 2024, total electricity use rose from ~1.64 million kWh to ~1.92 million kWh, an increase of 17%. This increase reflects the expansion of the property, with the SPA and Bastion Pool, which did not exist in 2015. When assessed on a like-for-like basis, the core hotel maintained highly efficient operations through its VRF air-conditioning systems, inverter-driven ventilation, and advanced BMS controls. Importantly, the hotel's turnover and gross profit have grown more rapidly than electricity demand, demonstrating improved energy efficiency per € revenue generated (lower energy intensity). The investment has therefore resulted in a net-positive outcome by stabilising consumption despite increased guest facilities. The energy investments implemented since 2015 have delivered clear environmental gains alongside economic returns. The replacement of diesel boilers with modular LPG systems has reduced particulate emissions and improved local air quality, supporting both guest comfort and compliance with modern EU standards. The installation of a Building Management System (BMS), VRF air-conditioning, and inverter-driven pumps and ventilation has optimised demand, limiting electricity growth despite the addition of new guest facilities such as the SPA and Bastion Pool. Cold rooms designed for energy efficiency, double-glazing with low-e glass, and enhanced roof insulation have reduced cooling loads and noise transmission, lowering overall energy intensity. Fresh-air systems with inverter control ensure high indoor air quality while using less energy compared with conventional equipment. While absolute CO_2 emissions increased due to the enlarged footprint, the environmental impact per guest and per euro of turnover has decreased, demonstrating improved efficiency of resource use. The investments have therefore balanced growth with sustainability, enabling the hotel to deliver a higher level of service while contributing to Malta's wider goals for greener tourism infrastructure.

Environmental analysis

In 2015, the hotel consumed ~42,111 litres of diesel fuel, equivalent to ~35 tons. By 2024, this was replaced by LPG, with a total consumption of ~169,145 litters. Adjusting for the SPA and Bastion Pool (which together account for an estimated 20–30% of this total), the main hotel's comparable fuel use is in the range of 59–67 tons. While absolute fuel mass is higher, the switch to LPG ensures cleaner combustion, lower particulates, and alignment with modern energy standards. Furthermore, when normalized against guest numbers and turnover, the fossil fuel demand per unit of service delivered has decreased, confirming that the investment delivered a more sustainable and commercially beneficial energy profile. On a raw comparison, diesel emissions in 2015 were ~113 tCO_2 while 2024 LPG emissions (excluding SPA and pool) are ~165–188 tCO_2. The increase reflects the expanded facilities, not inefficiency. In fact, the transition to LPG has improved the environmental footprint per guest and per € revenue, as LPG emits significantly less CO_2 per unit of useful energy compared with diesel. Importantly, the SPA and Bastion Pool generate their own revenue streams, which more than compensate for their additional carbon impact. This demonstrates that the 2015 investment created a balanced outcome: improved guest offering, higher profitability, and controlled carbon intensity relative to economic growth.

Economic analysis

Over the last five years, the hotel's investment in replacing diesel with LPG has delivered a clear financial and environmental benefit. While the absolute volume of fuel rose due to the SPA and Bastion Pool, the use of LPG at an average cost of € 0.44 per lit has limited annual fossil fuel expenditure to € 75,000, compared with an estimated € 200,000 if diesel had remained in use at current market prices. This translates into an average saving of approximately € 125,000 per year, while also reducing particulate emissions and ensuring compliance with modern standards.

Cost estimations of sustainable energy systems installed in The Phoenicia Malta Hotel

Energy system	Value
Installation cost of sustainable energy systems	€ 32.95 per m^2
Installation cost of sustainable energy systems	€ 3,788 per bed
Installation cost of sustainable energy systems per kWh used	€ 0.52 per kWh used annually
Installation cost of sustainable energy systems per annual CO_2 emission savings due to grid electricity use	€ 7.92 per kg of annual CO_2 emission savings

Simplified cost-benefit analysis of sustainable energy investments

Based on the combined benefits of reduced electricity costs (€ 15,000–18,000 per year) and avoided fossil fuel expenditure (€ 150,000 per year), the hotel has realised total average annual savings of approximately € 165,000 in the last five years. Given the scale of the 2015–2017 investment in BMS, VRF systems, LPG boilers, inverters, and cold room efficiency (estimated at € 0.8–1.0 million), the payback period is in the range of 5–6 years. This demonstrates that the investment has already repaid itself within the last five years, while continuing to provide ongoing financial and environmental benefits.

Financial sources used for the sustainable energy investments

The sustainable energy investments have been financed by own capital (100%).

Phoenicia Malta hotel – Key characteristics

Location	Floriana, Malta
Capacity	264 beds, full-year operation
Covered area	30,350 m^2
Energy intensity	120 kWh/m^2 year
Annual carbon emissions	~60 $kgCO_2/m^2$
Building envelope	Double wall limestone
Energy sources used	Grid electricity, LPG
Sustainable energy technologies used	High efficiency air-conditioning, BMS control, Shift from diesel to LPG for heating
Installation cost of sustainable energy systems	€ 1 million
Payback time of the sustainable energy investments	6 years

2.8 The Westin Dragonara resort - MALTA

Standing apart on a natural peninsula fringed by the sea, the Westin Dragonara Resort, Malta brings warm-hearted, luxurious Mediterranean living to a vibrant, historic island. The property has an enviable beachside position and is accessed via private gateway, inscribed with Virgil thoughtful proverb, ‘Devs Nobis Haec Otia Fecit’ - God made this gem for us. A reflection of Malta’s character lives through the way each guest is welcomed with easy-going charm and personalized attention. Our family resort features 413 rooms and suites which have been renovated. Landscaped around age-old artefacts, sunken gardens and impressive pools, this large 5-star hotel has stunning sea views throughout. The villa-style lobby is naturally light and spacious where floor-to-ceiling windows and sun-drenched terrace overlook unspoiled coastline. The Hotel holds the Green Key certification.

Characteristics of the region

The Westin Dragonara Hotel is located in St. Julian’s, best known today as a vibrant tourist and entertainment hub, and having historical and religious monuments that reflect its rich heritage. One of the most significant is Balluta Church, with its striking modern architecture and seaside location, serving as both a place of worship and a landmark. The Spinola Palace, built in 1688by Fra Paolo Raffaele Spinola, is another monument, originally intended to offer hospitality and embodying the Knights of St. John’s influence in the area. Scattered chapels highlight the town’s religious roots and connection to its patron saint, St. Julian protector of hunters and fishermen. These monuments stand as reminders that beyond the bustling nightlife and modern development, St. Julian’s retains deep cultural and spiritual significance. St. Julian’s has a total area of 1.6 km^2 and has 13,792 permanent residents, even though in summer the actual number grow exponentially due to the presence of many touristic amenities and accommodation in the area. In 2023, the tourism density in St. Julian’s amounted to 10,825 per km^2, which translates to a tourism intensity of 128.8 bed-nights per resident. Despite its modern development, St. Julian’s is also surrounded by fragile natural ecosystems that form part of the EU's Natura 2000 network. Along its coastline, small but important stretches of rocky shorelines and marine habitats provide shelter for endemic plants and serves breeding grounds for seabirds and marine life. These ecosystems are highly sensitive to human impact, requiring careful management to preserve biodiversity. The nearby marine protected zones safeguard seagrass meadows (Posidonia Oceanica), which play a vital role in oxygen production, erosion prevention, and supporting fish populations. Within and around St. Julian's, Natura 2000 areas remind residents and visitors of the delicate balance between tourism, urban life, and nature. Protecting these fragile habitats ensures that future generations can continue to enjoy both the natural beauty and ecological richness that complement St. Julian's cultural and social vibrancy.

Characteristics of the Westin Dragonara Hotel

The total covered area of the hotel is 74,000 m^2, while its green area is circa 7,000 m^2. The built-up area amounts to 38,800 m^2 of air-conditioned space and 4,459 m^2 of outdoor pools. The hotel's capacity is 413 rooms (625 beds), and the number of visitors in 2024 amounted to 52,485.

Figure 4. The Westin Dragonara Hotel, St. Julian's

Figure 5. The Westin Dragonara Hotel Outdoor Pool Area

Figure 6. Entrance to the Westin Dragonara Hotel

Local climate characteristics

The annual global horizontal solar irradiance is 1,825 kWh/m^2, the annual precipitation 450 mm/year (average over the past 10 years), while the average annual air temperature is 20.6°C.

Summer: Temperatures are hot and humid, with average daily highs ranging from 28-34°C and lows from 20-24°C with some heat waves reaching up to 40°C at times.

Winter: Temperatures are moderately cool, with average daily maximums of 12-15°C and average daily minimums of 7-10°C.

Description of energy systems used in The Westin Dragonara Hotel

The hotel's energy systems are designed to maximise efficiency and sustainability through an integrated approach. Heat pumps play a central role by transferring ambient heat from the air or ground to provide heating and cooling. In winter, they supply hot water with significantly lower electricity consumption compared to conventional boilers. In summer, they operate in reverse to provide cooling. Solar technologies further enhance efficiency. Solar panels (photovoltaic) generate renewable electricity, reducing dependence on the national grid and lowering carbon emissions. Meanwhile, solar thermal collectors are dedicated to water heating, particularly for the guest suite pools. This reduces the need for additional fuel-based heating, especially during peak sunshine periods. All systems and guest rooms are centrally monitored and controlled through a Building Management System (BMS). The BMS optimises performance by regulating set points, and balancing demand across the property. For example, it can adjust room settings based on occupancy and ensure that lighting and HVAC run only when needed. Real-time monitoring allows for predictive maintenance and swift troubleshooting, minimising energy waste. By combining heat pumps, solar power, solar collectors, and a sophisticated BMS, the hotel achieves a sustainable, efficient, and well-managed energy ecosystem that supports both environmental goals and cost control. The 2024 total annual energy consumption of the hotel was 10,043,668 kWh/year, and its specific annual energy consumption is 231 kWh/m^2 based on total covered-up area.

Characteristics of the energy systems used in the Westin Dragonara Hotel Malta

The hotel has invested in a Building Management System (BMS) that monitors and controls energy usage across all guest rooms and public spaces. This system ensures that heating, ventilation, air conditioning, and lighting operate at peak efficiency, balancing guest comfort with sustainable practices. In each guest room, the BMS is connected to occupancy sensors that automatically adjust temperature and lighting when the room is unoccupied, along with door sensors to recognise if the balcony or main door are left open, thereby minimising energy waste without compromising the guest experience. Similarly, in most public areas such as the lobby and conference centre, the system is programmed to regulate environmental conditions in line with usage patterns, optimising energy consumption throughout the day. The BMS also allows our engineering team to monitor performance in real time, promptly identify inefficiencies, and make proactive adjustments that maintain consistent service quality. By integrating advanced data collection and smart controls, the hotel is able to significantly reduce its carbon footprint while controlling operational costs. The Hotel has also invested in a 330 kWp solar photovoltaics generating circa 500,000 kWh/year, as well as solar heating. Furthermore, there is a large green roof with total area of 1,985 m^2.

Environmental analysis

The motivation behind implementing sustainable practices is driven by a commitment to protecting the natural and cultural heritage of the Maltese Islands while meeting the expectations of increasingly eco-conscious travellers and ensure we remain in line with Marriott International objectives. Guests today not only seek comfort and luxury but also want assurance that their stay supports responsible tourism. For us, sustainability initiatives such as energy efficiency, water conservation and waste reduction help preserve our ecosystems and reduce environmental impact. Beyond environmental responsibility, these practices also enhance the resort's reputation, strengthen its competitive advantage, and align with international hospitality standards, ensuring long-term profitability and community support. However, implementing sustainable practices in such a property presents notable challenges. The balance between maintaining high levels of guest comfort and reducing resource consumption is often difficult to achieve. Retrofitting older infrastructure with modern, energy-efficient technology also involves high costs and operational disruption. Additionally, engaging and training staff to adopt sustainable practices consistently can be demanding, requiring continuous education and monitoring. Despite these challenges, the long-term benefits of sustainability—both for the environment and for the resort's brand—make the effort essential and rewarding. In the past five years, we have focused on reducing our reliance on fossil fuels by replacing systems with heat pumps and also added solar collectors. As a result, while our methods are now cleaner and more sustainable, our electric consumption has not necessarily decreased. More time is required for year-on-year comparison. However, the pictogram below shows last year's savings (2024) thanks to the rooms energy management system which has been in place for more than 5 years in all our guest rooms. This is solely for the energy management system and does not include other sustainable initiatives.

Investing in solar collectors and a heat pump for our outdoor pools delivers strong environmental benefits. Solar collectors capture renewable energy from the sun to heat pool water, cutting reliance on fossil fuels and reducing greenhouse gas emissions. This clean, abundant energy source lowers air pollution and supports sustainable operations. The heat pump maximises efficiency by transferring ambient heat to the pool water using fearless electricity than traditional systems. In summer, when the outdoor pool no longer requires heating, the same system is redirected to heat the indoor pool, ensuring year-round energy optimisation. Furthermore, the heat pump's by-product—cool air—is harnessed to reduce the energy needed for cooling the fitness facility, replacing or supplementing conventional air-conditioning. This integrated use of solar and heat pump technology conserves natural resources, reduces emissions, and supports a circular approach to energy use. By re-purposing energy flows instead of wasting them, the system creates a highly sustainable solution. Overall, the investment not only extends pool usability but also significantly lowers environmental impact, aligning with global efforts to reduce climate change and transition to renewable energy.

Economic analysis

Over the last five years, the hotel's investment can be summarised as follows:

Solar collectors for plunge pools € 107,720

Heat pump for main pool € 254,097

Cost estimations of sustainable energy systems installed in the Westin Dragonara Hotel

Energy system	Value
Installation cost of sustainable energy systems	€ 9.32 per m^2
Installation cost of sustainable energy systems	€ 579 per bed
Installation cost of sustainable energy systems per kWh used	€ 0.04 per kWh used annually
Installation cost of sustainable energy systems per annual CO_2 emission savings due to grid electricity use	€ 0.70 per kg of annual CO_2 emission savings

Simplified cost-benefit analysis of sustainable energy investments

Savings from electricity use € 2,548 due to use of heat pump

Savings on fuels € 65,396

Payback period 5 years

Financial sources used for the sustainable energy investments The sustainable energy investments have been financed by own capital (100%).

The Westin Dragonara hotel – Key characteristics

Location	St. Julian's, Malta
Capacity	625 beds, full-year operation
Covered area	43,259 m^2
Energy intensity	231 kWh/m^2 year
Annual carbon emissions	90 kgCO_2 per m^2
Building envelope	Double wall limestone
Energy sources used	Grid electricity, LPG
Sustainable energy technologies used	Solar collectors for plunge pools and heat pump for main pool
Installation cost of sustainable energy systems	€ 361,817
Payback time of the sustainable energy investments	5 years

2.9 The Mulberries wellbeing chateau guesthouse - MALTA

Long-term sustainability is rooted in every aspect of the Mulberries Wellbeing Château operation, from the initial property design to our hospitality offering. From the first line drawn in creating the blueprints for the regeneration of the property, only the utmost respect for the natural and local surroundings was sought. From the get-go, the set goal was to cause minimal environmental impact as the priority and mission. The main objective has always been to reduce the carbon footprint as much as possible during the renovation and design and construction of new additions at Mulberries, as well as throughout the operations and daily hospitality services. Adopting a zero-waste approach, the guesthouse has turned waste into a resource, salvaging tones of local stone and materials. Where not reclaimed, materials were sourced from the vicinities to minimise transportation-generated emissions. Where raw materials were not available locally, such as flooring and wall tiles, it was made sure to source these responsibly from green and sustainably managed suppliers. The shipments were organised in a way that helped reduce transportation and the project's overall carbon footprint for transport. The commitment to sustainability is woven into the heritage of the building itself, as the guesthouse continues to find practical ways to improve energy efficiency, water conservation, and waste reduction while preserving the historic integrity of the guesthouse.

Characteristics of the region

The guesthouse is located in Zabbar, also known as Città Hompesch, which is a city in the Port Region of Malta. It is the seventh largest city in the country. Originally a part of Żejtun, Żabbar was granted the title of Città Hompesch by the last of the Grand Masters of the Order of St. John to reign in Malta, Ferdinand von Hompesch zu Bolheim in 1797. Zabbar has a total area of 5 km^2 and has circa 15,000 permanent residents. There is no specific bed-night data for Zabbar only, but one can reference national/regional data as a proxy. In 2024, Malta recorded ~11.32 million bed-nights in collective accommodation. Zabbar has only one guesthouse and therefore it may be assumed to account for ~0.05% of total Maltese hotel capacity. Therefore, one can estimate a total of ~5,660 bed-nights annually (approximation), which is in line with the actual figures of bed-nights in the guesthouse for 2024. This translates to a tourism density of ~1,132 bed-nights per km^2 and a tourism intensity of 0.37 bed-nights per permanent resident. Żabbar, located in Malta's southeast, is renowned for its rich religious heritage and historical monuments. The town's most prominent landmark is the Sanctuary of Our Lady of Graces, a major pilgrimage site adorned with votive offerings and artwork that testify to centuries of devotion. Its adjoining Sanctuary Museum houses an impressive collection of ecclesiastical art, silver, and historic artifacts, including items linked to the Great Siege of 1565 and the Knights of St John. Żabbar also features several wayside chapels, such as those dedicated to St Roque and St Leonard, reflecting the town's deep-rooted faith and traditions. The monumental arch at the town's entrance, built to commemorate Grand Master Ferdinand von Hompesch's visit, stands as a symbol of Żabbar's historic ties to the Order of St John. Together, these sites highlight the town's enduring spiritual significance and its role in Malta's cultural and religious landscape. Near Żabbar, several Natura 2000 sites safeguard fragile ecosystems that are vital for Malta's biodiversity. One of the most significant is Wied GħajnRiħana and Wied il-Għajn valleys, which host Mediterranean scrub, carob, and olive groves, providing habitats for birds, reptiles, and pollinators. Close to the coast, the Xgħajra–Munxar area and Il-Magħluq at Marsaskala are also protected. Il-Magħluq, a saline wetland, supports brackish-water flora and fauna, including migratory birds that rely on it as a resting point. The coastal cliffs near Delimara, not far from Żabbar, form another Natura 2000 zone where endemic plants and nesting seabirds thrive. These ecosystems face threats from urban expansion, agriculture, and recreational use, making conservation essential. Their protection under Natura 2000 ensures a balance between human activity and ecological resilience, allowing both residents and visitors to appreciate the natural heritage that complements Żabbar's cultural identity.

Characteristics of the Mulberries Wellbeing Chateau Guesthouse

The total built-up area of the hotel is 1,000 m^2, while its green area is circa 2,700 m^2. The hotel's capacity is 19 beds, and the annual number of visitors in 2024 amounted to 1,200.

Local climate characteristics

The annual global horizontal solar irradiance is 1,825 kWh/m^2 year, the annual precipitation 450 mm/year (average over the past 10 years), while the average annual air temperature is 20.6°C.

Summer: Temperatures are hot and humid, with average daily highs ranging from 28-34°C and lows from 20-24°C with some heat waves reaching up to 40°C at times.

Winter: Temperatures are moderately cool, with average daily maximums of 12-15°C and average daily minimums of 7-10°C.

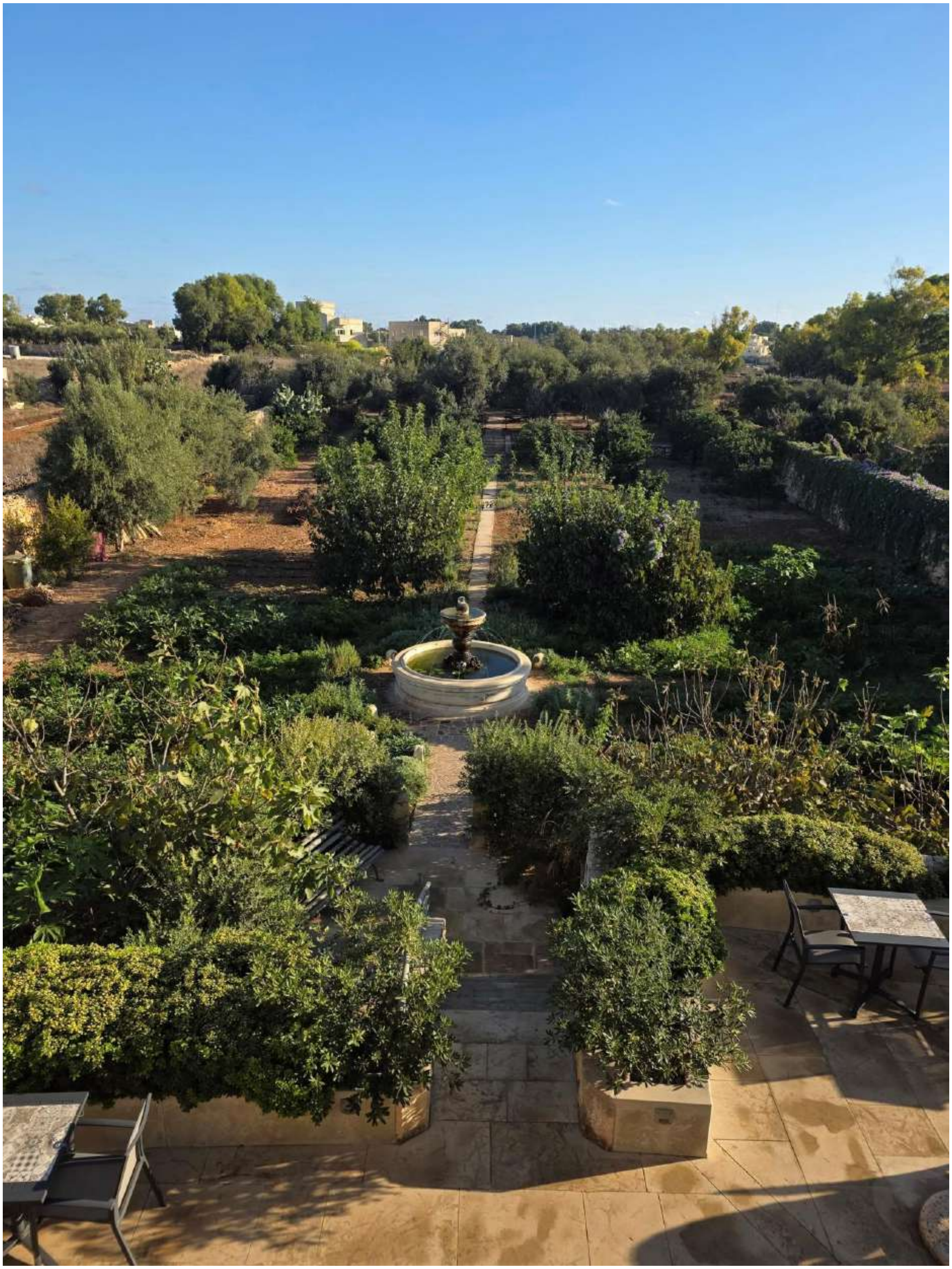

Figure 7. The Organic Kitchen Garden of the Mulberries Wellbeing Chateau

Description of energy systems used in The Mulberries Wellbeing Chateau Guesthouse

Conscientious construction and conservation

The whole building forming the guesthouse was fully renovated respecting the circular economy principles. For example, all building materials were sourced from demolished sites, some aged hundreds of years.

Energy-efficient design

Passive and active energy efficiency measures

- A central courtyard, borrowed from Mediterranean vernacular architecture, which renders the building naturally responsive to seasonal changes.
- High efficiency double-glazed external apertures composed of sustainably engineered wooden frames.
- Shading is extensively used throughout the built areas.
- White-washed roofs reflect and minimise the effects of direct sun heat in the summer.
- Lime-based plaster on walls with no volatile solvents.
- Reclaimed and restored furniture.

Responsible resource management

- Intelligent water management system and a rainwater reservoir, as well as reuse of wastewater.
- Solar-powered water heating system.
- No plastic water bottle policy.

Eco-conscious practices

- Eco-friendly toiletries and cleaning products
- Linen & Towel Reuse Options
- Organic kitchen garden

- Seasonal and local food sourcing
- Eco-conscious purchasing
- Full waste recycling

Characteristics of the energy systems used in the Mulberries Wellbeing Chateau Guesthouse

The guesthouse incorporates passive and active energy principles and practices. To counter local buildings' reliance on conventional, electric cooling systems that generate global warming emissions, Mulberries boasts features that drastically reduce heat gains in a passive manner. Environmental design best practices include a central courtyard, borrowed from Mediterranean vernacular architecture, which renders the building naturally responsive to seasonal changes. It is joined by high-efficiency, double-glazed external apertures composed of sustainably engineered wood, loggias for enhanced natural cross-ventilation, double-leaf and cavity external walls, and shaded outdoor areas. The white-washed roofs reflect and minimise the effects of direct sun heat in the summer and contain a thermal insulation layer used in refrigeration systems to ensure optimal thermal performance. In line with the guesthouse's renewable energy solutions ethos, an extensive solar-powered water heating system, reduces dependency on fossil fuels or electricity for heating water. The highly sophisticated, inverter-type circulating pumps immediately supply hot water to each guest bathroom, greatly lessening water runoff. Moreover, heat recovery from the computer servers is fed into the indoor pool for pre-heating. Grid electricity is the main commodity used throughout the Chateau (95%) and liquefied petroleum gas for cooking (5%). The average annual electricity consumption is 27,000 kWh, which translates to circa 7.71 kWh/bed-night and a specific annual electricity consumption of 27 kWh/m^2 of built-up area.

Environmental analysis

Abiding by the principle of minimal intervention for reduced environmental impact, most of the stone used in the construction of the edifice has been left in its raw, natural state. The walls in most of the rooms are rendered in a lime-based plaster and treated only with a water-based dust-proof solution, primarily to eliminate high-volatility solvent-based paints. The natural flagstone flooring is composed of a layer of bedrock known as "Pietra Modicana," a sustainable resource whose extraction process involves requalifying agricultural land instead of quarrying. Reclaimed and restored furniture sits alongside bespoke designs, custom-built by a local artisan using natural wood from sustainably managed forests. The guesthouse does not compromise on the driving principle and mission of sustainable hospitality. In the daily running of Mulberries Wellbeing Château, priority is given to three core values: generating the least possible waste, creating minimal environmental impact, and conserving energy through responsible processes and systems. To that purpose, the guesthouse has implemented an intelligent water management system via a purposely created underground reservoir that harvests around 300 $m^3$of rainwater run-off annually. Every drop of rain that falls on the terraces, roofs, and courtyards is reused for irrigation purposes, washing floors, and toilet flushing. Additionally, as part of a no-plastic-water-bottle policy, all drinking water comes from an on-site reverse osmosis plant.

Economic analysis

Over the last five years, the hotel's investment in solar heating can be summarised as follows:

Solar collectors, calorifiers, pumps and controllers	€ 35,000

Cost estimations of sustainable energy systems installed in the Mulberries Wellbeing Chateau Hostel

Energy system	Value
Installation cost of sustainable energy systems	€ 35 per m^2
Installation cost of sustainable energy systems	€ 1,842 per bed
Installation cost of sustainable energy systems per kWh used	€ 1.29 per kWh used annually
Installation cost of sustainable energy systems per annual CO_2 emission savings due to grid electricity use	€ 3.33 per kg of annual CO_2 emission savings

Simplified cost-benefit analysis of sustainable energy investments

Annual Savings from electricity use: € 5,735

Payback period: 6 years

Financial sources used for sustainable energy investments

The sustainable energy investments have been financed by own capital (72%) and a grant of € 10,000 (28%) from Energy of the European Commission.

The Mulberries wellbeing chateau guesthouse – Key characteristics

Location	Zabbar, Malta
Capacity	19 beds, full-year operation
Covered area	1,000 m^2
Energy intensity	27 kWh/m^2 year
Annual carbon emissions	10.5 $kgCO_2/m^2$
Building envelope	Double wall limestone
Energy sources used	Grid electricity, LPG
Sustainable energy technologies used	Solar collectors for water heating and indoor pool heating + calorifier, pumps and controllers
Installation cost of sustainable energy systems	€ 35,000 (2024)
Payback time of sustainable energy investments	6 years

2.10 Kuortane Olympic Training Centre – FINLAND

The area of South Ostrobothnia is 14,355.63 km². The population is 191,762 inhabitants and the number of bed-nights of tourists is 789,968. The tourism density in South Ostrobothnia is 55overnight stays per km² while its tourism intensity 4.12 overnight stays per permanent resident.

Local climate characteristics

The annual solar irradiance is 890 kWh/m^2, the annual precipitation 500 mm/year while the average annual air temperature is presented below.

Month	Average temperature
Jan	-5.6°C
Feb	-6.2°C
Mar	-2.5°C
Apr	3.3°C
May	9.2°C
Jun	14.1°C

Month	Average temperature
Jul	16.7°C
Aug	14.9°C
Sep	10°C
Oct	4.3°C
Nov	-0.1°C
Dec	-3.4°C

Natura 2000 areas

South Ostrobothnia is home to several Natura 2000 areas, which are typically treeless wet swamp. The region’s fens are low-lying wetlands that are often nutrient-rich and fed by groundwater. These areas support a diverse range of plant species, including sedges, mosses, and various wetland grasses. Fens in South Ostrobothnia are usually open landscapes with sparse tree cover, and they play a crucial role in maintaining biodiversity and regulating water cycles. Many of these wetlands are also important habitats for birds and other wildlife, making them valuable for conservation. Kauhaneva–Pohjankangas

National Park is a pristine peatland area with vast bogs, pine forests, and glacially formed esker ridges. It includes the Kauhaneva bog, one of Finland's most ecologically significant wetlands, and is part of both the Ramsar Convention and the Natura 2000 network. Lauhanvuori National Park is known for its rolling hills, pine forests, and mires. It features Lauhanvuori Hill, one of the highest points in western Finland, and is part of the UNESCO-listed Lauhanvuori–Hämeenkangas Geopark. Lauhanvuori–Hämeenkangas UNESCO Global Geopark spans South Ostrobothnia, Satakunta, and Pirkanmaa. It tells the story of an ancient mountain range that eroded into today's marshy terrain. The area features extensive mires, forested ridges, and geological formations shaped by glaciation and land uplift. Lappajärvi Geopark centres around Lake Lappajärvi, Europe's largest crater lake formed by a meteorite impact around 78 million years ago. The geopark highlights unique geological features such as impactite rock (kärnäite).

Historical and religious monuments

South Ostrobothnia

Alvar Aalto (1898–1976) was a world-renowned Finnish architect and designer, born in Kuortane, South Ostrobothnia. His work is known for blending modernist architecture with natural forms and human-centred design. In South Ostrobothnia, Aalto's architecture can be seen in Seinäjoki and Alajärvi. Aalto designed a unified city centre for Seinäjoki, which includes Lakeuden Risti Church, City Hall, Aalto Library, Parish Centre, Theatre and Government Offices. Alajärvi have Alajärvi Town Hall and Library, Villa Väinölä and Villa Flora (designed by Aalto). The military history monuments of South Ostrobothnia tell of the region's rich and varied past. For example, the Ilkka statue in Ilmajoki honours Jaakko Ilkka, a leader of the Finnish rebels, and the Battle of Napue memorial in Isokyrö commemorates the decisive battle of 1714. In Menkijärvi, Alajärvi, you can explore a military training area and an armoured vehicle, while the Jaeger Museum in Kauhava brings the story of the Jaeger movement to life. The Civil Guard and Lotta Svärd Museum in Seinäjoki is housed in a building designed by Alvar Aalto and offers insights into voluntary national defence.

Kuortane Olympic Training Centre

The Kuortane Olympic Training Centre is a versatile sports training centre, an official training centre for elite sports (the Finnish Olympic Committee) and a centre for wellness and leisure, located on the shore of Lake Kuortane. Accommodation is available in hotel rooms, apartments and cottages, visitors are served by several restaurants and there are sports facilities such as a gym, swimming pool, bowling alley and great outdoor areas. The Kuortane Olympic Training Centre's responsibility extends to all its operations. Sustainable development measures include for example the use of renewable energy, energy-efficient equipment, the preference for wood construction, the minimisation of food waste, environmentally friendly cleaning products, waste sorting, and the use of digital materials. Kuortane Olympic Training Centre has been granted the Ekokompassi environmental certificate, which demonstrates the organisation's commitment to sustainable development and reducing its environmental impact. Ekokompassi is a Finnish environmental management system based on international environmental management principles. The Kuortane Olympic Training Centre total covered area is 47 hectares (470,000 m^2) and built-up area is 50,000 m^2. Other covered areas include terraces and green areas including sports fields and frisbee golf track. The Kuortane Olympic Centre have nearly 1,000 beds in summer and 850 beds all year round. The centre attracts approximately 250,000 visitors annually including day visitors.

Motivation and Challenges in Implementing Sustainable Practices

The Kuortane Olympic Training Centre is guided by both environmental conservation and cost reduction. The transition to renewable energy sources, such as geothermal and solar energy, reflects a commitment to sustainable development. The challenge is long-term (decade) planning and strategic planning and large one-off investments. The introduction of systems such as geothermal heating required significant initial investments and changes in maintenance practices. Unlike the previous peat-based system, which was managed by external contractors, the new system required more involvement from the property management team. The Kuortane Olympic Training Centre has successfully integrated sustainable energy solutions and achieved significant environmental and economic benefits.

Energy Systems Overview

The centre’s energy system is anchored by geothermal heating, which supplies 99% of its heating needs. Over 3,000 solar photovoltaic panels contribute 15% of annual electricity demand, with the remaining electricity sourced from the grid. The remaining energy demand is covered by grid electricity. Building automation, LED lighting with motion sensors, and HVAC optimisation further enhance energy efficiency. These systems have led to annual savings of € 500,000 and a reduction of 1,500 tCO_2 emissions per year. The total annual energy consumption of the facility is 14,585.6 MWh (14,585,600 kWh), with a specific energy consumption of 291.7 kWh/m² year. A significant portion of the electricity, 87.6%, is purchased from an external provider, which accounts for 34% of the total energy consumption. In terms of renewable energy contributions, 14.4 MWh of electricity generated by the on-site solar power plant was sold externally. The energy mix is fully fossil-free. This reflects a strong commitment to sustainable and low-carbon energy sourcing. Due to Finland's climate, insulation and energy-efficient windows and doors have been in use for a long time and for this reason they have not been highlighted in energy efficiency measures.

Environmental analysis

Over the past five years, significant investments in renewable energy and energy efficiency have led to substantial environmental and economic benefits. The implementation of a geothermal heating system has resulted in annual savings of € 80,000 to € 100,000 on electricity costs, even when accounting for the 15-year payback period of the investment. The payback period for the solar power plant is 6.9 years. Replacing the peat-based system with geothermal heating had a significant impact on reducing carbon dioxide emissions, and thanks to the reduction in fossil fuel consumption, emissions have fallen by 800 tCO_2/year. In addition, savings in grid electricity have led to an additional annual reduction of 700 tCO_2/year in carbon dioxide emissions. These measures have resulted in a combined annual decrease of approximately 1,500 tCO_2 emissions, underscoring the environmental impact of the investments made.

Economic analysis

Over the past five years, a total of approximately € 4 to 5 million has been invested in renewable power generation systems. These investments have included technologies such as geothermal energy, photovoltaic solar panels, building automation systems, energy-efficient lighting, and modern electrical appliances. Renewable heat generation systems account for approximately € 3.5 million. As a result of these investments, the average annual financial benefit from reduced use of grid electricity and fossil fuels has been estimated at € 250,000.

Simplified cost-benefit analysis of the sustainable energy investments

The total economic benefit of energy investments over five years is approximately € 500,000 due to geothermal heating. After 15 years' payback time geothermal systems offer annual savings of € 250,000 compared to peat. Solar panels payback time is 6.9 years, covering around 15% of annual electricity needs. With electricity prices between 5–6 cents per kWh, this translates to yearly savings of € 70,000–90,000. The environmental benefits of these energy investments are substantial. Water consumption has also been reduced through the use of saving nozzles and flow limiters in showers and taps. At the Kourtney Olympic Training Centre, the implemented energy systems are expected to save around 2,800 megawatt-hours of energy annually. This amount of energy can power many private homes, demonstrating the strong environmental impact of the investments.

Financial sources used for the sustainable energy investments

Most of the financing for the energy investments at the Kourtney Olympic Training Centre, 75%, was covered by lease financing. In addition, 15% was covered by public subsidies and 10% by self-financing.

2.11 Opintola B&B – FINLAND

The area of South Ostrobothnia is 14,355.63 km^2. The population is 191,762 inhabitants and the number of bed-nights of tourists is 789,968. The tourism density in South Ostrobothnia is 55 overnight stays per km^2 while its tourism intensity 4.12 overnight stays per permanent resident.

Local climate characteristics

The annual solar irradiance is 890 kWh/m^2, the annual precipitation 500 mm/year while the average annual air temperature is presented below.

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Jan	-5.6°C
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Month	Average temperature
Jul	16.7°C
Aug	14.9°C
Sep	10°C
Oct	4.3°C
Nov	-0.1°C
Dec	-3.4°C

Natura 2000 areas

South Ostrobothnia is home to several Natura 2000 areas, which are typically treeless wet swamp. The region's fens are low-lying wetlands that are often nutrient-rich and fed by groundwater. These areas support a diverse range of plant species, including sedges, mosses, and various wetland grasses. Fens in South Ostrobothnia are usually open landscapes with sparse tree cover, and they play a crucial role in maintaining biodiversity and regulating water cycles. Many of these wetlands are also important habitats for birds and other wildlife, making them valuable for conservation. Kauhaneva–Pohjankangas National Park is a pristine peatland area with vast bogs, pine forests, and glacially formed esker ridges. It includes the Kauhaneva bog, one of Finland's most ecologically significant wetlands, and is part of both the Ramsar Convention and the Natura 2000 network. Lauhanvuori National Park is known for its rolling hills, pine forests, and mires. It features Lauhanvuori Hill, one of the highest points in western Finland, and is part of the UNESCO-listed Lauhanvuori–Hämeenkangas Geopark. Lauhanvuori–Hämeenkangas UNESCO Global

Geopark spans South Ostrobothnia, Satakunta, and Pirkanmaa. It tells the story of an ancient mountain range that eroded into today's marshy terrain. The area features extensive mires, forested ridges, and geological formations shaped by glaciation and land uplift. Lappajärvi Geopark centres around Lake Lappajärvi, Europe's largest crater lake formed by a meteorite impact around 78 million years ago. The geopark highlights unique geological features such as impactite rock (kärnäite).

Historical and religious monuments

Alvar Aalto (1898–1976) was a world-renowned Finnish architect and designer, born in Kuortane, South Ostrobothnia. His work is known for blending modernist architecture with natural forms and human-centred design. In South Ostrobothnia, Aalto's architecture can be seen in Seinäjoki and Alajärvi. Aalto designed a unified city centre for Seinäjoki, which includes Lakeuden Risti Church, City Hall, Aalto Library, Parish Centre, Theatre and Government Offices. Alajärvi have Alajärvi Town Hall and Library, Villa Väinölä and Villa Flora designed by Aalto. The military history monuments of South Ostrobothnia tell of the region's rich and varied past. For example, the Ilkka statue in Ilmajoki honours Jaakko Ilkka, a leader of the Finnish rebels, and the Battle of Napue memorial in Isokyrö commemorates the decisive battle of 1714. In Menkijärvi, Alajärvi, you can explore a military training area and an armoured vehicle, while the Jaeger Museum in Kauhava brings the story of the Jaeger movement to life. The Civil Guard and Lotta Svärd Museum in Seinäjoki is housed in a building designed by Alvar Aalto and offers insights into voluntary national defence.

Hotel characteristics

Opintola B&B is a cozy accommodation located in Norinkylä, Teuva, in the rural heart of South Ostrobothnia. Opintola B&B housed in a beautifully renovated former elementary school building, offering a peaceful setting ideal for relaxation. The establishment holds both the Ekokompassi environmental certificate and the Sustainable Travel Finland (STF) label, reflecting its commitment to sustainability. Opintola B&B sustainable development measures include for example the use of renewable energy, environmentally friendly cleaning products and waste sorting. Opintola B&B total covered area is 7,000 m^2 and built-up area is 500 m^2. The area features garden sections, some of which are left in their natural state, as well as a gravel parking area. Opintola B&B has 23 beds, and it attracts approximately 1,000 visitors annually.

Motivation and Challenges in Implementing Sustainable Practices

At Opintola B&B, circular economy principles have long been part of operations, by a family background in crafts where repairing and reusing materials was second nature. Waste sorting has also been a consistent part of the routine. The motivation to formalize sustainable practices grew from a personal interest in environmental responsibility and the support offered by Seinäjoki University of Applied Sciences (SeAMK). Through SeAMK's business group project, new knowledge and peer support became available, helping to guide the process. Opintola B&B first pursued the Ekokompassi environmental certification, which laid the groundwork for completing the Sustainable Travel Finland (STF) path. These certifications did not initially require large financial investments, making them accessible. However, the process demanded time and effort, particularly in terms of documentation. Economic feasibility remains a key consideration in all sustainability decisions. Clearer instructions for waste sorting have already led to a noticeable reduction in mixed waste. In the future, introducing composting could further decrease mixed waste and extend the interval between waste bin collections. This example shows that even small businesses can implement sustainability measures by relying on existing resources and making cost-effective choices.

Energy Systems Overview

Opintola B&B energy system is based on an air-to-water heat pump and room-specific air source heat pumps. In addition, an oil heating system is used, particularly for heating domestic water. Heat pumps have reduced oil consumption to one third (from 9,000 litres to 3,000 litres). These systems have led to annual savings of € 2,500 and a reduction of 15 tCO_2 emissions per year. The total energy consumption is divided between grid electricity and diesel oil. Grid electricity accounts for the majority, with a usage of 55,000 kWh, representing 65% of the total energy consumed. Diesel oil contributes the remaining 35%, with a volume of 3,000 litres. The total annual energy consumption of the facility is 85,000 kWh, with a specific energy consumption of 170 kWh/m^2 year. The energy mix is fully fossil-free, renewable energy sources and nuclear power. The site utilises LED lighting, although some older fixtures remain in use and will be replaced with LED alternatives as they reach the end of their life span. Outdoor lighting is controlled by a twilights witch to optimise energy use. Electrical equipment has been gradually replaced with more energy-efficient models as needed, while existing devices are used until the end of their service life. In line with circular economy principles, used equipment in good condition has also been acquired to support sustainable operations. The five-year development plan includes roof renovation, during which solar panels will be installed to enable future utilisation of solar energy.

Environmental analysis

Over the past five years, the implemented investments have led to notable environmental improvements. The transition from oil heating to heat pumps has resulted in a significant reduction in fossil fuels. The annual use of fossil fuels has decreased by approximately 6,000 litres, which corresponds to a reduction of around 15 tCO_2 emissions per year. These of fossil fuels is steadily declining, contributing to a reduction in carbon dioxide emissions. From the customer's perspective, air source heat pumps offer environmental benefits while also enhancing comfort, particularly during hot summer days.

Economic analysis

Over the past five years, a total of approximately € 32,000 has been invested in renewable power generation systems. These investments have included heat. The annual benefit resulting from reduced fossil fuel use has averaged € 2,500 over the past five years. This is based on an annual saving of 5,000 kWh in energy consumption and replacing oil with electricity.

Financial sources used for the sustainable energy investments

Most of the financing for the energy investments at Opintola B&B, 62.5 %, was covered by bank loan. In addition, 37.5% by self-financing and once the investment has been completed, 20 % subsidy on the tax-free price (€ 3,000) of the investment in a water-air heat pump.

2.12 Alphaville Cinema Theatre - ITALY

The Alphaville Cinema Theatre property is inside a building owned by the Municipality of Campobasso called "Palazzo EX ONMI", located on Via Muricchio, in the central area of the Municipal Capital. The "Ex ONMI" building, which began operating in the 1930s, is owned by the Municipality of Campobasso and managed by a Temporary Association of Enterprises dedicated to promoting cultural events in the city. These initiatives attract visitors both from the Molise region and beyond. Located on the ground floor of the structure, the Alphaville cinema-theatre hosts a wide range of cultural activities, including book presentations, conferences, screenings of art-house films, concerts, and events promoting the local area. On the exterior façade at the entrance to the cinema hall, there is a mural created during the Covid-19 pandemic by the internationally renowned Italian street artist "Blu," recognised by The Guardian as one of the top ten street artists in the world. The artwork, titled "Pandemia," depicts numerous fierce pandas climbing and destroying urban buildings, transforming the cityscape. It offers an open-ended reflection on harmful human habits that damage nature and evokes the surprise of seeing animals roam city streets during lockdown—animals that had never been seen in such settings before. The mural is part of a broader urban regeneration project called "Draw the Line," promoted by the associations operating within the building, which has become a significant tourist attraction in the city. The cinema-theatre has a seating capacity of 80–90 guests and has undergone energy-efficient renovations, making it fully independent from the rest of the building in terms of energy needs and eliminating the use of natural gas entirely.

Characteristics of the region

Molise is a southern Italian region characterised by a predominantly mountainous and hilly landscape that faces the Adriatic Sea. Its history is marked by ancient populations such as the Samnites, followed by Roman and Lombard rule, and later becoming part of the Kingdom of Naples until the establishment of the autonomous region in 1963. Geographically, Molise features a narrow coastal strip, rivers that cross the territory, and remarkable biodiversity. The region is renowned for its ancient villages and lush green landscapes. Numerous archaeological sites, castles, and protected natural areas are found throughout Molise. The entire network of Protected Areas and the Natura 2000 Network safeguards approximately 125,000 hectares, representing 28% of the region's total area. Despite its modest size of just over 446,000 hectares, Molise stands out for its high geological and environmental diversity. These features contribute significantly to its rich biodiversity and natural heritage, supported by one of the lowest population densities in Italy—70 inhabitants per square kilometre—with a total population of around 290,000. The region's elevation ranges from sea level up to 2,200 meters above sea level near the summit of Monte la Meta, located on the border between Molise and Abruzzo. The highest mountain ranges, including the Mainarde and the Matese Mountains, are found along the western and southwestern borders. Campobasso is the capital city of Molise, located between the basins of the Biferno and Fortore rivers. Its coat of arms features a red oval with six battlemented towers, one of which is topped by a crown, symbolizing its feudal origins. The six towers represent the fortified city's six gates: Sant'Antonio Abate, San Nicola, Santa Maria della Croce, San Leonardo, Santa Cristina, and San Paolo; only four of these gates still exist today. With a population of 47,500, Campobasso is not only the most populous city in Molise but also its administrative centre. Situated at about 700 meters above sea level, the city consists of some medieval historic core rich in artistic and historical value, perched on a hillside dominated by Monforte Castle, and a more modern, elegant section dating back to the 19th century, located on the plain below. The historic centre fans out around the castle, featuring winding alleys and stairways flanked by stone houses and buildings, often with characteristic inner courtyards. Many doorways are adorned with decorative elements, noble family crests, and allegorical figures. The 19th-century part of the city, known as the Murattian centre, is laid out on flat terrain and reflects the urban planning ideals of the time, including the garden city concept, with numerous green spaces. Campobasso hosts a variety of events that attract tourists, including international music festivals, sports events such as "Bici in città" (Bike in the City), with its welcome point located in the garden of the former ONMI building, and cultural traditions like the historic "Processione dei Misteri" held during Corpus Domini, among other similar events.

Characteristics of the Alphaville Cinema Theatre

Cinema Alphaville is located in the heart of Campobasso, within the historic building of the former ONMI on Via Muricchio. The venue covers an area of approximately 300 m² on the ground floor, divided into a foyer, a cinema hall with 80–90 seats, offices, and service areas. Today, it represents the only municipally owned cinema/theatre space actively operating in the city centre. Since its founding, Cinema Alphaville has served as a vital cultural hub for the city, offering an alternative and high-quality film program. The name of the venue is inspired by Jean-Luc Godard's iconic film "Alphaville," a symbol of visionary auteur cinema. Its management is entrusted to local cultural associations, which run its activities with dedication and continuity. With the aim of improving audience comfort and promoting sustainable practices, the Municipality of Campobasso has implemented a comprehensive energy retrofit, financed through PNRR funds. Photovoltaic panels with storage systems have been installed on the roof; windows and doors facing unheated areas have been replaced; the heating system has been renewed with heat pumps, eliminating gas use. Energy demand for climate control has been significantly reduced thanks to internal insulation and the replacement of windows, which addressed both thermal and acoustic performance. A new LED lighting system has also been introduced, designed with attention to both architectural aesthetics and energy efficiency. Seating and flooring have been completely renovated, enhancing the comfort and safety of the venue. Looking ahead, Cinema Alphaville envisions strengthening its role as a sustainable cultural and tourist space. New collaborations with film festivals and educational initiatives for schools are planned. These efforts aim to further reduce environmental impact and offer the community a modern, inclusive experience in harmony with the local territory.

Local climate characteristics

Campobasso is located in Climate Zone E, with 2,346 heating degree days. It receives annually approximately 1,300 to 1,400 kWh/m² of solar radiation and records an average annual precipitation ranging between 500 and 800 mm. The climate is temperate, with cold winters and mild summers, which influences both indoor comfort and the energy strategies adopted for managing the building. Average temperatures range between 2 °C and 28 °C, with extreme events below –3 °C or above 33 °C being very rare. Winter, from December to February, is relatively cold and marked by alternating sunny and rainy periods. Temperatures generally remain above freezing, but the city is exposed to cold air outbreaks from the northeast, which can bring periods of snow and frost. Snowfall can be significant, with an average of about one meter per year. Snow may also occur in March and occasionally even in April. These climatic conditions have guided the technical choices in the recent energy retrofit of the cinema, encouraging the installation of photovoltaic systems combined with heat pump heating solutions, capable of ensuring efficiency even during the coldest months. LED lighting and thermal insulation form the foundation for reducing energy demand, improving the building's sustainability and the comfort of its visitors. The presence of next-generation fan coil units further contributes to maintaining healthy indoor air quality during periods of high occupancy, enhancing overall comfort within the facility.

Description of energy systems used in Cinema Alphaville

Cinema Alphaville has undergone a comprehensive redevelopment aligned with principles of environmental sustainability and spatial safety. The implemented solutions aim to enhance the building's energy efficiency, reduce consumption, and ensure more comfortable and secure environments for both audiences and cultural operators.

<u>Opaque Envelope</u>

The building envelope has been upgraded through the installation of internal insulation on the perimeter walls using double-density glass wool panels, with thicknesses ranging from 40 cm to 60 cm, and plasterboard counter-walls. This intervention significantly reduces heat loss and improves the overall energy performance of the structure. Similarly, the intermediate floor has been insulated with glass wool panels, beneath which soundproofing panels have been installed, separated by an air gap.

Transparent Envelope

To further improve thermal performance, all windows facing unheated areas have been replaced with high-performance thermal fixtures, featuring a global thermal transmittance below 1.2 W/m^2K and integrated blackout shutters. The window openings were also thermally insulated to eliminate thermal bridges.

Renewable Energy Photovoltaic System

A three-phase low-voltage photovoltaic system with a capacity of 10 kWp has been installed on the inclined roof of the building, paired with a battery storage system of approximately 10 kWh. This setup supports energy demand during evening hours, when the facility is most active. The system enables the cinema to self-produce a significant portion of its electricity needs, reducing reliance on the grid and contributing to lower CO_2 emissions. Solar energy is a key resource for ensuring the long-term sustainability of the facility.

Climate Control System

Replacing the old gas boiler and traditional radiators, the new climate control system consists of a 16-kW thermal heat pump connected to next-generation fan coil units and highly efficient circulators. Thanks to the photovoltaic contribution, the system has made the cinema entirely independent from the rest of the building complex.


CORDIVARI

Lighting System

All internal lighting fixtures have been replaced with state-of-the-art LED lamps. This upgrade has improved both energy efficiency and visual quality. The new lamps were selected following a thorough lighting analysis to ensure optimal visual comfort across different functional areas while minimising electricity demand. These interventions are part of a broader vision of sustainability and cultural innovation, positioning Cinema Alphaville as a local landmark that integrates energy efficiency, safety, and high-quality cultural programming.

Characteristics of the energy systems used in Cinema Alphaville

The interventions carried out on the Alphaville cultural hub have made it possible, on one hand, to bring the building and all its systems up to code, making it energy independent, and on the other hand, to completely eliminate gas as an energy source. From a decarburization perspective, the project is highly relevant and perfectly aligned with decarburization policies.

<u>Opaque and Transparent Envelope</u>

Before sizing the new air conditioning and photovoltaic systems, the existing energy model was updated by adding the insulation described in the previous section and modifying the thermal transmittance parameters of the external doors and windows. As a result, the updated energy model showed a reduction in thermal load of approximately 55%. This allowed for a significant downsizing of the new heat pump system, substantially reducing the energy demand for climate control. The installation of glass wool insulation on both the perimeter walls and the ceiling, along with high-performance thermal windows and doors, reduced transmission losses from 11,438 W to 3,898 W.

<u>Renewable Energy Photovoltaic System</u>

The complete elimination of gas and the replacement of the climate control system with electric heat pump technology resulted in the total removal of gas consumption and an increase in electricity demand to approximately 17,369 kWh/year. To meet this demand, a photovoltaic system with integrated storage was installed. The system generates an average of 12,000 kWh/year of renewable electricity, helping to offset the increased consumption from the heat pump.

Climate Control System

The complete elimination of gas and the replacement of the climate control system with electric heat pump technology resulted in the total removal of gas consumption and an increase in electricity demand to approximately 17,369 kWh/year. To meet this demand, a photovoltaic system with integrated storage was installed. The system generates an average of 12,000 kWh/year of renewable electricity, helping to offset the increased consumption from the heat pump.

Wall insulation and window replacement led to a reduction in the design thermal load from 16.97 kW (pre-intervention) to 9.26 kW (post-intervention). This enables the heat pump to operate at lower capacity and allows fan coil units to run at reduced levels, significantly lowering energy bills. With reduced energy demand, the system can maintain indoor temperatures more efficiently. The installed heat pump has a Coefficient of Performance (COP) of 4.5 (at 7–35°C), meaning that for every kWh of electricity consumed, it delivers 4.5 kWh of thermal energy.

Lighting System

The previous lighting system consisted of halogen spotlights and fluorescent lamps, which were insufficient to ensure proper illumination. A total of 36 new LED fixtures were installed, with a total installed power of 0.84 kW. Compared to the initial state, this resulted in a 74% improvement in energy efficiency and consumption, while also enhancing functionality and ensuring proper lighting throughout the space.

Environmental analysis

Before the interventions, the Alphaville building had an energy rating of class C. Following the implementation of the improvement measures, the building achieved an A2 energy rating, with a global non-renewable annual energy demand of 286.89 kWh/m² and a total annual saving of 125 MWh of non-renewable energy. Using the residual mix emission factor of 0.457 $kgCO_2$/kWh, this results in a reduction of annual CO_2 emissions amounting to 57,125 $kgCO_2$.

Economic analysis

The total investment for the energy and functional renovation of the Alphaville Cinema amounted to € 257,112.15, of which € 198,822.93 was allocated to construction works. The remaining amount covered energy audits, design and project management, as well as additional expenses and charges for the contracting authority. The breakdown of the construction costs is as follows:

- Replacement of windows and doors: 20%
- Replacement of indoor lighting fixtures: 8%
- Replacement of the air conditioning system: 17%
- Insulation of the opaque building envelope: 25.23%
- Installation of photovoltaic system: 12%
- Restoration works: 17.77%

The interventions led to a reduction in operating costs of approximately € 6,700 per year. The overall investment was largely funded through the National Recovery and Resilience Plan (PNRR) under the public notice "Call for proposals to promote eco-efficiency and reduce energy consumption in public and private theatres and cinemas," with a contribution of € 200,000. Therefore, the actual investment borne for the works was € 57,112.15. The simple payback period for the energy efficiency measures is estimated at 8.5 years.

The importance of the energy audit in defining interventions

The identification of the interventions stemmed from an in-depth Energy Audit carried out on the municipal building, which highlighted the main structural deficiencies in terms of energy performance, as well as the key needs arising from the building's usage patterns.

Thanks to the drafting of this analysis, conducted in accordance with the UNI CEI EN 16247 series, the most effective Energy Saving Opportunities were defined. The energy characterisation of the building-plant system reconstructed the energy behaviour of the building envelope (both opaque and transparent) in relation to the climatic context in which it is located and interacts, while also considering variables that influence specific consumption such as operating conditions, occupancy levels, and usage profiles of both the building and its systems. This type of audit enabled the interventions to be tailored to the specific needs of the property in question, also taking into account the available investment capacity for their implementation. The outcome revealed a significant reduction in energy consumption, improved indoor comfort, and enhanced organisation and functionality of the spaces. Notably, the full electrification of the building positioned it at the forefront of urban decarburization efforts, also contributing to raising awareness among the many users and tourists who visit the facility.

2.13 Theatre and restaurant Koepoort – NETHERLANDS

The City Theatre of Middelburg (Stadsschouwburg) was built in the late 1960s and has undergone several renovations since. During the most recent renovation, the Koepoort restaurant was added to the building, named after and offering a view of the historic Koepoort gate. The theatre seats 530 guests and hosts a variety of performances including cabaret, musicals, music, and small-scale arts.

The Koepoort gate, located next to the theatre, is a 17th century monumental building. It is the only fully preserved gate of the original eight that once surrounded the city. In 2018, the interior of the Koepoort was transformed into two bed-and-breakfast apartments, which opened in 2019. Both buildings are owned by the Municipality of Middelburg and are part of the city’s cultural heritage.

Middelburg is the capital city of the province of Zeeland and is centrally located on the Isle of Walcheren. The city has approximately 50,000 inhabitants and has long played an important role in Dutch and international history. During the Golden Age of the seventeenth century, Middelburg was the second most important city of the Dutch East India Company (VOC), after Amsterdam, due to its extensive trade activities and the large number of ships built there. Although the city was severely affected during the Second World War, its rich historical legacy remains clearly visible today. This heritage is reflected in the approximately 1,200 listed monuments that continue to shape the cityscape. Middelburg's long-standing international orientation has contributed to an open and outward-looking urban culture, which is further underlined by the biennial presentation of the Four Freedom Awards in the city.

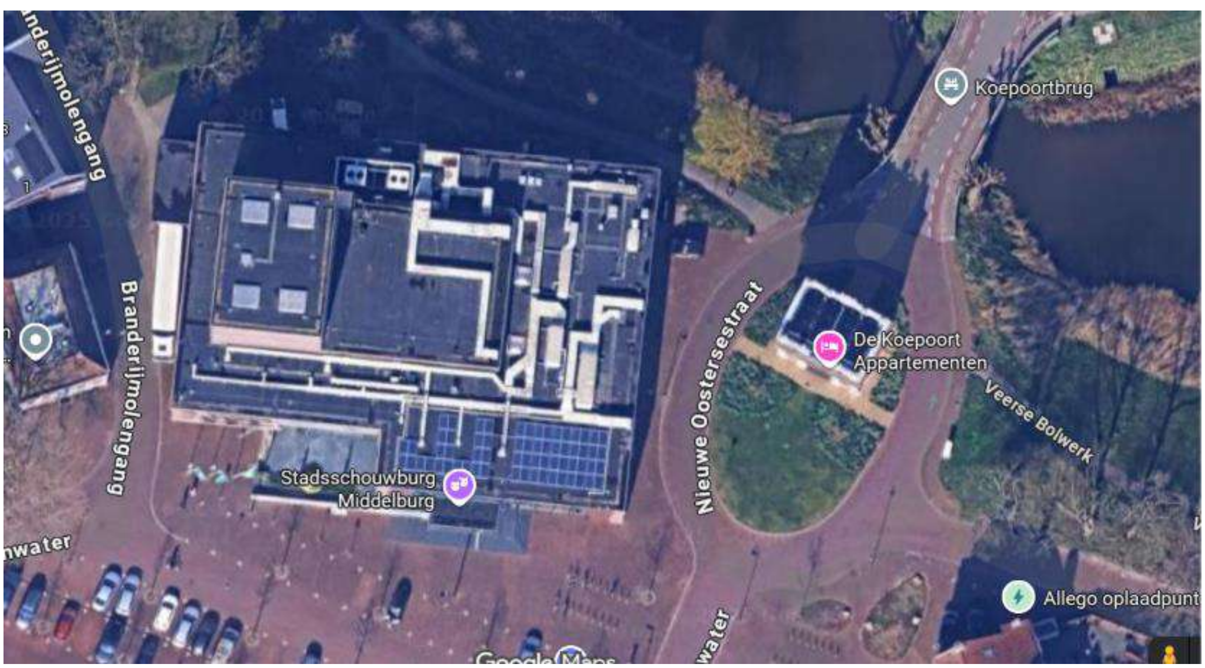
The city offers a broad range of shops, restaurants, cafés and bars, many of which are sustained largely by visitor numbers. Middelburg features numerous attractions that encourage visitors to explore the city on foot, including the Zeeuws Museum, the Kloveniersdoelen and the Oostkerk, which functions as an experimental stage for a wide variety of cultural activities. The city theatre provides an extensive year-round programme and includes a theatre restaurant that is open not only in the evenings but also during the daytime for lunch. In addition, the theatre building regularly hosts conferences and private events.

A notable example of adaptive reuse is the historic town hall, which has been given a new function as University College Roosevelt and attracts a relatively high number of visitors. As a result of its cultural offer, historical significance and urban atmosphere, Middelburg is considered a key destination for visitors staying in Zeeland, and particularly on Walcheren.

Middelburg records approximately 520,000 overnight stays per year. The majority of visitors originate from the Netherlands, Germany and Belgium, while international visitors from countries such as France, the United Kingdom, Italy and Spain are increasingly present. Over the past 10 to 15 years, the city has seen significant development in its accommodation sector, including new hotels, a growing number of bed and breakfasts and various city apartments. This development aligns with the broader trend of increasing urban tourism, in which visitors consciously choose city destinations for organised packages, self-organised day trips or multi-day stays. The city currently offers around 6,500 beds. In addition, a substantial number of river cruise ships dock in Middelburg along the canal. In recent years, there has been a noticeable increase in cultural visitors exploring the city.

Characteristics of Theatre and Restaurant

Both buildings are located along the historic ramparts ('bolwerken') and border the Mole waterpark. This park is around 2020 re-developed with a strong focus on climate adaptive measures, including a wade system and underground water storage, cooling through greenery and a reflective pond and ecological landscaping to support biodiversity. The theatre has a surface area of 2,052 m^2 (ground floor level) and an average of 45,000 visitors per year. The location is clearly significant for tourism and culture. The motivation for implementing sustainable practices stems from the municipality's ownership and its commitment to accelerating the energy transition. The main challenge was integrating renewable energy solutions into protected cityscapes without compromising historical value.




STADSSCHOUWBURG

Local Climate Characteristics

Middelburg has a temperate maritime climate, strongly influenced by the nearby sea and the warm Atlantic Gulf Stream. This results in mild winters, cool summers, and fairly even rainfall throughout the year. In recent years, climate change has led to more extreme weather: heavier rainfall in autumn and winter, and drier summers. These shifts cause water-related challenges such as drought, irrigation difficulties, and flood risks. Rising temperatures also increase the risk of urban heat islands and heat stress, especially in the historic city centre. The figures below are based on long-term average climate statistics, with temperatures shown in degrees Celsius (°C).

	Max temperature	Min temperature	Hours of Sunshine / day	Days of rain / month	Amount of rain / month
januari	6°C	2°C	2	23	💧💧
februari	6°C	2°C	3	18	💧💧
maart	9°C	4°C	4	21	💧💧
april	12°C	6°C	5	19	💧💧
mei	16°C	10°C	7	18	💧💧
juni	19°C	12°C	6	19	💧💧💧
juli	21°C	15°C	7	18	💧💧💧
augustus	21°C	15°C	7	17	💧💧💧
september	18°C	13°C	5	19	💧💧💧
oktober	14°C	9°C	4	21	💧💧💧
november	10°C	7°C	2	23	💧💧💧
december	7°C	3°C	2	24	💧💧💧

0-5 mm = NIHIL | 6-30 mm = 💧 | 31-60 mm = 💧💧 | 61-100 mm = 💧💧💧 | 101-200 mm = 💧💧💧💧 | meer dan 200 mm = 💧💧💧💧💧

Annual Solar Irradiance: 1,042.9 kWh/m²

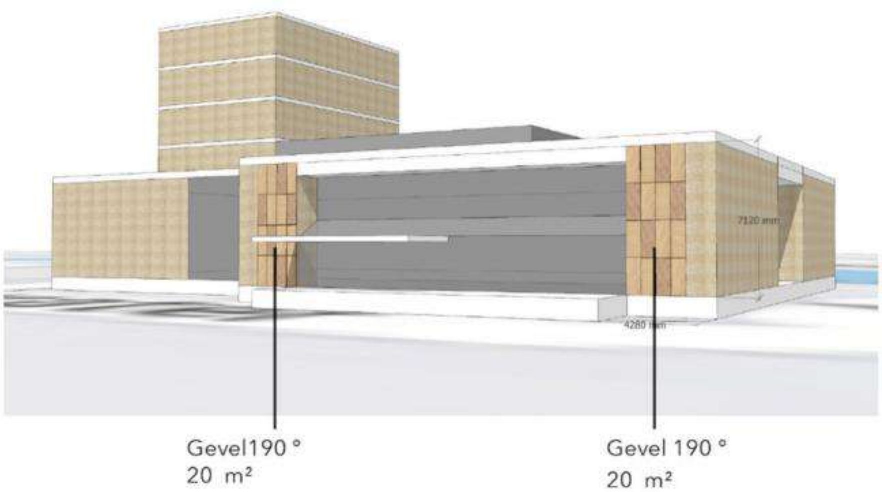
Annual Precipitation: 684 mm

Average Annual Temperature: 11.1 °C

These climate conditions support the use of solar energy as a viable renewable source.

Description of the Energy Systems Used in the Theatre and B&B

The Theatre is equipped with 64 rooftop solar panels, two heat pumps, a battery of 68 kW and 32 vertical solar panels installed on the façade. During the renovation in 2018, a mechanical ventilation system with heat recovery was installed. In addition, the theatre replaced almost all lighting into LED and replaced all windows with isolating glass (HR++). However, the building is still quite old, and the insulation level is not yet optimal. In 2024, a gas boiler was replaced by two electrical boilers of both 42 kW. The restaurant kitchen is still using natural gas for cooking. The most unique part are the vertical solar panels that have been installed on the facade of the Schouwburg and Koepoort restaurant. This is a demonstration project to show that generating sustainable energy is possible even on architecturally valuable buildings in the historic city centre. The innovative vertical Solarix design panels feature a graphic print that evokes the look of stage curtains. RTL News filmed the installation, and the footage was used as a best practice example of energy transition at the climate conference in Glasgow. The energy generated by the facade panels is stored in a battery, as the Schouwburg and restaurant primarily use electricity during evening hours. The battery is also used to power charging stations for electric bicycles, telephones and/or laptops.


7120 mm
4280 mm
Gevel190 °
20 m²
Gevel 190 °
20 m²

The Koepoort B&B has 24 solar panels and is fully electric, with no natural gas connection. For the Koepoort, solar panels were integrated invisibly within the roof, to preserve the building's monumental character. To install solar panels in the historic city centre, a special framework was placed to ensure the panels are not visible from the street. The combination of solar panels with low-temperature heating-ventilation units and a heat pump makes the building a strong example for the tertiary sector in a heritage-sensitive environment.

Characteristics of the Energy System

Theatre:

Rooftop solar panels

- 64 panels of 275 Wp each,

- Estimated annual Energy production: 17 MWh

- Estimated annual CO_2 reduction: 6,8 tCO_2

Vertical Solarix Panels on Theatre Façade:

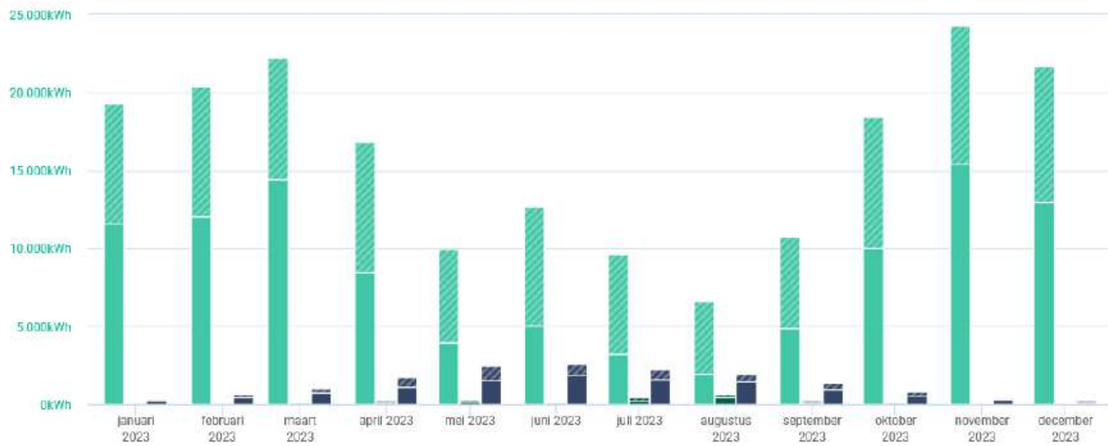
- 32 panels of 151 Wp each, surface Area: 40 m^2

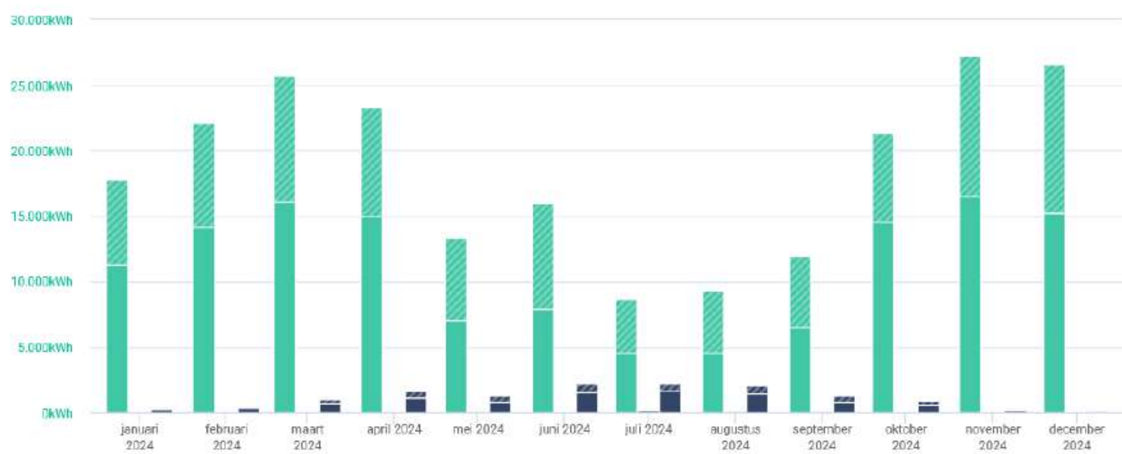
- Estimated Annual Energy Production: 3,200 kWh

- Estimated Annual CO_2 Reduction: 1,379 $kgCO_2$ (~69 trees)

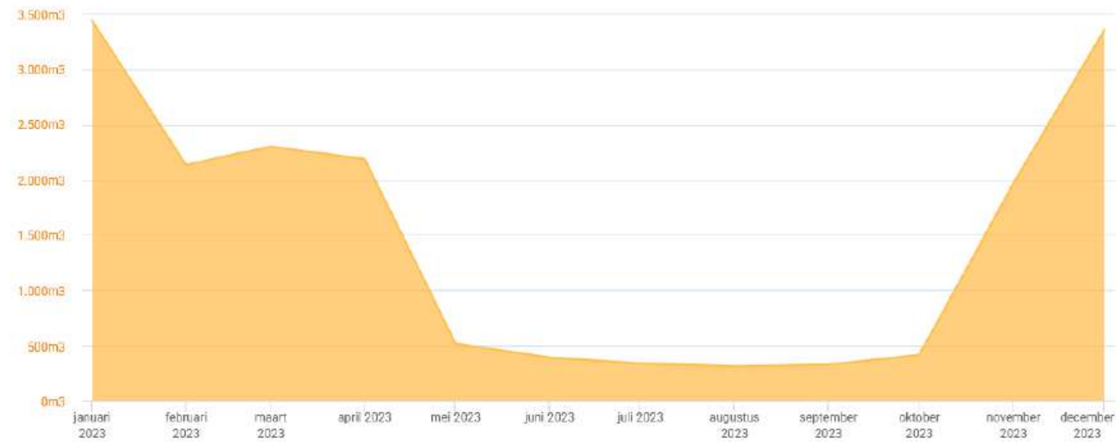
Next to the production of renewable energy, the theatre uses electricity from the grid and natural gas. In 2024, the total gas amount used was 13,858 m^3 natural gas. The total electricity consumption in 2024 was 223,000 kWh in total, of which 13,800 kWh was produced by both solar systems. The existing solar panels currently generate approximately 6% of the building's total electricity demand. However, the transition from a gas boiler to an electric heating system in 2024 led to a further increase in overall electricity consumption. In response, the venue operator and the municipality, as the building owner, are jointly exploring the feasibility of a second renovation phase. This phase would potentially include measures such as replacing the rooftop solar panels, upgrading the heat pumps to more energy-efficient models, and reducing overall energy consumption through improved thermal insulation of the building.

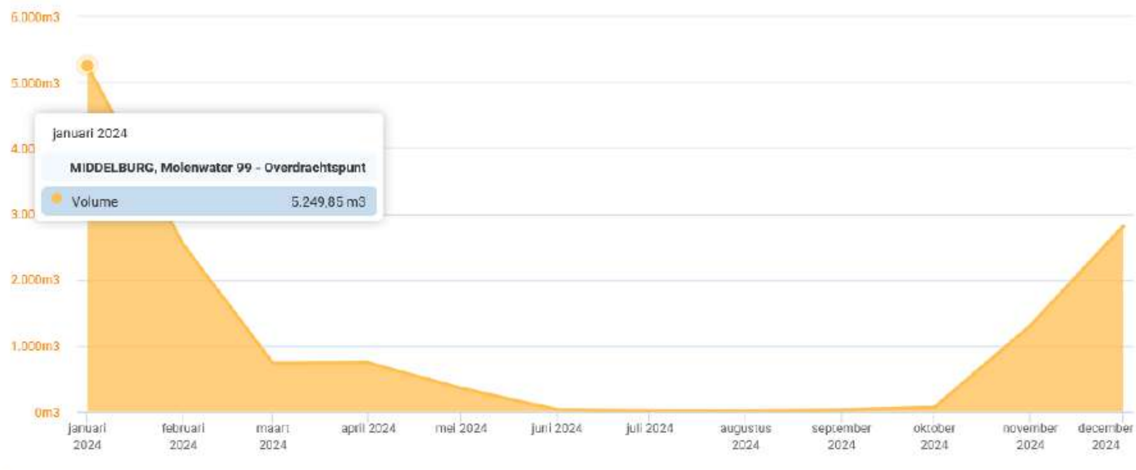
This is the monthly electricity consumption and production of the theatre in 2023 and 2024:





This is the monthly gas consumption of the theatre in 2023 and 2024:





The exact electricity use and production of the Koepoort B&B is currently not known.

Environmental Analysis

The sustainable investments have led to a measurable reduction in CO_2 emissions, particularly through the use of solar panels and heat pumps. Future further improvements are being investigated.

Simplified Cost-Benefit Analysis

The solar system is covering around 6% of the total electricity consumption. This has to do with the total capacity of the panels installed and the age of the rooftop panels. However, the solar panels on the façade are also to be seen as a demonstration case of visibly attractive installation for specific locations. As these are part of a pilot, the cost-benefit analysis has a wider scope than purely financial.

Financial Sources Used for the Sustainable Energy Investments

The Battery, heat pumps and Vertical Solar panels are partly funded by an Interreg A project (50 %) and co-funded by the municipality of Middelburg.

2.14 Wellness and B&B Zeeuws Ontspannen - NETHERLANDS

Zeeuws Ontspannen is a 'private wellness' located in the city centre of Middelburg (Zeeland) for small groups of two to four people. In addition, they offer two beautiful luxury wellness suites. In short, a complete space for relaxation, suitable for recreational day and overnight stays. For day and overnight stays, Zeeuws Ontspannen provides a beautiful private wellness suite with a Finnish sauna, an infrared sauna with salt stones, a steam cabin, a foot bath, a warm and cold rain shower with hand shower, a relaxation area, and a massage/whirlpool bath. Zeeuws Ontspannen is the ideal place to relax with your family or friends, completely private in your own suite, as no one else is present. Guests rate Zeeuws Ontspannen highly because you enjoy guaranteed privacy in the luxury wellness suite, with relaxing facilities, atmosphere, coziness, peace, and romance in a Zeeland style. Zeeuws Ontspannen is a great example of a small tourism entrepreneur: an initiative by a couple who realised their dream by creating this sustainable wellness business. Despite significant private investments, sustainability remains their guiding principle: both as a responsibility towards nature and society, and as an opportunity to distinguish Zeeuws Ontspannen as a wellness destination where relaxation, innovation, and conscious living come together.

Characteristics of the region

Middelburg is the capital city of Zeeland and is centrally located on the Isle of Walcheren. Its population is 50,000 inhabitants. During the Golden Age (17th century) Middelburg was the second city of the Dutch East India Company (VOC) in the Netherlands after Amsterdam, because of the trade and the hundreds of ships that were built there. And although Middelburg was hit hard in the Second World War, its glorious past is still fully visible. Today you can still experience the time of the VOC in Middelburg by its 1,200 listed monuments. Its international orientation made Middelburg a city with an open mind to other cultures. It is no coincidence that here every two years the presentation of the Four Freedom Awards take place. The city has an extensive range of shops, restaurants, cafes and bars, which mainly can exist thanks to its visitors. The city has many attractions for tourists to stroll along such as the Zeeuws Museum, Kloveniersdoelen, the Oostkerk experiment as a stage for all kind of cultural activities. The architectural town hall is given a new role (University College Roosevelt) and attracts a relatively high number of visitors. Middelburg is a must-see destination for anyone staying in Zeeland and Walcheren in particular. Middelburg has about

520.000 overnight stays a year. Most visitors come from the Netherlands, Germany and Belgium. Many hotels have been developed in the past 10-15 years, increase of B &B's and various city apartments. This is in line with the trend of increased urban tourism, in which people consciously choose to visit a city. This can be in the form of organised packages, via a tour operator, via self -organised day trips or multi-day stays. These visitors come from France, UK, Italy, Spain etc. A large number of river cruise ships moor in Middelburg along the Canal. In recent years there is an increase of cultural visitors exploring the city.

Characteristics of Zeeuws Ontspannen

Zeeuws Ontspannen was created as a joint initiative by Erwin Veldman and his wife Bianca: Bianca runs the wellness business in daily life, while Erwin works as an architect (Veldman Architecten B.V.) and is responsible for the technical and innovative aspects. This combination forms the basis of their motivation to implement sustainability in all facets. Since they are full owners, they can make all decisions independently and translate their vision into practice without compromise. Quote from Erwin and Bianca: "For our guests, everything revolves around relaxation, privacy, and well-being. We believe that well-being is inextricably linked to respect for nature and the environment in which we operate. By limiting our ecological footprint, we contribute to the preservation of the unique Zeeland landscape that defines the appeal of our location. At the same time, this aligns with the growing demand from guests for experiences that are both comfortable and responsible. We also see Zeeuws Ontspannen as a valuable test case. It enables us as architects to investigate innovative techniques and sustainable solutions in a realistic setting: do energy-efficient systems perform as expected in a wellness environment, do water-saving systems truly work in practice, and which materials combine comfort with sustainability? These insights not only advance our own business but also generate knowledge that can be applied in future projects. "Challenges remain. Sustainable investments often require significant upfront costs, while the payback period is long. Moreover, the wellness sector is naturally energy-intensive, and existing regularly.

Local climate characteristics

Middelburg has a temperate maritime climate that is strongly influenced by its proximity to the sea and the warm Atlantic Gulf Stream. This results in generally mild winters, cool summers and relatively evenly distributed rainfall throughout the year, with temperatures rarely falling below 5 °C. In recent years, however, climate change has led to increasingly extreme weather patterns, including heavier rainfall in autumn and winter and drier conditions during the summer months. These developments have created a range of water-related challenges, such as periods of drought, difficulties with irrigation and an increased risk of flooding. Rising average temperatures also contribute to the formation of urban heated islands and heightened heat stress, particularly in the historic city centre. These impacts are expected to intensify further as climate change progresses in the coming years.

	Max temperature	Min temperature	Hours of Sunshine / day	Days of rain / month	Amount of rain / month
januari	6°C	2°C	2	23	💧💧
februari	6°C	2°C	3	18	💧💧
maart	9°C	4°C	4	21	💧💧
april	12°C	6°C	5	19	💧💧
mei	16°C	10°C	7	18	💧💧
juni	19°C	12°C	6	19	💧💧💧
juli	21°C	15°C	7	18	💧💧💧
augustus	21°C	15°C	7	17	💧💧💧
september	18°C	13°C	5	19	💧💧💧
oktober	14°C	9°C	4	21	💧💧💧
november	10°C	7°C	2	23	💧💧💧
december	7°C	3°C	2	24	💧💧💧

0-5 mm = NIHIL | 6-30 mm = 💧 | 31-60 mm = 💧💧 | 61-100 mm = 💧💧💧 | 101-200 mm = 💧💧💧💧 | meer dan 200 mm = 💧💧💧💧💧

Description of the energy systems used in the private wellness and suites

Deliberate choices were made for sustainable and innovative systems that contribute to lower energy consumption and a comfortable stay. The solar panels generate a large part of the required electricity themselves. This not only reduces energy costs but also limits CO_2 emissions. In addition, they have installed a hybrid add-on. This technology connects the existing heating system to a hybrid heat pump. As a result, they make optimal use of sustainable heating and switch to traditional heating only when necessary. The result is a significant reduction in gas consumption without compromising comfort and quality for the guests. The centrepiece of it all is the smart Energy Management System (EMS). This system controls almost all installations in the building and ensures that the supply and demand of energy remain balanced. What is special is that they can fully script the EMS themselves. This allows them to set very specific rules, such as using solar energy during peak production or smartly switching heating and ventilation systems based on occupancy. The EMS is therefore more than just a control system. It forms the basis for daily operations while simultaneously serving as a practical laboratory where they test and refine technologies. This way, they combine comfort with energy efficiency and actively contribute to a more sustainable future. Total annual energy consumption: 7,000 kWh

Characteristics of the energy system

The Energy Management System (EMS) serves as the central hub for all installations at Zeeuws Ontspannen, enabling optimal coordination of the building's various appliances and systems. Unlike traditional systems that are typically limited to simple on/off functions, the EMS provides advanced and intelligent control. Each appliance has been carefully optimised by the owners with three key objectives in mind: efficient usage, high quality, and guest comfort. Equipment is activated only when necessary, ensuring energy consumption remains minimal while maintaining the desired level of luxury for visitors. For instance, ventilation and heating are adjusted intelligently based on occupancy, and systems are prioritised according to peak energy production.

A distinguishing feature of the EMS is that the owners can fully script its operations themselves. This allows for the creation of tailor-made rules rather than relying on standard settings, ensuring that the system aligns precisely with usage patterns and Erwin and Bianca's sustainability vision. As a result, the EMS evolves alongside their experience and innovations, providing a dynamic tool for testing and refining new approaches. In this way, the EMS not only underpins energy management but also functions as an instrument for continuous improvement, seamlessly integrating comfort, efficiency, and sustainability into a single intelligent system.

Environmental analysis

(due to implemented investments in the last 5 years)

7.1 Annual saving in grid electricity 5,000 kWh

7.2 Annual saving in fossil fuels 2,000 m^3 (gas)

7.3 Annual decrease of CO_2 emissions due to fossil fuels saving 3.8 tCO_2

7.4 Annual decrease of CO_2 emissions due to grid electricity saving 2.4 tCO_2

7.5 Annual decrease of CO_2 emissions due to fossil fuels and grid electricity saving 6.2 tCO_2

Economic Analysis

Total annual economic benefit of the energy investments € 18,000 in 5 years.

Simplified cost-benefit analysis

The energy investments at Zeeuws Ontspannen result in clear and measurable savings. By installing solar panels, they save around 5,000 kWh of electricity annually, which amounts to about € 1,250 per year (assuming an average electricity price of € 0.25 per kWh). They have also achieved significant savings in gas consumption. Thanks to the hybrid add-on in combination with the existing installation, they use around 2,000 m^3 less gas per year, which equals a saving of about € 2,400 per year (at a gas price of € 1.20 per m^3). A third pillar of their approach is good insulation combined with ventilation of the building. By carefully insulating, they minimise heat loss, so that generated heat is efficiently retained. This not only reduces energy demand but also increases guest comfort. Together, these measures lead to annual savings of around € 3,650. Over a period of five years, this adds up to more than € 18,000, excluding possible price increases. With the smart Energy Management System (EMS), they optimally align all facilities. In this way, they combine insulation, sustainable generation, and intelligent control into an efficient whole with lasting financial benefits.

Financial sources used for the sustainable energy investments

Own capital and a bank loan.

No subsidies.

No financial support for the investment costs.

2.15 DámPont- Eco-tourism Visitor Centre - HUNGARY

The DámPont Eco-tourism Visitor Centre in the vicinity of the Miklósvár Park Forest and Miklósvár Lake, nor far from the Game Park of Gyulaj Zrtin Tamási has been open to guests since 2020. The building is made of natural materials to blend in naturally with its surroundings. The visitor centre functions as an exhibition space and event venue as well. Its exhibition fully meets the demands of the 21st century: interactive digital tools (touch screens, sound shower, 3D projector and glasses, phot wall, etc.) allow visitors to learn about the hunting culture of the area, the natural and historical values of the town and its surroundings. The visitor centre is on several hiking trails, including the Tamási Várhegy Hiking Trail, which highlights the town's main built and natural attractions, as well as its cultural heritage. The visitor centre pays special attention to sustainability and environmental education, so it offers a wide range of school programmes for visitors. As an eco-tourism centre, it also aims to introduce the natural heritage to make the flora and fauna of the area more understandable to new generations. This process is supported by both interactive tools and static exhibition elements. In February 2025, the DámPont Eco-Tourism

Visitor Centre was awarded the platinum certification of the Good Travel Seal, a globally recognised certification scheme based on the guidelines of the Global Sustainable Tourism Council (GSTC), which assesses sustainability through a single set of rigorous standards.

Characteristics of the region

Hungary's Central Danube Priority Area (CDPA) covers a total area of 4,464.9 km² and is home to 234,020 permanent residents as of 2023. That year, the region recorded 253,427 bed-nights, resulting in a tourism density of 56.76 bed-nights per km² and a tourism intensity of 1.08 bed-nights per resident. The CDPA encompasses a diverse and extensive territory, including numerous protected areas and 30 Natura 2000 sites, which are managed by three national parks.

Among these, the Pacsmag Lakes Special Protection Area, designated under the Birds Directive (code HUDD10006) and covering 440 hectares, is situated within the administrative area of Tamási. The site has been protected as a nature reserve since 1990 and consists of a system of seven lakes, including wetlands, as well as smaller areas of forests and grasslands. The area was primarily established to safeguard the rich nesting and migratory water bird populations, which are of significant regional importance. In 1997, the Pacsmag Lakes were recognised internationally through their inclusion on the Ramsar List of Wetlands of International Importance.

In addition to the Pacsmag Lakes, the wider Tamási area hosts several other Natura 2000 sites designated to protect habitats and species of European significance, including the middle-spotted woodpecker, the European fire-bellied toad, and the stag beetle. These protected areas play a dual role, both preserving biodiversity and supporting sustainable development by offering opportunities for active and eco-tourism, as well as environmental education.

Characteristics of the hotel

The DámPont Eco-Tourism Visitor Centre in Tamási occupies a total area of 2,472 m^2, comprising a built-up area of 460 m^2, additional covered spaces of 1,205 m^2, and green areas of 807 m^2. The Centre receives approximately 5,000 visitors annually and is committed to integrating sustainable practices into its operations. The primary motivation behind these initiatives is to preserve and promote the local natural and cultural heritage while minimising environmental impact. Sustainability at the Visitor Centre is understood not only as an environmental imperative but also as a social and economic opportunity, reflecting a long-term vision for the region's well-being.

The Centre places strong emphasis on educating visitors about environmental stewardship, biodiversity conservation, and responsible resource use. Initiatives such as local sourcing and eco-friendly procurement reinforce the economic vitality and cultural identity of the region, fostering community pride and enhancing visitor engagement. Key challenges in implementing these practices include maintaining consistent operational efficiency, continuously reducing the environmental footprint, and promoting active visitor participation through education and outreach. While the Centre has successfully integrated local, environmentally conscious suppliers, identifying and sourcing new vendors who meet sustainability standards remains an ongoing challenge. The Visitor Centre addresses these obstacles through regular staff training, active community involvement, and a commitment to continuous improvement in sustainability performance.

Local climate characteristics

The local climate is characterised by an annual solar irradiance of 1,280 kWh/m^2, an average annual precipitation of 640 mm, and an average annual temperature of 10.3 °C, providing a temperate environment that supports the Centre's eco-tourism and sustainability objectives.

Description of the energy systems

DámPont Eco-Tourism Visitor Centre employs carefully selected, environmentally friendly energy systems with a strong emphasis on efficiency and sustainability. The facility primarily utilises LED lighting systems throughout the building, significantly reducing energy consumption compared to conventional lighting methods. Additionally, the restrooms are equipped with motion-sensor lighting, ensuring that lights are active only, when necessary, further contributing to overall energy savings. For heating, the Centre utilises a **wood gasification boiler system**. This system represents an efficient and sustainable choice as it significantly reduces reliance on fossil fuels by utilising locally sourced, renewable biomass resources. The use of biomass not only contributes to lower greenhouse gas emissions but also supports the local economy by sourcing fuel materials from the immediate surroundings. Energy management at the Centre is strategically oriented towards reducing consumption and environmental impact through active monitoring and efficient operational practices. The electrical equipment used in the exhibition spaces and elsewhere is only switched on when visitors arrive, preventing unnecessary energy consumption during periods of inactivity. The Centre's management and staff are continuously trained to adhere strictly to energy-saving protocols, promoting an institutional culture of responsibility toward resource use and environmental stewardship. Through these comprehensive measures, the Visitor Centre demonstrates a strong commitment to sustainability, simultaneously achieving ecological benefits and cost efficiencies. In the energy certificate, the annual GHG emissions for the building are 1.38 tCO_2, which is derived from electricity consumption, as the use of wood gasification (biomass) boiler, in line with the sustainable forestry practices typical Hungary, does not statistically generate CO_2 emissions when considering absorption capacity. This means that significant GHG emissions have been avoided from the start, and these can be further minimised with additional attention during maintenance/operation (use of lighting, etc.).

Characteristics of the energy systems

The centre employs modern equipment designed to minimise energy consumption, including LED lighting throughout the building and motion-sensor lighting in rest rooms. Climate control systems are energy-efficient (rated A+++), and the visitor centre actively limits unnecessary energy use by operating exhibitions only when visitors are present. Seasonal operations also reduce heating and cooling requirements significantly. The centre uses a biomass wood gasification boiler (Atmos DC32S, 35 kW) which provides renewable heating. The heat is stored in a 1,500-litre buffer tank (CONCEPT), and hot water is supplied via a 300-litre Reflex WPS storage unit. The low-carbon emission system primarily consists of the biomass wood gasification boiler, significantly reducing CO_2 emissions compared to conventional fossil fuel-based heating systems. Additional low-carbon practices include high-quality insulation, energy-efficient windows and doors, and climate control practices minimising energy consumption. The centre features various environmentally conscious practices such as the use of natural construction materials (reed roofing, wooden furniture), permeable pavement in the parking areas to prevent erosion, and encourages sustainable transportation methods, including cycling and public transportation. Environmentally friendly cleaning products are also used throughout the facility to minimise pollution and maintain air quality. A solar thermal system is also used with installed power 35 kW.

Environmental analysis

The DámPont Eco-Tourism Visitor Centre, established in 2020, was designed with sustainability as a core consideration, aiming to minimise its ecological footprint through specific environmental practices and energy-efficient technologies. The new building features high-quality insulation, energy-efficient wooden doors and windows, and a modern wood gasification boiler, which significantly reduces fossil fuel dependency. Additionally, all lighting has been upgraded to LED and energy-saving bulbs, combined with motion-sensor lighting systems to further minimise unnecessary energy consumption. Energy use is actively managed by operating equipment and interactive exhibitions only when visitors are present, substantially reducing the overall electricity consumption. During extreme weather conditions, such as heatwaves, efficient air conditioning units operate within strict temperature differentials to conserve energy while maintaining comfort. Furthermore, seasonal adjustments to operations, such as limited winter openings exclusively for pre-booked groups, contribute significantly to lower energy and heating demands. Regarding water management, dual-flush toilets and awareness campaigns contribute to lower water use and reduced water pollution risks. These combined investments and management practices effectively minimise the environmental impact of the Visitor Centre, contributing positively to the region's ecological sustainability.

Economic analysis

The annual benefit due to lower use of grid electricity (average) was estimated at € 4,000. The annual benefit due to lower use of fossil fuels (average) was estimated at € 11,500. The total annual benefit due to lower use of grid electricity and fossil fuels, on average, was estimated at € 15,500. The total annual economic benefit cannot be calculated because the investment cost (and consequently the replacement cost) of the renewable heat and energy production systems is unknown. The main direct environmental benefit of the building's energy-smart design and operation is reducing greenhouse gas emissions that cause climate change. This is achieved by using locally sourced biomass with low transport needs to meet heating demand, using energy-efficient lighting and equipment, and adjusting lighting based on the number of visitors. Indirectly, the building's design and operation also support other environmental benefits associated with climate change mitigation, such as biodiversity conservation and water resource preservation. However, the extent of these indirect effects is very low. Partly for this reason and partly due to their very indirect nature, the environmental benefits of this type related to the building's design and operation cannot be quantified. The development was carried out within the framework of the project entitled "*Sustainable Ecotourism Development of the Town of Tamási*", with 100% funding intensity and a total value of around € 1.15 million (HUF 458,681,950). Of this, the construction cost of the Visitor Centre amounted to around € 520,000 (HUF 208 million) gross.


TÍZ TÉNY
A DÁMVADAKRÓL

2.16 Jankovich Kuria Hotel - HUNGARY

The hotel is housed in the 18th-century Jankovich Manor, located in the heart of the country, in the centre of the old village of Rácalmás in a park filled with ancient trees. The hotel opened its doors in 2007 with 25 rooms and a Korean restaurant. The first major developments took place between 2009 and 2012, during which the hotel was awarded a 4-star rating, its capacity was expanded, and a wellness area and a winter garden were created. Between 2018 and 2022, the restaurant was modernised, and the hotel room, lobby and communal areas were renovated with unique interior design solutions and clean lines. Energy upgrades and rationalisation of energy consumption have been priorities from the very beginning. Currently, the hotel has 20 superiors and 24 deluxe rooms, a specially designed, barrier-free room for guests with disabilities, and superior rooms that can be connected to accommodate families. The 500 m^2 wellness area features an indoor swimming pool, a 10-person Jacuzzi, saunas (Finnish, aroma, infrared, steam cabin), a Kneipp pedal pool, a fitness room and massage rooms. The hotel is perfect for corporate events, conferences, team-building training sessions and family events with two 100 m^2 naturally lit ballrooms, nine naturally lit 30-60 m^2meeting rooms, a wine cellar, a gastronomic room and a craft showroom. The hotel places particular emphasis on environmental protection and sustainability in its operations. Through improvements such as the installation of solar collectors and solar panels, an automatic air conditioning system and energy-saving windows with sensors, as well as the use of heat recovery air handling unit, the hotel strives to achieve the smallest possible ecological footprint. In 2022, the Jankovich Hotel**** won the Silver Award in Independent Hotels category of the Green Hotel Competition launched by the Hungarian Hotel and Restaurant Association, followed by the Gold Award 3rd place in 2024, and a 1st place in 2025. The future goal is to win the title of 'Evergreen Hotel'.

Characteristics of the region

Hungary's Central Danube Priority Area (CDPA) encompasses a total area of 4,464.9 km² and is home to 234,020 permanent residents. In 2023, the region recorded 253,427 bed-nights, resulting in a tourism density of 56.76 bed-nights per km² and a tourism intensity of 1.08 bed-nights per resident. The CDPA covers a diverse and extensive territory, including numerous protected areas and 30 Natura 2000 sites, which are managed by three national parks.

The natural heritage of the Rácalmás area is characterised by wetlands associated with the Danube River, alongside an environment shaped by built cultural heritage. The Rácalmás branch of the Danube and its adjacent coastal strip form part of the 'Danube and its floodplain' (code HUDI20034), a Natura 2000 Special Area of Conservation covering 580 hectares within the Rácalmás administrative area. In addition, the 386-hectare Rácalmás Islands Nature Reserve is recognised as a protected natural area of national importance. The 4.82-hectare Jankovich Manor and the 138-hectare Rácalmás branch of the Danube are also under local protection. These sites collectively preserve the ecological and cultural value of the region while providing opportunities for sustainable tourism and environmental education.

Characteristics of the hotel

The hotel occupies a total area of 4,230 m², including a built-up area of 1,274 m², other covered spaces of 500 m², and green areas of 2,456 m². It has a total guest capacity of 88, with additional accommodation options including extra beds in some rooms for 10 guests and a guesthouse accommodating an additional five guests, bringing the total capacity to 103 guests. The hotel welcomes approximately 6,900 visitors per year.


JANKOVICH HOTEL


JANKOVICH HOTEL

Local climate characteristics

Annual Solar irradiance: 1,280 kWh/m^2

Annual precipitation rate: 593 mm

Average annual temperature: 11.4 ^oC

Type of energy sources used

The Jankovich Hotel**** is committed to sustainability and environmental protection. The hotel's environmental policy enables it to take effective measures to reduce its environmental impact and ensure that its activities align with sustainability goals. The environmental programme places particular emphasis on reducing the hotel's environmental impact during operation. As part of this, they have committed to continuous improvement and the use of the best available technology. During the developments, they strive to minimise their ecological and carbon footprint, thus promoting sustainable development, contributing to a sustainable future, and having a positive impact on the environment and the community. The aim of the Jankovich Hotel****'s Environmental Program is to reduce environmental impact and promote sustainable business practices. The Green Hotel Program's efforts are continuously communicated to guests. These sustainable practices can be summarised as follows:

- Solar collectors were installed on the roof of the hotel in 2016, and all lights are energy-efficient and equipped with automatic sensors in the communal areas.
- Solar panels were installed in addition to the solar collectors in 2023.
- Since the modernisation of the kitchen, modern machines and equipment, which are less energy-intensive than their predecessors, have been used to perform the necessary tasks.
- The kitchen uses 100% biodegradable packaging materials.
- The grease-contaminated water is not returned to the sewage system, it first passes through a special filter, a 'grease trap'.
- The restaurant uses environmentally friendly, biodegradable napkins.
- The bar serves 'Jankovich Aqua', a magnesium-enriched filtered water that is freshly bottled, replacing 95% of pre-bottled mineral water, saving the environment from a lot of unnecessary transport.
- Due to the introduction of Hotel TV, guests can access the guest information pack and essential hotel-related information electronically, thus a lot of paper is saved.
- Electric car charging is available at discounted rates at the hotel.
- Waste is collected separately, and guests are encouraged to do the same by using separate waste bins provided in communal areas.

- The hotel uses environmentally friendly plastic ballpoint pens made from recycled wheat straw.

The Jankovich Hotel**** covers the energy required to operate the facility form the following three sources: electricity, piped natural gas and solar energy. To reduce grid electricity consumption, a 50 kWp solar panel system was installed on the east- and west-facing roofs of the building in 2023-2024. In 2024 the solar panel system generated 57,156 kWh of green electricity. As the hotel does not have an energy storage facility, it continues to draw electricity from the grid. In 2024 this amounted to 437,037 kWh. The building's heat demand (heating, hot water production) is met by natural gas-fired boilers. In 2024, the facility's natural gas consumption was 54,953 m^3, amounting to approximately 366,353 kWh. In order to reduce natural gas consumption, a 20 m^2 solar thermal collector was installed in 2016 to assist in heating the pool in the wellness area. It is estimated that the annual heat energy production in 2024 was 11 MWh. In order to reduce energy consumption, the electrical network was modernised in 2021-2022, which included the installation of modern air conditioning units, automatic motion and presence detectors in communal areas, as well as replacing all lighting with energy-efficient LED light sources. Since the modernisation of the kitchen, modern machines and equipment, which are less energy-intensive than their predecessors, have been used to perform the necessary tasks. The wellness area is equipped with a heat recovery air handling unit, enabling its heat demand to be met in an energy-efficient way.

In order to optimise energy consumption, the Panda energy management system is used that highlights energy saving opportunities, organises energy bills and provides analyses based on time series data from service providers and sub-metering. Since the system allows for continuous monitoring of the hotel's energy consumption, providing up-to-date information on every aspect and moment its operation, any operational anomalies are quickly identified and can be quickly remedied.

Type of energy systems used

The hotel uses modern equipment designed to minimise energy consumption, including LED lighting throughout the building and motion-sensor lighting. Each room has individually controlled heating and air conditioning, and energy-saving windows with sensors have been installed. The combination of these significantly reduces heating and cooling costs. The hotel's park, which contains ancient trees also contributes to the favourable microclimate, as the vegetation cools the air through evaporation and shading, reduces the temperature, improves air quality, has a positive effect on wind conditions, and also reduces the amount of sunlight and the temperature in the interior spaces due to natural shading. Offices, meeting and hotel rooms have natural lighting, which further reduces electricity consumption. Energy consumption is optimised by Panda's intelligent energy management system, which highlights energy saving opportunities, organises energy bills and provides analyses based on time series data from service providers and sub-metering. Since the modernisation of the kitchen in 2019-2020, modern machines and equipment, which are less energy-intensive than their predecessors, have been used to perform the necessary tasks. The heat recovery air handling unit operating in the wellness area ensures that the heat content of the used, humid air is not wasted but contributes to heating the fresh air flowing in from outside, thus reducing the amount of fossil fuel (natural gas) needed to meet the heat demand of the wellness area. The Jankovich Hotel**** implements several environmentally friendly practices, such as organising waste-free events and paperless communication. In the spirit of sustainable gastronomy, the hotel's culinary offerings are based on local and seasonal ingredients, supporting environmentally conscious producers, while the vegetarian and vegan menu options provide further opportunities to reduce ecological footprint. Environmentally friendly cleaning products are used in the hotel to minimise pollution and maintain air quality.

Environmental analysis

Compared to previous years, electricity consumption was reduced by 15% in 2024.

The annual saving in grid electricity was 57,516 kWh

The annual saving in fossil fuels was 1.12 tons

The annual decrease of CO_2 emissions due to fossil fuels saving was 3.14 tCO_2

The annual decrease of CO_2 emissions due to grid electricity saving: 2.24 tCO_2

The annual decrease of CO_2 emissions due to fossil fuels and grid electricity saving was 5.38 tCO_2

The primary direct environmental benefit of the energy investments made in the facility is the reduction of greenhouse gas emissions that cause climate change. Indirectly, the project contributes to all environmental benefits expected from climate change mitigation (e.g., biodiversity conservation). However, the extent of these latter effects is extremely low, and partly because of this, and partly due to their very indirect nature, the extent of the environmental benefits of this type cannot be quantified. Another environmental benefit of energy investments is the reduction of air pollution in settlements. However, as the investments in this case replaced the use of natural gas that causes low local air pollutant emissions, the extent of this effect is not significant, although it is undoubtedly demonstrable.

Economic analysis

As a result of developments made in previous years, annual savings of around € 7,500-10,000 (3-4 million HUF) have been achieved. The following costs are calculated based on the energy consumption in 2024 and average energy prices in 2025.

The total investments in renewable power generation systems were € 31,646.

The total investments in renewable heat generation systems were € 5,823.

The annual benefit due to lower use of grid electricity was € 10,208.

The annual benefit due to lower use of fossil fuels was € 992.

The total annual benefit due to lower use of grid electricity and fossil fuels was € 11,200.

The payback period of the investments was 3.3 years.

The net-present value of the sustainable energy investments in the last 5 years was € 89,051.

The total annual economic benefit of the energy investments was € 6,52.

The sustainable energy investments were realized by using own capital at 95% and bank loan at 5%.

2.17 Nagyatád Thermal Spa complex - HUNGARY

The Nagyatád Thermal and Medical Spa welcomes those seeking relaxation and healing all year round with its therapeutic thermal water and various medical treatments. The spa is located in a nature reserve park, where guests can take advantage of the latest medical services with the help of specialist doctors. The indoor area features therapeutic pools with temperatures of 34^{o}C, 38 ^{o}C and 42 ^{o}C, while separate rooms offer baths. The building also has a Finnish sauna and an atrium pool for guests to enjoy. The outdoor pools in the park, like the rest of the spa, are open all year round. The thermal water of Nagyatád has been used for bathing since 1906. The water, which is also suitable for drinking cures, is considered one of the best medicinal waters in the country. The thermal water is excellent for treating rheumatic diseases, joint complaints, rehabilitation after fractures, gynaecological complaints, and stomach problems. It is recommended for drinking cures in cases of hyperacidity, digestive disorders, gallbladder problems, and constipation. Foreign and domestic visitors can take advantage of personalized medical treatments after a medical examination. The Tourist Centre is located in the heart of the city, opposite the main entrance to the spa. The building, which was completely renovated in 2014, also houses numerous exhibitions, as well as the tourist office and the Gift and Local Products Shop. The completely renovated Cultural Centre building was also opened to the public in 2014. The institution has rooms, equipment, and technical devices that meet today's requirements. The Cultural Centre's theatre hall can accommodate 300 people, while the two smaller halls can comfortably seat 80 and 50 people, respectively. Located in the city centre, the institution is a venue for community events, which the staff strive to fill with life and organise programs that bring colour and excitement to the everyday lives of visitors.

Characteristics of the region

Hungary's Southern Transdanubia touristic region covers an area of 12,322.8 km² and is home to 733,802 permanent residents as of 2024. In the same year, the region recorded 1,376,238 bed-nights, resulting in a tourism density of 111.68 bed-nights per km² and a tourism intensity of 1.88 bed-nights per resident.

The Nagyatád area is influenced by two Natura 2000 protected sites. The "Inner Somogy" Special Bird Protection Area covers 563 hectares within the Nagyatád administrative boundaries, while the "Rinyaszentkirály Forest" Special Nature Conservation Area, partially overlapping with the former, covers 228 hectares. The landscape is highly diverse, comprising a mosaic of wooded and treeless communities. Treeless areas include transitional marshes and swamps in depressions, while dry grasslands dominate the tops of sand dunes. Wooded pastures are another characteristic and ecologically valuable feature, though many are currently in poor condition.

The vegetation of the Rinyaszentkirály Forest consists predominantly of various deciduous forest types. English oak (Quercus robur) is the dominant tree species, while higher areas feature oak-ash-elm gallery forests. In periodically flooded zones, older forest communities develop, contributing to the ecological richness and conservation value of the area.

Characteristics of the hotel

The Thermal and Medical Spa occupies a total area of 17,925 m², comprising a built-up area of 3,955 m², other covered spaces of 3,430 m², and green areas of 10,540 m². The facility welcomes approximately 18,072 visitors annually. It utilises around 300,000 m³ of thermal water each year, which emerges at a temperature of 50°C. Since this is higher than the temperatures required for medical baths (34–42°C), the water must be cooled before use. Direct local use of the excess heat is limited due to fluctuating hot water demand and the relatively low temperature level. The temperature of water exiting the pools, averaging 29.5°C, occasionally exceeds regulatory limits, presenting an additional opportunity for heat utilisation.

Although the thermal water well is located immediately adjacent to the spa building, the facility's heating system was previously powered by natural gas and was outdated. To address these challenges, a heat pump system was installed, designed to capture and reuse waste heat from the thermal water. The volume of thermal water available is sufficient to supply four additional nearby buildings, including two municipal offices and two tourist offices. As these buildings are aligned in close proximity, thermal water could be transported to them via pipelines. However, the high maximum temperatures required by the heating systems of these buildings (70–80°C) imposed specific technological demands on the heat pump system. Consequently, the electricity demand for the heat pumps is relatively high, prompting the installation of solar panels on the roofs of all buildings to meet the additional energy requirements. The installation of solar panels faced two main challenges. Firstly, the spa building is a listed structure, restricting panels to flat roof areas and preventing broader energy efficiency modifications. Secondly, regulatory procedures for high-capacity solar systems (above 50 kWp) are complex, limiting the systems to smaller installations. Despite these constraints, the combined heat pump and solar panel system enables effective utilisation of the thermal water while improving the overall energy efficiency of the spa and surrounding buildings.

Local climate characteristics

Annual Solar irradiance: 1,300 kWh.

Annual precipitation rate: 720 mm.

Average annual temperature: 10.5°C.

Description of the energy system

The three buildings (spa, cultural centre, tourist centre) continue to receive their electricity primarily from the national grid. This is supplemented by a solar-PV panel system in all three buildings (15.40 kWp, 20.35 kWp and 50.05 kWp), which was installed primarily to cover the energy needs of the heat pumps. However, the solar panels do not fully cover the additional energy demand, so the project has slightly increased the buildings' electricity consumption. Heating energy and hot water for domestic use are provided entirely by a heat pumps system. The primary heat source is a 250 m^3 buffer storage tank built next to the production well of the Nagyatád Thermal and Medicinal Spa. This reservoir receives water continuously from the overflow of the medicinal pools, periodically in larger quantities when the pools are emptied, and thirdly, the heat generated when the fresh thermal water of the bath is cooled through a heat exchange system. The heat is transported to consumers via a thermal water pipeline, always in the amount required by the buildings. The thermal water pipeline is connected to heat pumps in the machine rooms of the consumer buildings, which are specialized in supplying heat to the institutions' high-temperature radiator heating and hot water systems. With a heat pump designed for the waste heat range, even with a maximum heating flow temperature of 80 °C, SCOP=6.0 is the expected value (whereas with a standard water-to-water heat pump, even at a maximum heating flow temperature of 62 °C, SCOP=4.5 is only possible).

Total annual energy consumption: 995,328 kWh

Specific annual energy consumption: 245 kWh/m^2

Share of fossil fuels in the electricity generation mix: 25%

Share of fossil fuels in the heat generation mix: 0%

Share of fossil fuels in the total energy (heat and electricity) generation mix: 8 %

Characteristics of the energy system

The entire heat pump heating system is energy efficient, and thanks to the control system and buffer storage tanks, it only sends as much energy to users as they need.

The installed power of the solar photovoltaic system is 85.8 kW_p.

The installed heat power of the solar collectors is 530.3 kW_{th}.

Environmental analysis

Annual saving in grid electricity 2,766 kWh

Annual saving in fossil fuels 36.34 tons/year

Annual decrease of CO_2 emissions due to fossil fuels saving 216.26 tCO_2

Annual decrease of CO_2 emissions due to grid electricity saving 121.36 tCO_2

Annual decrease of CO_2 emissions due to fossil fuels and grid electricity saving 337.62 tCO_2

The primary direct environmental benefit of the energy investments made in the facility is the reduction of greenhouse gas emissions that cause climate change. Indirectly, the project contributes to all environmental benefits expected from climate change mitigation (e.g., biodiversity conservation). However, the extent of these latter effects is extremely low, and partly because of this, and partly due to their very indirect nature, the extent of the environmental benefits of this type cannot be quantified. Another environmental benefit of energy investments is the reduction of air pollution in settlements. However, as the investments in this case replaced the use of natural gas that causes low local air pollutant emissions, the extent of this effect is not significant, although it is undoubtedly demonstrable.

Economic analysis

The total investments in renewable power generation systems were € 494,441

The total investments in renewable heat generation systems were € 410,525

The annual benefit due to lower use of grid electricity was € -1,808

The annual benefit due to lower use of fossil fuels was € 23,177

The total annual benefit due to lower use of grid electricity and fossil fuels was € 21,369

The payback period of the investments was 23 years

The total annual economic benefit of the energy investments was € 33,425

The sustainable energy investments were realised with the use of own capital at 53% and the support of public subsidies at 47%.

2.18 Seaside resort Albena - BULGARIA

Albena SA is the largest hotel company in Bulgaria. The company owns three resorts on the Bulgarian Black Sea coast – Albena Holiday Village, Primorsko Holiday Village, and Byalata Laguna Holiday Village. The company manages numerous subsidiaries in industries supporting the main business - transport, medicine and balneology, tour operator activity, agriculture, and construction. Fifty percent of the annual energy consumption in the resort Albena Holiday Village is covered by electricity generated from its own renewable sources. The company began investing in solar water heating systems back in 2007. The management of the company made the decision after precise calculations showing that nearly 35% of each hotel's total energy costs came from water heating. Over time and with experience, these installations have become not only a source of clean solar hot water, but also reservoirs for electricity flexibility – when energy is needed from the grid, the boilers are activated during hours when the price on the Bulgarian electricity market is low. Albena currently has heating installations located on the roofs of selected suitable hotels.

Characteristics of the region

Albena Resort is located in the Varna region, northeastern Bulgaria, occupying part of a 3,818 km^2 coastal area along the Black Sea. The resort is situated near the Baltata Nature Reserve, a protected area under the Natura 2000 network, featuring rare riverine forests, diverse bird species, and a delicate mix of freshwater and marine ecosystems. Albena resort in Bulgaria is primarily a purpose-built tourist complex, not a traditional town. As such, it does not have a permanent residential population in the usual sense. Although Albena does not have a permanent residential population, its surrounding region includes rural communities that depend heavily on tourism and agriculture. The Province of Varna hosts approximately 470,000 inhabitants and serves as a major economic and cultural hub. Tourism intensity in the area is estimated at 498 bed-nights per km^2, indicating a high level of seasonal tourism concentration. Despite this, Albena maintains strict environmental policies to minimise overdevelopment and preserve natural landscapes.

Cultural and Natural Context

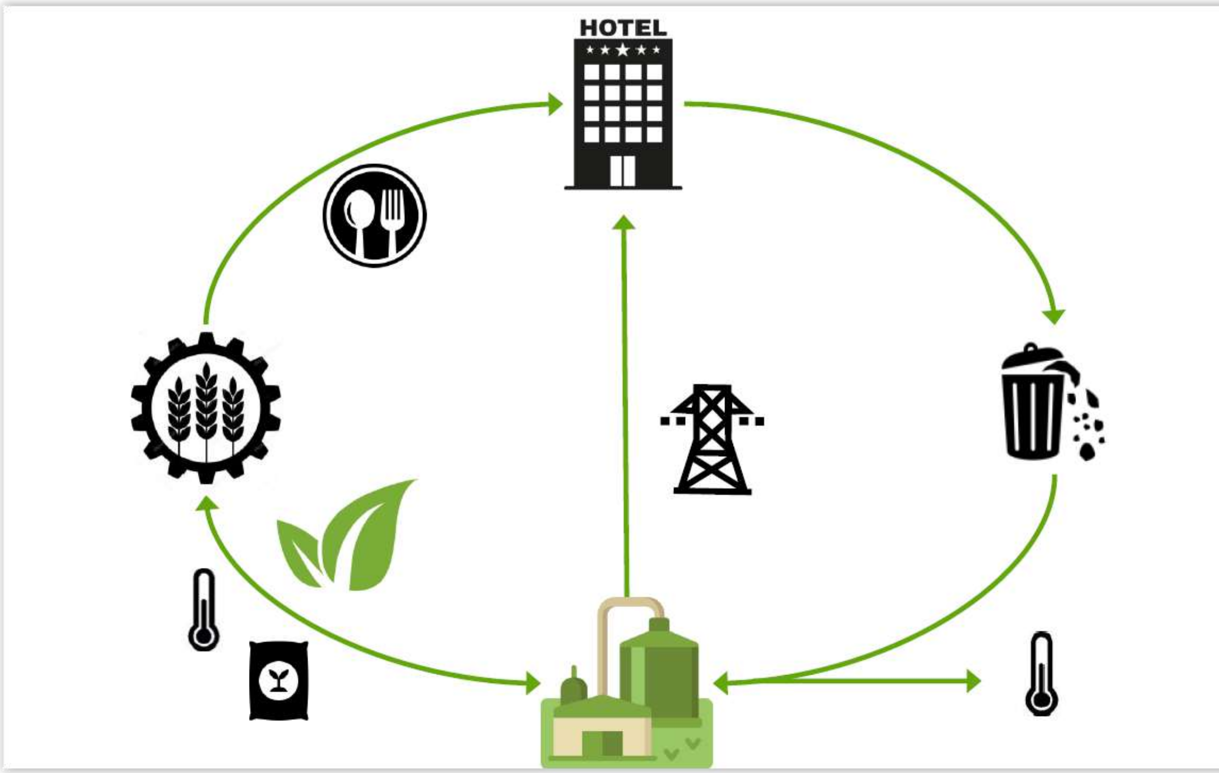
The resort itself does not include in-town historical monuments, but its proximity to Balchik Palace, Cape Kaliakra, and the Aladzha Monastery offers access to significant cultural and historical landmarks. Moreover, the Baltata Reserve, adjacent to the resort, protects unique alluvial forests and wetlands that serve as natural buffers against coastal erosion and provide habitat for numerous bird species. This strong connection between tourism, nature, and heritage underscores Albena's holistic approach to sustainable regional development.

Characteristics of the Albena SA seaside resort

The total surface area of the Albena resort is approximately 700,000 m^2, with a built-up area of around 120,000 m^2. Green spaces - lawns, parks, and natural zones - cover more than 182,000 m^2, creating a balance between urbanized and natural environments. The resort provides 12,909 beds distributed across multiple hotels of different categories. Its annual tourist flow reaches approximately 160,630 visitors, generating over 1,904,101 bed-nights. As part of its integrated management model, Albena SA operates several support sectors, including:

- an organic farm producing fresh food for its restaurants,
- a biogas power plant converting agricultural and food waste into energy,
- a transport company operating electric and low-emission vehicles,
- and an on-site water and waste management facility.

The resort's vision for sustainability is driven by a belief that economic success and ecological responsibility are mutually reinforcing. This approach strengthens Albena's brand image and contributes to Bulgaria's reputation as an emerging green destination. The installation for the production of electricity and heat from biogas is established with the aim of reducing costs, CO_2 emissions, and improving the internal circular economy in the Albena resort. Albena Resort's commitment to sustainability stems from its desire to protect the pristine Black Sea coastal environment, ensure long-term economic viability, and meet growing global expectations for eco-friendly tourism. The resort recognises that preserving natural resources – such as clean air, water, and biodiversity. This is essential not only for the well-being of its visitors but also for the local community that depends on tourism. Environmental degradation, climate change, and resource scarcity motivated Albena to transition toward renewable energy, waste reduction, and energy efficiency. Implementing sustainable practices which enhance the resort's brand reputation, attracting eco-conscious tourists and differentiating Albena in a competitive market. Furthermore, reducing carbon emissions and operational costs aligns with broader EU climate goals and regulatory requirements, enabling access to green funding and partnerships. The resort's seasonal nature causes large fluctuations in energy and water demand, complicating efficient resource management. Balancing high summer occupancy with off-season maintenance requires flexible yet reliable energy systems. Infrastructure modernisation is costly and requires long-term investment, while integrating new technologies, such as biogas plants, solar arrays, and smart grids, demands technical expertise and staff training. Regulatory hurdles and permitting processes impede renewable energy projects. Additionally, educating guests and employees about sustainable behaviours remains ongoing work. Changing habits and perceptions takes time and consistent effort to reduce waste, conserve energy, and promote recycling.



Local climate characteristics

Albena enjoys a humid subtropical coastal climate with warm summers, mild winters, and high solar potential. The region benefits from abundant sunshine throughout the year, ideal for renewable energy generation. The annual solar irradiance in the region of Varna is approximately 1,500 kWh/m². The annual precipitation is 509 mm, while the average annual air temperature is 13°C.

Month	Average temperature
Jan	3.5°C
Feb	4°C
Mar	7.5°C
Apr	11°C
May	16.1°C
Jun	20.1°C

Month	Average temperature
Jul	22.8°C
Aug	23.3°C
Sep	19.5°C
Oct	14.0°C
Nov	8.5°C
Dec	4.2°C

These conditions allow Albena to efficiently utilise solar photovoltaic and solar thermal systems throughout the year, making the region one of the most favourable in Bulgaria for renewable energy integration.

Description of energy systems used in Albina SA seaside resort

Albina Resort utilises a mix of conventional and renewable energy sources, with increasing emphasis on sustainability in recent years. Traditionally, electricity from the national grid, largely powered by fossil fuels (coal and natural gas), has been the primary energy source for hotels, restaurants, and infrastructure. However, Albina SA, the company managing the resort, has actively integrated renewable energy and energy efficiency systems into its operations. A significant component of Albena's energy strategy involves solar power. Several hotels and facilities have installed solar thermal panels for hot water production, reducing reliance on electric or gas boilers. In addition, photovoltaic (PV) systems are being expanded gradually to cover parts of the resort's electricity demand. The region receives high solar irradiance (~1,500 kWh/m² year), making solar energy particularly viable. District heating and centralized cooling systems also contribute to energy management. Some buildings are connected to centralized HVAC systems, which are more efficient than individual units and easier to monitor for energy optimisation. CHP (co-generation of heat and power): In 2013, a 1 MWp biogas plant was built, which annually produces over 8,000 MWh of clean electricity and another 8,000 MWh of clean heat, using silage corn as raw material. In 2022, an additional investment was made to use biodegradable waste as raw material, which also generates savings from reduced amounts of general household waste. Energy consumption is managed through a centralized building management system (BMS) that monitors heating, cooling, lighting, and occupancy in real-time. Smart meters and automation allow facilities to adjust energy use dynamically – particularly important in a seasonal resort with fluctuating occupancy. Furthermore, Albena SA implements ISO 50001 energy management standards, aligning with EU sustainability goals. These practices help to reduce carbon emissions, manage costs, and improve the guest experience through climate-friendly infrastructure. As part of its long-term strategy, Albena aims to transition toward carbon neutrality, integrating more renewables, battery storage, and smart grid solutions across the resort. In Albena resort, over 50% of the energy consumed annually is generated on-site using renewable energy sources. This includes photovoltaic panels on building roofs and a CHP biogas plant. While the exact percentage of fossil fuel usage is not specified, the resort is actively working towards generating all its electricity from renewables.

Characteristics of the energy systems used in Albena SA seaside resort

Albena Resort has developed a comprehensive and forward-thinking energy-saving system that integrates renewable energy, smart monitoring, green mobility, and circular economy principles. It's a testament to how tourism and environmental stewardship can harmonise effectively. Energy consumption is managed through a centralized building management system (BMS) that monitors heating, cooling, lighting, and occupancy in real-time. Smart meters and automation allow facilities to adjust energy use dynamically – particularly important in a seasonal resort with fluctuating occupancy. Energy flows are managed by an intelligent SCADA monitoring system, which optimises energy consumption and reduces reliance on external electricity. Furthermore, Albena SA implements ISO 50001 energy management standards, aligning with EU sustainability goals. These practices help to reduce carbon emissions, manage costs, and improve the guest experience through climate-friendly infrastructure.

Renewable Energy & Smart Monitoring

The resort generates over 50% of its energy needs on-site using a combination of photovoltaic solar panels, solar thermal systems, biogas power, a heat pump, and battery storage. Photovoltaic installations span rooftops with capacities ranging from 1.5 MWp (solar-PV panels) to covering hot water needs via solar collectors. A robust biogas plant converts organic waste (from food and agriculture) into clean energy and high-quality fertilizer, closing the loop in a farm-to-table cycle. Energy flows are managed by an intelligent SCADA monitoring system, which optimises energy consumption and reduces reliance on external electricity.

Green Mobility & Low Emission Infrastructure

Albena restricts car traffic within the resort and relies on electric buses and even an outdoor escalator to limit carbon emissions and improve visitor mobility.

Resource Efficiency & Holistic Management

The resort employs waste separation systems, water monitoring, and an on-site laboratory to ensure high standards in environmental quality and health safety. It maintains a meteorological station to measure sunlight, air and water temperature, UV levels, and air quality—supporting continuous environmental monitoring. For each overnight stay, €1 is contributed to Albena's internal Green Fund to support ongoing sustainable projects. Albena currently has heating installations with over 3,000 kW located on the roofs of several hotels. Albena Resort operates a comprehensive low-carbon emission system integrating renewable energy, smart technology, and sustainable transport. Over 50% of the resort’s energy is produced on-site through photovoltaic solar panels, solar thermal collectors, a CHP biogas plant (from organic and agricultural waste), and heat pump systems. The resort reduces transport emissions by restricting cars and providing electric buses and escalators. Waste is converted into energy and fertilizer, supporting a circular economy. These measures significantly reduce CO_2 emissions and support sustainable tourism.

Environmental analysis

Albina Resort likely offsets approximately 8,000,000 kWh/year of grid electricity use thanks to its solar PV system and biogas CHP generation – this corresponds to more than 50% of its annual electricity demand. Albina Resort avoids burning hundreds of tons of fossil fuel each year, thanks to their solar-PV, solar thermal, and biogas investments—resulting in roughly 800 to 1,000 tCO_2 reduced per year. This aligns with over 50% renewable energy use across their annual electricity needs.

Annual decrease of CO_2 emissions due to fossil fuels saving (tCO_2 /year)

From current analyses (source: REAP), the data for thermal energy is: 0.311 $kgCO_2$/kWh and for natural gas: 0.247 $kgCO_2$/kWh. On an annual basis, the savings in thermal energy amount to 8,000 MWh.

0.311 $kgCO_2$/kWh - 0.247 $kgCO_2$/kWh = 0.064 $kgCO_2$/kWh

0.064 $kgCO_2$/kWh x 8,000 MWh = 512 tCO_2/year of CO_2 emissions due to fossil fuels saving.

Annual decrease of CO_2 emissions due to grid electricity saving (tCO_2/year)

From current analyses (source: REAP), the data for electricity is: 0.616 $kgCO_2$/kWh and for natural gas: 0.247 $kgCO_2$/kWh. On an annual basis, the electricity savings amount to 8,000 MWh.

0.616 $kgCO_2$/kWh – 0.247 $kgCO_2$/kWh = 0.369 $kgCO_2$/kWh

0.369 $kgCO_2$/kWh x 8,000 MWh = 2,952 tCO_2/year of CO_2 emissions due to grid electricity saving.

Annual decrease of CO_2 emissions due to fossil fuels and grid electricity saving (tCO_2/year)

From the previous analyses:

512 tCO_2/year + 2,952 tCO_2/year = 3,464 tCO_2/year of CO_2 emissions due to fossil fuels and grid electricity saving.

These results demonstrate how integrated renewable systems can drastically reduce emissions in large-scale tourism. By using biogas and solar energy, Albena minimises landfill waste, improves local air quality, and promotes a circular economy that turns food and agricultural waste into valuable energy resources. The resort's ongoing environmental monitoring, meteorological station, and laboratory ensure data-driven management of air, water, and soil quality, further contributing to regional ecological preservation.

Economic analysis

Albina SA has invested approximately € 7,311,474 in renewable electricity and heat production installations, including solar and biogas systems. The annual economic benefits are substantial:

- Savings from reduced grid electricity: € 818,000 per year [8,000 GWe_n X € 102,25 per GWe_n]
- Savings from reduced fossil fuel use: € 613,520 per year [8,000 GWh_{th} X € 76,69 per GWh_{th}]
- Total annual benefit due to lower use of grid electricity and fossil fuels: € 1,431,520 (average in the last 5 years).

The estimated payback period for these investments is 5.1 years, reflecting both energy efficiency and cost competitiveness. These sustainable investments not only improve profitability but also strengthen Albena's market position as a leading European eco-resort, appealing to environmentally conscious travellers and investors.

Simplified cost-benefit analysis of the sustainable energy investments

Albina Resort's energy investments have led to significant environmental improvements, positioning it as a model for sustainable tourism in Europe. By generating over 50% of its energy from on-site renewable sources—such as solar panels, biogas, and heat pumps—the resort reduces greenhouse gas emissions and helps combat climate change. These efforts also improve local air quality and reduce reliance on fossil fuels. The use of biogas supports waste reduction by converting organic waste into electricity and fertilizer, promoting circular economy practices. Additionally, the solar thermal systems decrease the need for natural gas or electric heating, further reducing emissions and energy costs. These efforts demonstrate how sustainable tourism can align with energy efficiency and environmental stewardship, setting a model for low-carbon resort operations. The total annual economic benefit of Albina's sustainable energy investments is approximately € 1,431,520 per year, or € 7,157,600 over five years. Beyond financial returns, these investments have yielded far-reaching environmental and social advantages:

- Reduction of over 3,400 tons of CO_2 emissions annually,
- Substantial decrease in fossil fuel dependence,
- Conversion of organic waste into clean energy and natural fertilizer,
- Enhanced environmental image of Bulgaria's Black Sea coast.

Albena stands as a model of how sustainable tourism, green infrastructure, and responsible management can coexist profitably, setting a European benchmark for climate-smart resort operation.

Financial sources used for the sustainable energy investments

Albena SA financed its renewable energy projects primarily through its own capital, demonstrating a strong corporate commitment to sustainability. No bank loans or public subsidies were used for the latest installations. This self-financing model reflects both the economic strength of the company and the profitability of renewable energy investments when applied strategically in tourism.

Albena seaside resort – Key characteristics

Parameter	**Value**
Location	Albena, Varna Region, Bulgaria
Total area	700,000 m^2
Built-up area	120,000 m^2
Green area	182,000 m^2
Capacity	12,909 beds
Annual visitors	160,630
Annual bed-nights	1,904,101
Annual energy consumption	24,000 MWh
Renewable energy share	>50%
Annual CO_2 reduction	3,464 tCO_2
Total investment	€ 7.31 million
Annual economic benefit	€ 1.43 million per year
Payback period	5.1 years

Main energy systems	Solar PV, solar thermal, biogas CHP, SCADA/BMS
Sustainability certifications	ISO 50001 Energy Management
Key sustainability measures	Waste-to-energy, electric mobility, and internal Green Fund

2.19 Catamaran “Burgus” – BULGARIA

The solar-powered tourist catamaran “Burgus” is a sustainable tourism infrastructure developed by the Municipality of Burgas under the project “The Power of Water,” financed through Operational Programme Regions in Growth 2014–2020. With a capacity for 100 passengers, the catamaran represents an innovative product promoting eco-friendly maritime tourism in the Black Sea. The vessel operates regular routes to St. Anastasia Island and Chengene Skele Cultural-Ethnographic Complex, while also offering chartered experiences such as family events, corporate meetings, and team-building activities. Built in 2021 by Galera 07 Ltd., “Burgus” is a 20-meter-long, 7.8-meter-wide aluminium hybrid catamaran with both open and closed decks. Its lower deck features a bar, large presentation screen, and audio-visual systems, ensuring passenger comfort. Equipped with photovoltaic modules of 4.4 kWp, the solar system provides up to 25% of its energy needs, powering critical onboard systems while reducing fuel use and harmful emissions. Over three years, it produced 9 MWh of clean energy, replacing about 2,250 litres of diesel fuel. “Burgus” is the only solar-powered tourist vessel of its kind in Bulgaria, making Burgas the only municipality in the country with two tourist ships. It strengthens the city’s position as a sustainable coastal destination, combining maritime heritage, green innovation, and cultural tourism.

Characteristics of the region

The Tourist Catamaran "Burgus" operates in Burgas Province, situated on the Black Sea coast of Bulgaria, covering an area of 7,748 km^2. The municipality, which comprises 12 settlements, has a population of 211,850 citizens, while the province, which comprises 13 municipalities, has 384,446 citizens. Tourism plays a vital role in the regional economy, with an average of 9,905,089 bed-nights per year and a tourism density of 1,278.41 bed-nights/km^2, indicating Burgos's strong position as a key coastal tourism hub.

Historical and Religious Monuments

Burgos Province offers a diverse cultural heritage, with Nosebag standing out as a UNESCO World Heritage Site. Its medieval churches, such as St. Sofia and Christ Pantocrator, reflect Byzantine traditions and attract visitors worldwide. Sozopol, one of the oldest towns on the Black Sea coast, preserves Thracian, Greek, and Roman remains, as well as Orthodox churches and monasteries. Inland, smaller religious sites such as Ahtopol Monastery and chapels scattered in the Strandzha region testify to centuries of spiritual tradition. The province also features Ottoman-era mosques and Bulgarian Revival houses, highlighting its multicultural history. Together, these monuments form a rich mosaic of civilizations, making Burgas a unique blend of ancient heritage and modern tourism.

Fragile Natural Ecosystems (Natura 2000 Areas)

Burgas Province hosts some of the most important NATURA 2000 protected areas in Bulgaria, particularly around the coastal lagoons and wetlands. The Burgas Lakes complex (Atanasovsko, Vaya, Mandra) is a key site for biodiversity, home to over 250 bird species, including globally endangered ones like the Dalmatian pelican and the Pygmy cormorant. Strandzha Nature Park, part of the European ecological network, protects rare habitats, rivers, and forest ecosystems, where Mediterranean and continental flora meet. The coastal sand dunes near Nessebar and Pomorie, together with the salt marshes, are fragile ecosystems under strict protection. Tourism development in these areas requires careful management to balance visitor access and conservation. These ecosystems make Burgas not only a cultural but also an eco-tourism hotspot.

Characteristics of the tourist catamaran "Burgus"

Engines - The ship is powered by two 80 cm diameter propellers and two IVECO Marine Diesel main engines with a total power of 550 kW, which provide it with a maximum speed of 14 knots. Power is supplied by a single IVECO Marine Diesel generator with a capacity of 40 kW and photovoltaic panels.

- Length: 20 meters,
- Width: 7.8 meters,
- Deck height: 2.40 meters,
- Draft: 0.99 meters,
- Gross tonnage: 112, displacement 55.38 tons

The total covered area of the catamaran is approximately 156 m², including 100 m² closed area (lower deck, indoor facilities) and 56 m² open deck. The green area of 16 m² corresponds to the solar PV modules installed on the roof. While the vessel does not provide overnight accommodation, it welcomes an average of 25,000 visitors annually, strengthening the eco-tourism profile of Burgas.

	From Sept 2021	2022	2023	2024	To the 8th of Sept 2025
Ship "Burgus"	676	25,071	26,034	26,614	24,997

The Municipality of Burgas implemented sustainable practices on “Burgus” to reduce environmental impact, enhance tourism competitiveness, and diversify its cultural tourism offer. As a coastal city with strong traditions in maritime tourism, Burgas identified the need to integrate green technologies to meet modern sustainability standards and EU climate goals. The photovoltaic system on “Burgus” generates clean electricity, covering up to 80% of critical systems and reducing diesel dependence. This approach not only saves operational costs but also showcases Burgas as a forward-thinking, eco-friendly destination. Challenges include the relatively limited capacity of current photovoltaic modules, which cover only a fraction of total energy needs. Weather dependence and seasonal fluctuations also reduce efficiency. Expanding the solar system requires significant investment and technological adaptation. Another challenge is raising awareness among tourists and operators about the benefits of renewable energy in tourism. Despite these, the project demonstrates how innovation and sustainability can reinforce Burgas’s brand as a modern and responsible tourist hub.

Local climate characteristics

The annual solar irradiance in Burgas is approximately in the range of 1,350 kWh/m² to 1,750 kWh/m², placing it in a region with sufficient solar radiation for energy production. The annual precipitation is 550 mm, while the average annual air temperature is 14°C.

Month	**Average temperature**
Jan	4.2°C
Feb	3.8°C
Mar	7.9°C
Apr	11.2°C
May	15.8°C
Jun	19.8°C

Month	**Average temperature**
Jul	23.1°C
Aug	23.1°C
Sep	19.6°C
Oct	10.8°C
Nov	9.7°C
Dec	3.0°C

These climatic conditions ensure optimal operation of solar energy systems, supporting the integration of renewable technologies in maritime tourism infrastructure.

Description of energy systems used in the tourist catamaran "Burgus"

"Burgus" uses a hybrid energy system combining grid electricity (when docked), diesel generators, and solar photovoltaic modules. The vessel is powered primarily by a 40 kW IVECO Marine Diesel generator, providing propulsion and backup energy. To reduce emissions, a 4.4 kWp photovoltaic system was installed in 2021, consisting of 10 Longi 370 Wp modules and 4 Victron Energy 175 Wp modules. This system powers essential loads such as navigation equipment, lighting, and communication systems. Over three years, it produced 9 MWh of electricity, replacing about 2,250 litres of diesel fuel. The hybrid setup allows continuous operation, with the solar system covering around 20–25% of critical energy needs. When docked, the catamaran can also use grid electricity for recharging and auxiliary power. Burgas Municipality plans potential expansion to a 30.8 kWp system, which could generate over 100 MWh in three years and cover a larger share of energy demand. This demonstrates a practical approach to sustainable energy in maritime tourism, reducing carbon footprint while ensuring operational reliability.

Characteristics of the energy systems used in the tourist catamaran "Burgus"

The tourist catamaran "Burgus" integrates several energy-saving measures that optimise its hybrid operation and reduce overall consumption. One of the key systems is the use of LED lighting throughout the vessel. Compared to conventional lighting, LED fixtures consume up to 70% less electricity while providing higher durability and better illumination, which is particularly important for night cruises and passenger safety. In addition, the vessel is equipped with an optimised hybrid energy management system that coordinates the use of photovoltaic panels, batteries, and the diesel generator. The onboard control system ensures that critical loads (navigation equipment, communication systems, lighting, and safety devices) are primarily powered by solar energy when available. Batteries store excess energy and release it when solar input is insufficient, reducing reliance on the generator. The integration of photovoltaic generation with intelligent load prioritization leads to more efficient use of renewable energy, minimising unnecessary generator runtime. This results in fuel savings of up to 20–25% for onboard systems, lower CO_2 emissions, and reduced noise pollution, which enhances passenger comfort. Together, these energy-saving measures demonstrate how green technologies can be successfully applied in maritime tourism, setting a good example for sustainable practices in coastal destinations.

Environmental analysis

Over three years of operation, Burgos has produced 9 MWh of renewable electricity, covering around 80% of onboard critical systems. This achievement resulted in the following data:

Indicator	**Value**
Annual savings in grid electricity	~3,000 kWh/year
Annual savings in fossil fuels	~750 litres diesel (~0.65 tons)
Annual CO_2 reduction from fossil fuels	0.192 tCO_2
Annual CO_2 reduction from grid electricity	1,107 tCO_2
Total annual CO_2 reduction	1,299 tCO_2

The solar-PV system contributes directly to cleaner air, reduced noise, and decreased marine pollution, aligning with the EU Green Deal and the 2030 Climate Targets.

Economic analysis

The total investment in the solar photovoltaic system is approximately €20,000. The annual economic benefits are estimated at:

- € 600 per year from reduced grid electricity use.
- € 900 per year from reduced fossil fuel consumption.

This results in a total average benefit of € 1,500 per year, corresponding to a payback period of approximately 13 years. Although the return period is moderate, the environmental and social benefits — lower emissions, enhanced tourist satisfaction, and improved destination branding — make the project economically and socially viable.

Simplified cost-benefit analysis of the sustainable energy investments

The installation of a photovoltaic system on the tourist catamaran “Burgus” has delivered multiple environmental benefits, demonstrating the value of renewable energy in maritime tourism. By generating clean electricity directly on board, the system significantly reduces the vessel’s dependence on diesel fuel. Over a three-year period, the PV modules produced approximately 9 MWh of electricity, replacing the combustion of about 2,250 litres of diesel. This translates into an annual reduction of around 3.2 tCO_2 emissions, contributing directly to climate change mitigation. In addition to lowering greenhouse gases, the system reduces local air pollutants such as nitrogen oxides and particulate matter, which are typically emitted by marine engines. Less engine runtime also means lower noise levels, which improves passenger comfort and reduces disturbance to marine and coastal ecosystems. The shift towards renewable energy aligns with EU sustainability goals and highlights Burgas as a model for green innovation in coastal tourism. Overall, these energy investments not only improve operational efficiency but also protect fragile ecosystems, enhance the city’s environmental profile, and raise awareness among tourists about the importance of clean energy in preserving the Black Sea environment.

Financial sources used for the sustainable energy investments

The investments were financed entirely through public funds within the "Power of Water" Project and the Municipality of Burgas.

Source	Participation	Amount
Operational Programme "Regions in Growth 2014–2020"	100%	1,558,800 BGN
Municipality of Burgas (own contribution)	100%	69,900 BGN

The project demonstrates the successful application of EU and municipal financial instruments in advancing renewable energy and sustainable tourism infrastructure.

Tourist catamaran "BURGUS" – Key characteristics

Parameter	Value
Location	Burgas, Bulgaria
Type	Solar-powered hybrid tourist catamaran
Capacity	100 passengers
Total area	156 m^2
Solar-PV capacity	4.4 kWp

Annual solar-PV production	3,000 kWh
Fuel savings	750 lit diesel/year
Annual CO_2 reduction	1.3 t CO_2
Investment cost	€ 20,000
Annual benefit	€ 1,500
Payback period	13 years
Main energy sources	Solar PV, diesel generator, grid electricity (when docked)
Energy efficiency features	LED lighting, hybrid management system, onboard batteries
Environmental impact	Reduced emissions and noise, improved air quality

3. List of the sustainable energy technologies used in tourism entities

	Country	Type of tourism entity	Size of tourism entity	Sustainable energy systems involved	Payback period
1	Slovenia	Hotel	Small	Building envelope insulation, LED lights, Heat pumps	10 years
2	Slovenia	Culture centre – old historical building	Small to medium	High efficiency heat pumps, Resource consumption optimisation system	25 years
3	Greece	Hotel	Small	Solar collectors, Solar-PV panels, LED lights, Heat pump, Energy saving systems	6.95 years
4	Greece	Hotel	Small	Solar collectors, Solar-PV panels, LED lights, Heat pump	5.24 years
5	Greece	Hotel	Small	Solar-PV, solid biomass, electric batteries	Not estimated
6	Malta	Hotel	Large	Solar-PV panels, BEMS, LED lights,	5 years for the solar-PV

				Seawater chillers, Heat pump	system, 25 years for the other systems
7	Malta	Hotel	Large	Building insulation, BEMS	5-6 years
8	Malta	Hotel	Large	Heat pumps, solar-PV, solar thermal collectors, BEMS	5 years
9	Malta	Hotel	Small	Building insulation, passive energy measures, solar water heating	6 years
10	Finland	Leisure centre-Olympic training centre	Large	Solar-PV panels, geothermal heating, LED lights, modern HVAC system	6.9 for the solar-PV system, 15 years for the geothermal system
11	Finland	Hotel	Small	Heat pumps	6.4 years
12	Italy	Cultural hub-cinema	Small	Well ins stated building envelope, Solar-PV panels, LED lights, Heat pumps	8.5 years
13	Holland	Theater and restaurant	Medium	Solar-PV panels, heat pump, battery storage	Not estimated

14	Holland	Wellness centre	Small	Solar-PV panels, building insulation, energy management system	Not estimated
15	Hungary	Eco-tourism visitor centre	Small	LED lights, wood gasification boiler system	1 year
16	Hungary	Hotel and restaurant	Small	Solar thermal collectors, Solar-PV panels, LED lights, BEMS	3.3 years
17	Hungary	Thermal Spa and medical complex	Large	Solar-PV system, heat pumps, low-enthalpy geothermal energy	23 years
18	Bulgaria	Summer resort	Large	Solar-PV system, CHP with biogas, Solar thermal collectors, BEMS	5.1 years
19	Bulgaria	Tourist boat	Medium	Solar-PV system	13 years

Sustainable energy systems used in tourism entities studied

The following sustainable energy technologies were used in the abovementioned hotels and tourism facilities.

1. Energy Saving Achieved with Insulation of the Building Envelope
2. Solar Photovoltaic systems
3. Solar Thermal Systems for Hot Water Production
4. High-Efficiency Heat Pumps
5. Geothermal Heat Pumps
6. Solid Biomass Burning Systems for hot water production
7. Energy Management Systems
8. LED Lighting systems
9. Modern and energy efficient HVAC Systems
10. Seawater Chillers
11. Electric Batteries
12. Heat and power cogeneration systems using biogas
13. Wood Gasification Boiler Systems for Heat generation
14. Green roof
15. Waste heat recovery and reuse

4. Lessons learnt from the hotels and other tourism entities studied

The lessons learnt from the study of the abovementioned hotels and tourist entities can be summarised as follows:

1. Several sustainable energy technologies can be used in tourism-related enterprises in European regions reducing their carbon footprint and their environmental impacts.
2. Solar photovoltaic systems, solar thermal systems and high efficiency heat pumps are the most popular sustainable energy systems used in tourism-related enterprises in European regions.
3. Sustainable energy investments in tourism-related enterprises are financially supported and subsidized by national and EU funds.
4. The sustainable energy investments in the abovementioned tourism-related enterprises are mainly financed by own capital, bank loans and public subsidies.
5. In most cases the payback period of the energy investments was attractive.
6. Involvement of energy saving companies or energy cooperatives in the realisation of the energy investments in tourism entities was not noticed.
7. The aim of the tourism-related enterprises studied in the current survey is the reduction of the fossil fuels used and their carbon emissions. The majority of them did not try to eliminate all their carbon emissions achieving carbon neutrality.
8. The most of the identified sustainable energy technologies in tourism-related enterprises can be replicated in other European regions. These energy technologies include a) energy saving technologies, b) technologies using locally available renewable energy sources, and c) high efficiency energy technologies.

5. An overview of the sustainable energy technologies used in the abovementioned tourism entities

Energy Saving Achieved with Insulation of the Building Envelope

Energy efficiency has become a central concern in modern building design, with insulation of the building envelope playing a crucial role in reducing energy consumption. The building envelope—comprising walls, roofs, floors, windows, and doors—acts as the barrier between indoor and outdoor environments. Proper insulation minimises unwanted heat transfer through these elements, significantly reducing the need for mechanical heating and cooling. In cold climates, insulation helps retain indoor heat during winter, preventing energy losses through conduction and air leakage. Conversely, in hot climates, insulation restricts external heat from entering the building, reducing the load on air conditioning systems. This dual benefit ensures year-round comfort while lowering utility costs. Studies show that effective insulation can cut heating and cooling energy demands by up to 30–50%, depending on the building's design and local climate. Beyond direct energy savings, insulating the building envelope contributes to environmental sustainability. Lower energy use translates to reduced fossil fuel consumption and greenhouse gas emissions, supporting global efforts to mitigate climate change. Moreover, improved insulation enhances indoor comfort by maintaining stable temperatures and reducing drafts or cold spots. Various materials—such as mineral wool, polyurethane foam, cellulose, and rigid foam boards—are used depending on application and performance requirements. Advances in insulation technology, including reflective and phase-change materials, further enhance efficiency. Retrofitting existing buildings with improved insulation is one of the most cost-effective strategies for achieving large-scale energy savings in the built environment. Therefore, insulation of the building envelope is a fundamental measure for energy conservation. It not only reduces operational costs and environmental impact but also improves occupant comfort and building performance, making it an essential component of sustainable construction practices.

The Use of Solar Photovoltaics in Hotels

The hospitality industry is a major consumer of energy, with hotels requiring large amounts of electricity for lighting, air conditioning, heating, water pumping, and other services that ensure guest comfort. As sustainability becomes a growing priority, many hotels are turning to solar photovoltaic (PV) systems as a clean and cost-effective energy solution. Solar PV technology converts sunlight directly into electricity using semiconductor materials. By installing PV panels on rooftops, façades, or nearby open spaces, hotels can generate a significant portion of their electricity demand on-site. This reduces dependence on grid electricity, lowers energy bills, and protects hotels from fluctuating utility prices. In regions with abundant sunlight, such as the Mediterranean, the Middle East, and parts of Asia and Africa, solar energy can cover up to 30–60% of a hotel's total electricity consumption. Beyond economic benefits, solar-PV systems greatly enhance a hotel's environmental performance. By producing renewable energy, hotels can reduce their carbon footprint and contribute to climate change mitigation. This aligns with growing consumer demand for eco-friendly accommodations, strengthening a hotel's brand image and competitive advantage. Many international hotel chains now integrate solar energy into their sustainability strategies, achieving certifications such as LEED or Green Globe. Additionally, combining PV systems with energy storage technologies allows hotels to operate more efficiently and reliably, even during peak demand or power outages. The long lifespan of solar panels—typically over 25 years—further increases the return on investment. Therefore, the adoption of solar photovoltaics in hotels offers substantial economic, environmental, and reputational benefits. By harnessing clean solar energy, hotels can reduce operational costs, support global sustainability goals, and provide guests with a greener and more responsible hospitality experience.

The Use of Solar Thermal Systems in Hotels for Hot Water Production

Hotels are among the most energy-intensive buildings due to their continuous demand for hot water in guest rooms, kitchens, laundries, and swimming pools. To meet this demand sustainably, many hotels are adopting solar thermal systems as an efficient and environmentally friendly solution for hot water production. Solar thermal systems capture the sun's energy through solar collectors—typically flat-plate or evacuated tube types—which heat a working fluid that transfers heat to water stored in insulated tanks. This technology is highly suitable for hotels, as they have both large roof areas for collector installation and consistent daily hot water consumption. By using solar energy instead of conventional fuels like electricity, gas, or diesel, hotels can significantly reduce their energy bills and operational costs. In regions with high solar radiation, properly designed solar thermal systems can supply up to 60–80% of a hotel's annual hot water demand. This not only leads to considerable cost savings but also reduces dependence on fossil fuels, thereby lowering greenhouse gas emissions. The systems are relatively low-maintenance, have a lifespan exceeding 20 years, and can be integrated with auxiliary heating systems to ensure a reliable supply during cloudy periods or high-demand times. Beyond economic and environmental advantages, adopting solar thermal technology enhances a hotel's sustainability profile. Tourists are increasingly seeking eco-friendly accommodations, and the visible use of renewable energy improves a hotel's reputation and marketability. Many green certification programs, such as LEED or Green Key, also recognise solar water heating as a key measure for sustainable operation. Therefore, solar thermal systems represent a practical and cost-effective solution for meeting the hot water needs of hotels. By harnessing solar energy, hotels can achieve significant energy savings, reduce carbon emissions, and demonstrate genuine commitment to sustainable hospitality.

The Use of High-Efficiency Heat Pumps in Hotels

Energy efficiency and sustainability are becoming key priorities in the hospitality sector, as hotels strive to reduce operational costs and minimise their environmental impact. One of the most effective technologies for achieving these goals is the use of high-efficiency heat pumps for heating, cooling, and hot water production. Heat pumps operate by transferring heat from one place to another rather than generating it directly through combustion or electrical resistance. This process makes them significantly more efficient than conventional systems. For every unit of electricity consumed, a high-efficiency heat pump can deliver three to five units of heating or cooling energy. In hotels, where the demand for space conditioning and hot water is continuous, this efficiency translates into substantial energy savings and lower utility costs. Modern heat pumps can serve multiple functions within a hotel. Air-source heat pumps are suitable for moderate climates, while water-source and ground-source (geothermal) systems provide even higher efficiencies, particularly in large hotel complexes. Many installations use heat recovery technology, allowing waste heat from cooling processes—such as from air conditioning or refrigeration—to be reused for domestic hot water or pool heating. This integrated approach maximises energy utilisation and reduces overall consumption. Beyond economic advantages, high-efficiency heat pumps support environmental sustainability by reducing greenhouse gas emissions. When combined with renewable electricity, such as solar or wind power, they enable near-zero-carbon operation. Additionally, their quiet operation and compact design make them ideal for hotel environments where comfort and aesthetics are important. Therefore, high-efficiency heat pumps offer hotels a versatile, cost-effective, and environmentally responsible solution for thermal energy management. By adopting this technology, hotels can achieve significant reductions in energy use, operational costs, and carbon emissions—while enhancing comfort and demonstrating leadership in sustainable hospitality.

The Use of Geothermal Heat Pumps in Hotels

Among the most efficient technologies available today are geothermal heat pumps (GHPs), which utilise the stable temperature of the ground to provide heating, cooling, and hot water for hotels. Unlike conventional air-source systems that rely on fluctuating outdoor air temperatures, geothermal heat pumps exchange heat with the earth through underground loops filled with water or a refrigerant. Because ground temperatures remain relatively constant throughout the year, typically between 10°C and 16°C, these systems operate with very high efficiency. For every unit of electricity consumed, a geothermal heat pump can deliver three to six units of heating or cooling energy, resulting in significant reductions in energy bills and carbon emissions. In hotels, geothermal systems can provide space heating and cooling, domestic hot water, and even pool heating. Large properties benefit greatly from this technology because of their steady year-round energy demands. Additionally, geothermal systems can be designed with heat recovery functions, allowing waste heat from cooling operations to be reused for water heating, further improving overall system efficiency. Although the initial installation cost of geothermal systems is higher than that of conventional HVAC systems, the long-term savings in energy and maintenance quickly offset the investment. The systems have a lifespan exceeding 25 years for indoor components and over 50 years for underground loops. Beyond economic benefits, geothermal heat pumps contribute to a hotel's sustainability goals by minimising greenhouse gas emissions and reliance on fossil fuels. Their quiet operation and ability to maintain stable indoor temperatures also enhance guest comfort. Therefore, geothermal heat pumps represent a highly efficient and environmentally responsible solution for hotels, offering long-term economic savings, superior comfort, and a strong commitment to sustainable hospitality.

The Use of Solid Biomass Burning Systems in Hotels

One effective and environmentally responsible solution is the use of solid biomass burning systems, which utilise organic materials such as wood pellets, chips, or briquettes to produce heat for space heating and hot water. Solid biomass systems operate by burning sustainably sourced biomass in high-efficiency boilers or furnaces. The generated heat is transferred to water or air, which is then distributed throughout the hotel for heating or domestic hot water needs. This technology is particularly suitable for hotels located in rural or forested areas, where biomass fuel is locally available and cost-effective. The key advantage of biomass systems lies in their ability to provide a carbon-neutral energy source. The carbon dioxide released during combustion is approximately equal to the amount absorbed by the plants during their growth, resulting in a closed carbon cycle. By replacing oil, gas, or coal boilers, hotels can significantly reduce their greenhouse gas emissions and improve their environmental performance. From an economic perspective, biomass fuels are often cheaper and more stable in price compared to fossil fuels. Although the initial investment in biomass boilers and storage facilities can be relatively high, the long-term fuel savings and potential government incentives make them financially attractive. Additionally, the use of local biomass supports regional economies and creates green jobs. Modern biomass systems are equipped with advanced controls, automated fuel feeding, and efficient combustion technologies, ensuring clean operation and minimal emissions. Therefore, solid biomass burning systems offer hotels a reliable, renewable, and sustainable energy solution. By adopting biomass heating, hotels can lower energy costs, reduce carbon emissions, and demonstrate a strong commitment to environmental responsibility and sustainable tourism.

The Use of Energy Management Systems in Hotels

Energy Management Systems (EMS) have become essential tools for improving energy efficiency and sustainability in the hospitality sector. Hotels, which operate around the clock, consume large amounts of energy for lighting, heating, cooling, ventilation, and other guest services. Implementing an EMS allows hotel operators to monitor, control, and optimise energy use across all facilities, leading to significant cost savings and environmental benefits. An EMS integrates various building systems—such as HVAC, lighting, and water heating—into a centralized platform that collects real-time data on energy consumption. Through sensors, smart meters, and automation software, the system identifies inefficiencies, detects faults, and adjusts operations according to occupancy patterns and environmental conditions. For example, it can automatically reduce air conditioning or lighting in unoccupied rooms, regulate water temperature, or manage peak electricity loads. The use of EMS in hotels can lead to energy savings of 20–40%, depending on the size and complexity of the building. Beyond direct energy reduction, these systems also improve guest comfort by maintaining optimal indoor conditions while minimising waste. Additionally, data collected from EMS platforms can support sustainability reporting, helping hotels achieve green building certifications such as LEED, ISO 50001, or Green Key. Economically, while the initial installation of an EMS involves some investment, the payback period is often short due to substantial reductions in utility costs. Moreover, energy-efficient operation enhances the hotel's corporate image and attracts environmentally conscious guests. In conclusion, Energy Management Systems represent a powerful solution for hotels aiming to balance guest comfort with operational efficiency and environmental responsibility. By harnessing real-time data and automation, hotels can achieve significant energy savings, lower emissions, and strengthen their position as leaders in sustainable hospitality.

The Use of LED Lighting in Hotels

Lighting plays a crucial role in the hospitality industry, influencing not only the aesthetics and comfort of hotel spaces but also overall energy consumption. In recent years, the adoption of Light Emitting Diode (LED) lighting has become a key strategy for hotels aiming to reduce energy use, operational costs, and environmental impact. LED lighting is highly energy-efficient, consuming up to 80% less electricity than traditional incandescent or halogen lamps while providing the same or better quality of illumination. Given that lighting can account for 20–40% of a hotel's total electricity consumption, switching to LEDs offers substantial savings. Additionally, LEDs have an exceptionally long lifespan—often exceeding 50,000 hours—reducing the frequency of replacements and maintenance costs, which is especially beneficial in large hotels with extensive lighting systems. Beyond energy efficiency, LED lighting enhances the guest experience by offering greater design flexibility and control. Modern LED systems can be dimmed or colour-tuned to create different atmospheres in guest rooms, lobbies, restaurants, and outdoor areas. When integrated with smart lighting controls or Energy Management Systems, LEDs can automatically adjust based on occupancy or daylight availability, further improving efficiency. Environmentally, LEDs contribute to sustainability by reducing greenhouse gas emissions associated with electricity generation and by eliminating hazardous materials such as mercury found in fluorescent lamps. Many hotels implementing LED lighting have achieved green certifications and improved their public image as eco-friendly establishments. Therefore, the use of LED lighting in hotels represents a practical and impactful step toward energy conservation and sustainability. By combining efficiency, longevity, and superior lighting quality, LEDs help hotels lower operating costs, enhance guest satisfaction, and demonstrate a strong commitment to responsible and modern hospitality practices.

The Use of Modern HVAC Systems in Hotels

Heating, Ventilation, and Air Conditioning (HVAC) systems are vital components in hotels, directly influencing guest comfort, indoor air quality, and energy efficiency. As sustainability and cost-effectiveness become top priorities in the hospitality industry, many hotels are adopting modern HVAC systems that combine advanced technology, automation, and energy-efficient design. Modern HVAC systems are engineered to deliver optimal thermal comfort while minimising energy consumption. Technologies such as variable refrigerant flow (VRF), heat recovery systems, and demand-controlled ventilation allow hotels to tailor heating and cooling to occupancy levels and real-time conditions. By using smart sensors and automated controls, these systems can adjust temperature and airflow in individual rooms or zones, reducing waste and improving operational efficiency. Energy recovery ventilators (ERVs) and high-efficiency chillers further enhance performance by reclaiming waste heat and reducing electricity use. Integration with Building or Energy Management Systems (BMS/EMS) enables centralized monitoring and precise control of indoor environments. This integration not only improves energy performance but also simplifies maintenance through predictive analytics and fault detection. From an environmental perspective, modern HVAC systems significantly reduce greenhouse gas emissions by lowering energy demand and using eco-friendly refrigerants with low global warming potential (GWP). Many hotels incorporating these systems achieve green certifications such as LEED or ISO 50001, demonstrating their commitment to sustainable operations. Economically, although advanced HVAC installations require higher upfront investment, the long-term benefits—such as lower energy bills, reduced maintenance costs, and enhanced guest satisfaction—ensure a favourable return. Additionally, improved indoor air quality contributes to guest well-being and positive reviews, which are crucial for hotel reputation. Therefore, the adoption of modern HVAC systems enables hotels to achieve superior comfort, energy efficiency, and environmental responsibility. These systems represent a cornerstone of sustainable and intelligent hotel design in the modern era.

The Use of Seawater Chillers in Hotels

In coastal regions, hotels often face high energy demands for cooling due to warm climates and year-round occupancy. To enhance energy efficiency and sustainability, many seaside hotels are adopting seawater chiller systems as an innovative solution for air conditioning and cooling needs. These systems utilise the natural cooling capacity of seawater to improve the performance of conventional refrigeration processes while reducing environmental impact. Seawater chillers operate by using seawater as a heat sink in the chiller's condenser stage. Instead of rejecting heat to the atmosphere through cooling towers, the system transfers it to seawater, which is continuously available and maintains a stable temperature throughout the year. This process enhances the overall coefficient of performance (COP) of the chiller, leading to lower energy consumption compared to air-cooled or traditional water-cooled systems. For hotels, the benefits are significant. Energy savings of 20–30% can often be achieved, depending on local water conditions and system design. The elimination of cooling towers also reduces water consumption, maintenance needs, and the risk of issues such as Legionella growth. Additionally, seawater chillers contribute to quieter operation and a smaller footprint, making them ideal for luxury coastal resorts where guest comfort and aesthetics are priorities. From an environmental standpoint, these systems lower greenhouse gas emissions by reducing electricity use and make efficient use of a renewable natural resource. When combined with modern control technologies, such as variable-speed drives and automated monitoring, they offer reliable and adaptive cooling performance even under varying load conditions. Therefore, the use of seawater chillers in hotels represents a sustainable and energy-efficient approach to meeting cooling demands in coastal environments. By harnessing the natural thermal stability of seawater, hotels can reduce energy costs, minimise environmental impact, and enhance operational sustainability.

The Use of Electric Batteries in Hotels

As the hospitality industry moves toward sustainability and energy efficiency, electric battery systems are emerging as a transformative technology for hotels. These batteries, often paired with renewable energy sources such as solar panels, allow hotels to store electricity and use it strategically, reducing both costs and environmental impact. Hotels are significant energy consumers, operating 24 hours a day with constant demands for lighting, heating, cooling, and electronic devices. Traditionally, this energy comes from the grid, which can be expensive and carbon-intensive during peak hours. By installing electric battery storage systems, hotels can store cheap or renewable electricity during off-peak periods and use it when grid prices or demand are high, optimising energy costs and reducing strain on the power network. Moreover, batteries provide energy resilience. In regions prone to power outages or unstable grids, hotels can maintain essential services such as elevators, refrigeration, and emergency lighting. This ensures guest comfort and safety even during blackouts. Combined with renewable generation, such as rooftop solar panels, battery systems can even allow hotels to operate partially “off grid,” lowering their carbon footprint and enhancing their sustainability credentials. In addition to environmental and operational benefits, battery systems also improve a hotel’s market image. Modern travellers increasingly value eco-friendly accommodations, and energy-efficient technologies demonstrate corporate responsibility and innovation. Furthermore, as governments and cities introduce stricter emissions regulations and incentives for clean energy adoption, battery integration positions hotels ahead of compliance requirements. In summary, electric batteries offer hotels a path toward energy independence, cost efficiency, and environmental stewardship. By adopting energy storage solutions, the hospitality sector can not only lower its operational expenses but also contribute meaningfully to global sustainability goals—creating a smarter, greener, and more resilient future for tourism.

The Use of CHP Systems Consuming Biogas in Hotels

Combined Heat and Power (CHP) systems, also known as cogeneration systems, are an increasingly popular solution for improving energy efficiency in the hospitality sector. When fuelled by biogas, these systems offer hotels a sustainable and cost-effective way to produce both electricity and heat on-site, significantly reducing dependence on conventional energy sources and lowering greenhouse gas emissions. CHP systems operate by simultaneously generating electricity and capturing the waste heat produced during that process. In traditional power generation, this heat is usually lost, but in a hotel setting, it can be repurposed for water heating, space heating, or even pool and spa facilities. When powered by biogas—a renewable fuel derived from organic waste such as food scraps, sewage, or agricultural residues—the system achieves near carbon neutrality, aligning hotel operations with global sustainability targets. Hotels are ideal candidates for CHP with biogas due to their steady, year-round energy demand for heating, hot water, and electricity. By producing energy on-site, hotels can reduce utility costs, minimise transmission losses, and maintain power reliability during grid outages. Additionally, using locally produced biogas promotes a circular economy by turning waste into valuable energy, especially in resorts or rural hotels with access to organic waste streams. Beyond operational benefits, adopting CHP systems enhances a hotel's environmental reputation. Eco-conscious guests increasingly prefer establishments that demonstrate responsible energy practices. By integrating biogas-fuelled CHP technology, hotels can reduce their carbon footprint, achieve sustainability certifications, and appeal to this growing market segment. Therefore, CHP systems using biogas represent an innovative pathway toward cleaner, more resilient hotel operations. They combine economic efficiency with environmental responsibility—helping hotels cut emissions, manage energy costs, and contribute to a more sustainable hospitality industry.

The Use of Wood Gasification Boiler Systems for Heating in Hotels

As the hospitality industry seeks sustainable alternatives to fossil fuels, wood gasification boiler systems have emerged as an efficient and renewable solution for hotel heating. These systems utilise biomass, primarily wood logs or chips, to produce heat through a two-stage combustion process that maximises energy output while minimising emissions. In a wood gasification boiler, wood is first heated in a low-oxygen environment, releasing combustible gases such as carbon monoxide and hydrogen. These gases are then burned at high temperatures in a secondary chamber, achieving clean and complete combustion. The result is a highly efficient system that can reach thermal efficiencies of over 85%, significantly outperforming traditional wood-burning boilers. For hotels, this means reliable and cost-effective heating for guest rooms, hot water supply, and spa facilities. Using locally sourced wood as fuel supports regional forestry industries and reduces dependence on imported fossil fuels. This not only lowers operating costs but also contributes to carbon neutrality, since the CO_2 released during combustion is roughly balanced by the CO_2 absorbed during tree growth. When managed sustainably, wood gasification systems form part of a circular, renewable energy cycle. Beyond economic and environmental benefits, wood gasification boilers offer energy security. Hotels located in remote or rural areas, where grid energy may be unreliable or expensive, can maintain consistent heating using locally available biomass. Modern systems are also automated and low maintenance, providing the convenience expected in contemporary hotel operations. Therefore, wood gasification boiler systems can provide hotels with an effective pathway to sustainability by combining renewable fuel use, high efficiency, and reduced emissions. By adopting such systems, hotels can lower energy costs, enhance their environmental reputation, and contribute meaningfully to the transition toward a low-carbon hospitality industry.

Use of Green Roofs

Green roofs are increasingly being adopted by tourism entities—such as hotels, resorts, and eco-lodges—as part of broader efforts to enhance sustainability, reduce environmental impacts, and improve guest experience. Their primary advantage lies in improving building energy performance. By providing natural insulation, green roofs reduce heat gains in summer and heat losses in winter, thereby lowering the energy demand for cooling and heating. This contributes to both operational cost savings and reduced carbon emissions. Beyond energy benefits, green roofs enhance storm water management by absorbing rainfall and reducing runoff, an important feature for coastal or island destinations prone to flooding. They also improve local air quality and biodiversity by creating microhabitats for insects and birds, aligning with ecotourism values. From an aesthetic and marketing perspective, green roofs add visual appeal and help tourism entities differentiate themselves. Guests increasingly value natural, wellness-oriented environments, and rooftop gardens, terraces, or walking areas can enhance the overall visitor experience. However, installation costs, structural requirements, and maintenance needs may limit adoption, especially for older buildings or small operators. Despite these challenges, the trend is expected to grow as tourism entities pursue greener operations and seek nature-based solutions that combine environmental performance with guest satisfaction.

Heat Recovery and Reuse

Heat recovery and reuse have become increasingly important strategies for improving energy efficiency in tourism enterprises. Hotels, resorts, and wellness centres generate substantial waste heat from HVAC systems, laundries, kitchens, refrigeration units, and spa facilities. Instead of allowing this thermal energy to dissipate into the environment, heat recovery technologies capture it and redirect it to productive uses, significantly reducing overall energy demand. One of the most common applications is recovering heat from refrigeration and air-conditioning systems to preheat domestic hot water. This is particularly valuable in hotels, where hot water consumption is high and continuous. Similarly, heat from laundry operations or spa facilities can be reused for pool heating or space heating, lowering reliance on fossil-fuel boilers. Modern heat exchangers and heat-recovery ventilation systems also help maintain indoor comfort while preventing energy losses in guest rooms and common areas. Beyond reducing operational costs, heat recovery systems contribute to lower carbon emissions and align with the sustainability expectations of environmentally conscious travellers. Although initial investment and technical integration can pose challenges—especially in older buildings—the long-term financial and environmental benefits are substantial. As tourism enterprises seek deeper decarburization, heat recovery and reuse will continue to play a critical role in optimising energy performance and supporting greener operations.

6. Soft measures which can be used in tourism entities improving their environmental sustainability

The decarburization of the hotel industry is an important priority in the current era of climate crisis. Energy use in hotels accounts for around 3-6% of their operating cost and around 60% of their carbon footprint. *It has been indicated the required energy technologies for hotels' decarbonisation are mature, reliable and cost-effective.* They include energy saving technologies, renewable energy technologies, high-efficiency energy technologies and energy storage technologies. All of them are related with investments in benign energy systems. However, apart from these technologies, the decarbonisation of hotels requires several soft measures additional to energy investments. Soft measures facilitate the clean energy transition in hotels achieving their optimum way towards carbon neutrality. These soft measures include a) energy monitoring, b) energy auditing, c) energy benchmarking, d) behavioural changes of the guests and the staff**,** and e) offset of carbon emissions**.** Energy monitoring provides accurate, real-time insight into how, when, and where energy is used, energy audit identifies opportunities for improvement while energy benchmarking compares energy consumption with hotel peers and recognised patterns.

The Role of Energy Monitoring in Decarbonisation of Hotels

One of the most impactful strategies to achieve decarbonisation is the systematic monitoring of energy consumption, enabling hoteliers to understand, manage, and ultimately reduce their carbon footprint. Energy monitoring refers to the continuous collection, measurement, and analysis of energy usage data within a facility. In hotels, this process involves tracking the consumption of electricity, gas, water heating systems, and sometimes renewable energy outputs. Modern energy monitoring systems typically consist of:

a) Smart meters**:** Measure electricity and gas consumption in real-time.
b) Sensors**:** Track environmental conditions and occupancy.
c) Data management platforms**:** Aggregate and visualize data for analysis.
d) Automated controls**:** Integrate with building management systems (BMS) to adjust operations based on energy insights.

The purpose is not just to measure but to translate raw data into actionable insights that support carbon reduction strategies. Energy monitoring plays a critical role in hotel decarbonisation for several reasons including baseline establishment. To reduce emissions, hotels must first know their starting point. Monitoring establishes an accurate baseline for:

a) Total energy use (kWh or MJ).
b) Carbon intensity (kgCO_2e per occupied room night or per m^2).
c) Seasonal patterns and peak loads.

Without these baselines, targets are speculative and progress cannot be quantified. Hotels often suffer from "hidden" energy waste such as:

a) HVAC running in unoccupied rooms.
b) Inefficient lighting in low-traffic areas.
c) Kitchen equipment left on outside service hours. Monitoring highlights these inefficiencies, enabling corrective actions.

Sustainability commitments require year-on-year verification. Energy monitoring provides auditable data, proving that interventions (e.g., LED retrofits, solar photovoltaic installation) are delivering expected emission reductions. Energy monitoring is not simply a technical add-on; it is the strategic backbone of hotel decarbonisation. By providing accurate, real-time insight into how, when, and where energy is used, hotels can target interventions that yield measurable carbon reductions, operational savings, and competitive advantages.

The role of energy audits in the elimination of carbon emissions in hotels

One of the most effective strategies in the clean energy transition in hotels is the energy audit**,** a systematic process of evaluating a building's energy use to identify opportunities for improvement. Energy auditing serves as a diagnostic tool to pinpoint inefficiencies, recommend cost-effective measures, and create a roadmap toward carbon-neutral operations. In the context of hotels, energy audits play a pivotal role in both reducing operational costs and minimising carbon footprints, ultimately contributing to the elimination of emissions over the long term. An energy audit is a systematic inspection, analysis, and evaluation of energy flows in a building, process, or system, with the objective of understanding energy consumption patterns and identifying opportunities for improvement. In hotels, the goal is to achieve optimal energy efficiency while maintaining or enhancing guest comfort. Energy audits typically follow three levels:

a) Preliminary Energy Audit

It involves quick assessments to identify major problem areas while it is often based on utility bills, visual inspections, and basic measurements.

b) General Energy Audit

It includes detailed data collection and analysis of energy consumption while it Identifies savings opportunities with estimated costs and benefits.

c) Detailed Energy Audit

It involves comprehensive monitoring, simulations, and economic evaluations while it forms the basis for large-scale investment decisions, such as renewable energy systems or HVAC replacements. Energy auditing stands as one of the most powerful tools available to hotels seeking to eliminate carbon emissions. By identifying inefficiencies, enabling renewable integration, and providing a structured pathway toward sustainability, energy audits offer both environmental and financial rewards**.**

The role of energy benchmarking in the decarbonisation of hotels

Energy benchmarking is the process of measuring a building's energy use, normalizing it for variables such as size, climate, and occupancy, and comparing it with:

a) Historical performance (internal benchmarking).
b) Industry peers (external benchmarking).
c) Recognised performance standards (standard-based benchmarking).

By contextualizing these figures, hotels can understand how efficient they are relative to themselves over time and to similar properties in comparable markets. Several key metrics are used in hotel energy benchmarking that directly tie into decarbonisation such as:

a) Energy Use Intensity**:** Energy consumed per square meter or per available room.
b) Carbon Intensity**:** CO_2 equivalent emitted per m^2 or occupied room night.
c) Utility consumption breakdowns: Electricity, gas, heating oil, or renewable energy contributions.

Energy benchmarking is a cornerstone of hotel decarbonisation. By measuring, normalizing, and comparing performance, it provides the insight necessary to identify inefficiencies, priorities interventions, and verify progress towards carbon reduction goals. For hotels, benchmarking offers a strategic advantage: it not only drives environmental performance but also improves profitability, enhances brand reputation, and ensures compliance with evolving regulations.

The role of behavioural changes of tourists and employees in the decarbonisation of hotels

Behavioural changes from both tourists (guests) and employees represent a powerful, often underestimated, lever for reducing carbon footprints. Technical upgrades in hotels such as solar photovoltaic panels, LED lighting, and efficient HVAC systems are essential, but they require capital investment and time to implement. Human behaviour, by contrast, can change rapidly and often at low cost. For example:

a) A guest deciding to reuse towels instead of requesting daily laundering can save both water and energy.
b) An employee diligently turning off unused equipment can avoid “phantom loads” and unnecessary energy waste.

Behavioural changes matter because even in a high-tech, energy-efficient hotel, improper use by guests or staff can undermine performance. Conversely, conscious behaviour can amplify the benefits of existing technologies. Tourists often treat hotel stays as an escape from routine, which can lead to less sustainable behaviour—leaving lights on, taking long showers, or overusing air conditioning. Overcoming this “vacation indulgence” mindset is a challenge but not insurmountable. Low-Carbon Practices for Tourists include a) Energy-conscious use of amenities) Water conservation, c) Food-related choices, d) Mobility choices, and e) Waste minimisation. Hotels can facilitate these changes by making sustainable choices more convenient than unsustainable ones. For example:

a) Installing keycard systems that automatically cut electricity when the guest leaves.
b) Providing reusable bottles and clear water refill stations.
c) Offering appealing vegetarian dishes in prominent menu positions.

Employees interact with hotel systems daily—housekeeping, kitchen, maintenance, and front desk operations all influence energy and resource use. Staff can either uphold sustainability standards or undermine them through neglect or outdated habits. To encourage lasting behavioural change, management should:

a) Train employees in sustainability principles and link them to job performance metrics.
b) Recognise and reward staff who consistently demonstrate low-carbon practices.
c) Empower employees to suggest improvements and innovations for reducing resource use.

Behaviour change is most impactful when tourists and employees reinforce each other’s actions. Behavioural changes, when supported by infrastructure, policy, and culture, can produce rapid, low-cost emissions reductions while also fostering a deeper sense of shared responsibility. Decarbonising the hotel sector is not solely a matter of installing solar panels or retrofitting HVAC systems—it is also about shaping the everyday actions of the people who use and operate these spaces. Tourists’ decisions—whether to take a shorter shower, switch off a light, or choose a vegetarian meal—aggregate into significant carbon savings. Employees’ diligence in efficient housekeeping, energy management, and guest engagement ensures that sustainability goals are met consistently.

The role of carbon offsetting in the decarbonisation of hotels

Among various sustainability strategies, carbon offsetting has emerged as a pivotal tool for mitigating greenhouse gas emissions. Hotels, which are energy-intensive operations, are turning to carbon offsetting as a pathway to environmental responsibility. Carbon offsetting can be realised in two markets, the voluntary and compliance markets. The voluntary market allows companies, organisations, or individuals to purchase carbon credits on their own initiative, usually to demonstrate climate responsibility, enhance reputation, or meet internal sustainability goals. Participation is optional, and standards vary across certifiers. In contrast, the compliance market is regulated by governments under schemes like the EU Emissions Trading System or the Kyoto Protocol. Here, companies must offset emissions to meet legally binding caps, and only credits from approved projects are valid. Thus, compliance offsets are mandatory and strictly regulated, while voluntary offsets are flexible and market driven. Carbon offsetting is the process of compensating for emissions by funding projects that reduce or remove carbon dioxide (CO_2) or other greenhouse gases elsewhere. Common offsetting projects include reforestation, renewable energy development, methane capture, and energy efficiency improvements in developing regions. The idea is simple: while some emissions are currently unavoidable, hotels and other businesses can neutralize their environmental impact by investing in these projects. Carbon offsetting is often categorized into voluntary and compliance markets. Hotels generally participate in the voluntary carbon market (VCM), motivated by corporate social responsibility, brand image, and growing consumer expectations for sustainability. Carbon offsetting offers hotels a valuable but limited tool for addressing their environmental impact. When used responsibly—alongside aggressive emission reductions and transparency—offsetting can help hotels move toward carbon neutrality and contribute to global climate goals. However, it is not a silver bullet. The hospitality industry must resist the temptation of easy solutions and commit to deeper, systemic changes in operations, infrastructure, and culture. To maximise effectiveness and integrity, hotels should follow best practices: a) Prioritize Emission Reduction First, b) Choose High-Quality, Verified Projects, c) Communicate Transparently, and d) Engage Guests and Employees. For carbon offsetting to be truly effective, it must be treated not as the end goal but as a bridge to a low-carbon future, where sustainable practices are embedded into every facet of the hotel experience. Only then can hotels authentically claim leadership in the fight against climate change. According to several studies carbon emissions in tourism facilities vary in the range of 20-60 $kgCO_2$ per bed-night. The cost of carbon offsetting in the voluntary market falls in the range € 3-6 per tCO_2 with average price in the beginning of 2025 at €4.10 per tCO_2. Therefore, the current cost of carbon offsetting in tourism facilities in the voluntary market is rather low falling in the range of €0.07-0.20 per bed-night.

The cost of carbon offsetting for various types of projects in the voluntary market is presented in table 2 while, regarding the compliance market, the price of carbon credits in the EU emissions trading system in Table 3.

Cost of carbon offsetting for various types of projects in the voluntary market

Type of project	Cost (€ per tCO_2)
Reforestation	5-21
Development of renewable energy project (solar, wind, hydro, et cetera)	2-5
Methane (CH_4) capture	3-9

Price of carbon credits in the EU emissions trading system

Date	Price (€ per tCO_2)
1/2021	34.92
1/2022	85.42
1/2023	81.50
1/2024	78.80
1/2025	75.94

Linking Hotels with Local Food Suppliers to Reduce the Carbon Footprint

Hotels play a significant role in shaping sustainable tourism, and one effective approach is building strong linkages with local food suppliers. By sourcing ingredients from nearby farmers, markets, and small-scale producers, hotels can reduce their reliance on products transported over long distances. This not only lowers greenhouse gas emissions associated with transportation but also minimises the hotel's overall carbon footprint. The benefits of local sourcing extend beyond environmental gains. Hotels that prioritize regional food suppliers can offer fresher, seasonal menus that enhance the guest experience and showcase authentic local flavours. This strengthens the destination's cultural identity while creating economic opportunities for local farmers and small businesses. Such partnerships also promote shorter, more resilient supply chains, which are less vulnerable to global disruptions. From a sustainability perspective, integrating local food into hotel operations aligns with international environmental goals and growing consumer demand for eco-friendly practices. Many travellers now seek hotels that demonstrate genuine commitments to reducing environmental impacts. Therefore, collaboration with local suppliers is not only a responsible ecological choice but also a strategic business advantage. Therefore, establishing strong hotel–supplier networks support environmental conservation, strengthens the local economy, and enhances the overall sustainability of the hospitality industry.

The Role of Virtual Tourism in Reducing the Carbon Footprint of the Tourism Industry

Tourism is one of the fastest-growing sectors globally, generating economic benefits, cultural exchange, and employment opportunities. However, it is also a major contributor to greenhouse gas emissions. Air travel, cruise ships, and road transport account for a significant share of tourism's carbon footprint, with the United Nations World Tourism Organisation (UNWTO) estimating that tourism contributes around 6-8% of global carbon emissions. In the face of climate change, the industry is under pressure to adopt sustainable practices. One emerging solution is **virtual tourism**, which has the potential to reduce the environmental burden associated with traditional travel. **Virtual tourism** refers to the use of digital technologies—such as virtual reality (VR), augmented reality (AR), and immersive online platforms—to simulate travel experiences. From virtual museum tours and 360-degree destination videos to fully immersive VR experiences of natural landscapes, this form of tourism enables individuals to explore destinations without the need for physical travel. By reducing reliance on flights and long-distance journeys, virtual tourism can significantly lower the carbon emissions that would otherwise result from tourism activities. The carbon-saving potential of virtual tourism is particularly relevant in long-haul travel, which often represents the largest share of emissions in a tourist's footprint. For example, a round-trip international flight can generate a large amount of CO_2 per passenger. If some of these trips are substituted with high-quality virtual experiences, the environmental benefits could be substantial. Moreover, virtual tourism can provide access to fragile or ecologically sensitive destinations, such as coral reefs, glaciers, or cultural heritage sites that are threatened by over-tourism. This helps preserve these sites while still allowing global audiences to appreciate their value. Beyond environmental benefits, virtual tourism also increases accessibility. It allows individuals with financial, physical, or time limitations to experience destinations they might otherwise never visit. In doing so, it democratizes cultural and natural experiences while simultaneously reducing pressure on high-demand destinations. Nevertheless, virtual tourism cannot fully replace physical travel, as many travellers seek embodied, sensory, and social experiences that digital platforms cannot yet replicate. However, it can complement traditional tourism by offering sustainable alternatives for certain activities, pre-trip experiences, or educational purposes. As VR and AR technologies advance, the line between physical and virtual travel will continue to blur, creating new opportunities for sustainable tourism models. Therefore, virtual tourism offers a promising pathway to reducing the tourism industry's carbon footprint. While it may not eliminate the need for physical travel, it can reduce unnecessary emissions, protect vulnerable destinations, and expand accessibility. By integrating virtual experiences into the broader tourism landscape, the industry can move toward a more sustainable and climate-resilient future.

7. Conclusions

The report underlines the potential of sustainable energy technologies in reshaping the European tourism sector towards a low-carbon and energy-efficient model. The analysis demonstrates that technological innovation, combined with soft and behavioural measures, forms the foundation for achieving a sustainable energy transition within tourism enterprises. Firstly, it is evident that renewable and sustainable energy technologies—including solar, biomass, geothermal systems, heat pumps, cogeneration systems et cetera—are no longer niche alternatives but viable mainstream solutions. Their adoption has been accelerated by technological maturity, declining equipment costs, and supportive EU and national policies. Secondly, energy management and monitoring are identified as key enablers of efficiency. Several soft measures in tourism entities including energy monitoring, energy auditing, energy benchmarking, behavioural changes of tourists and employees, carbon offsetting, linking hotels with local food suppliers and promotion of virtual tourism can significantly improve energy use optimisation and reduce carbon emissions. Additionally, the report indicates that the integration of sustainable energy technologies can enhance competitiveness by reducing operating costs, attracting environmentally conscious travellers, and improving resilience against energy price volatility. Environmentally, widespread adoption could lead to significant carbon emission reductions, contributing to the EU's decarbonisation targets. Finally, the report underscores that the path towards sustainable tourism is evolutionary rather than revolutionary. Continuous monitoring, adaptive management, and stakeholder collaboration will be essential for maintaining progress. European tourism entities must embrace sustainability not merely as a regulatory obligation but as a strategic investment in their long-term viability and reputation. Therefore, the deployment of sustainable energy technologies—supported by soft measures, policy frameworks, and collective commitment—presents a clear pathway toward a greener, more efficient, and more competitive European tourism industry.