# Speyside Resort: A Sustainable Design for the Caribbean Coast

Janani Manathattai, Lauren Low, Lakshmi Chakka, Anika Kurup

Northwood High School

Coach: Emma Zschunke

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## Abstract (150-250)

Off the coast of Tyrrell's Bay in Speyside, Tobago, and Trinidad, frequent flooding[1] is a serious issue with climate damages projected to increase 20% by 2100[2] with other reports estimating the annual cost of climate disruptions at $22 billion by 2050[3]. Through mechanical, electrical, and environmental engineering disciplines, our proposal aims to overcome these challenges by employing technology that will prevent natural disasters from threatening occupant safety and sustainability of Speyside Resort. The methods outlined include utilizing steel construction for structural integrity while implementing advanced insulation to manage extreme weather. LiDAR and AI are used to optimize drainage systems, while bioremediation purifies stormwater for reuse, and native greenery is incorporated to prevent erosion and promote biodiversity. Renewable energy systems, such as D-TENG technology and wave energy converters, guarantee a reliable power supply. With the innovative strategies proposed, these efforts provide a well-established framework for targeted applications addressing the development of the Caribbean Islands. Speyside Resort aims not only to protect inhabitants from natural disasters but also to integrate the energy and resources harnessed from such disasters to support the hotel itself.



*Keywords: Speyside, Trinidad, flooding, steel, insulation, LiDAR, AI, drainage systems, bioremediation, greenery, D-TENG*


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[1] "In the midst of the climate crisis, Trinidad grapples with an increase in floods" (Caribois)
[2] "The Caribbean and Climate Change: The Costs of Inaction" (Stockholm Environment Institute)
[3] "Climate Change and Small Island Developing States" (Annual Review of Environment and Resources)

## Introduction (94)

With Trinidad & Tobago gathering about 1800 mm of annual rainfall[4], and flash-flooding on its coasts, it is important to consider the area's geography while building a weather-resistant hotel. Speyside, though known for its beauty, is currently underdeveloped for tourism, as its limited infrastructure and vulnerability to natural disasters deter potential visitors. However, with Speyside being Trinidad's primary tourist location, our proposal, Speyside Resort, which will have an enhanced structure, utilize multiple power sources to combat extreme weather conditions, and leverage natural resources available in the area, will help increase Trinidad's overall tourism rates.

[4] "Climate in Trinidad and Tobago" (World Climate Guide)

## Main Body

### Mechanical Engineering

### Material and Construction (251)

Building a hotel in an environment as diverse in climate and conditions as Trinidad requires a careful balance of material selection and design to withstand extreme weather while ensuring long-term durability. For this reason, steel has been chosen as the primary structural material for its strength and endurance which also contributes to its minimal maintenance requirements and cost-effectiveness.[5] To provide the necessary stability for a 6-story structure, 12-gauge steel will be utilized to construct key components, including beams, columns, and support frames to create a solid foundation for construction.

To ensure stability, the walls will additionally incorporate steel framing layered with materials designed to improve weather resistance and insulation[6]. Interior wood panels will help maintain a consistent indoor climate by reinforcing insulation, while the exterior will be covered with fiber cement, a material capable of protecting the structure from harsh conditions like wind, heavy rain, and UV exposure.

To address thermal concerns, advanced insulation systems will be integrated throughout the structure. Fiberglass windows[7] will minimize heat transfer, helping maintain indoor temperatures, and to supplement this, phase-change materials (PCMs), such as calcium chloride hexahydrate and eutectic mixtures, will be integrated into the system[8]. This will regulate indoor

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[5] "The Efficiency of Steel Material as Buildings Construction" (Research Gate)
[6] "The Advantages & Disadvantages of Steel Frame Construction" (GLW Engineering & Construction Ltd)
[7] "What is Fiberglass Insulation? How it Works and What it's Made of" (Retrofoam of Michigan)
[8] "Shape memory polymers with novel functions: electro-active, magnetically-active, light-adaptive and phase change materials" (Science Direct)

temperatures by absorbing heat during the day and releasing it when temperatures drop, establishing a climate-controlled indoor environment.

Additionally, by incorporating an eight-sided roof, the shell-shaped design will allow for rainwater to flow off the structure, minimizing the risk of damage, and also activating the D-TENG system, which will generate energy from the flowing water.

**Flood Management (98)**

Effective water management is critical for buildings in flood-prone environments like Trinidad. To combat this, we will incorporate a watergate system, which acts as a barrier to prevent water intrusion by using the natural pressure of the water to stabilize itself.[9] As water levels rise, the pressure forces the watergate into position, creating a secure boundary that stops water from breaching the structure. When pressure decreases, it will return to its resting position, ready to be used again. This allows it to easily adapt to varying water levels, making it a reliable and flexible solution for flood management.

[9] “Water-gate Barrier” (Flood Protection Solutions)

## Environmental Aspect

### LiDAR and AI (128)

Rainwater is the leading cause of flooding, as severe weather events endanger infrastructure and occupant safety. Environmental engineering offers innovative solutions to these challenges by integrating LiDAR (Light Detection and Ranging) technology and AI automation. LiDAR creates 3D elevation maps and digital surface models (DSMs), strategically designing optimized drainage systems. These models ensure efficient placement of retention ponds and stormwater drains while assessing vulnerabilities in existing infrastructure.

AI-powered systems complement these designs by automating flood management. Sensors monitor water levels in real-time, while machine-learning models strategically divert water to balance distribution, preventing overflow. Additionally, 24/7 AI-enabled camera surveillance detects obstructions like debris or fallen trees, enabling rapid intervention. The combination of LiDAR and AI reduces flood risks, enhances occupant safety, and promotes sustainability for Speyside Resort.

### Drainage Systems (60)

To utilize polluted storm waters, we will use drainage systems to provide a clean source of water for inhabitants, allowing for sustainability and allocation of resources. They will be placed at ground level surrounding the building, allowing for stormwater to be channeled to surface-level retention ponds which will be repurposed in the hotel for needs such as drinking and washing.

**Bioremediation (84)**

To clean collected stormwater, we will implement the dispersion of microorganisms through an automated dispensing system. By using bacteria such as *Acinetobacter*, *Pseudomonas*, and *Bacillus* to break down organic pollutants, lactic-acid bacteria to break down heavy metals, and *Bacillus*, *Streptomyces*, and *Rhodococcus ruber* to break down plastics, these microorganisms will use digestive enzymes to break down harmful matter within the water, purifying it in the process.[10] This concept of bioremediation will allow us to recycle rainwater in emergencies where freshwater is unavailable for residents.

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[10] "Bioremediation of Petroleum Hydrocarbons Using Acinetobacter sp. SCYY-5 Isolated from Contaminated Oil Sludge: Strategy and Effectiveness Study" (International Journal of Environmental Research and Public Health)

## Hydroelectric Power

To protect against moisture from floods and storms, we will construct our electrical systems underground. Additionally, we will install a hybrid electric grid, allowing electricity to be generated and distributed through multiple sources.

### Introduction of D-TENG Technology

To maximize energy output, we will incorporate hydroelectric components into the hotel's electrical system, including modified D-TENG technology on our roof. This system uses a top and bottom electrode to capture energy through triboelectric interactions and the electric field generated as rain droplets pass between the electrodes.[11] The dual-electrode configuration improves energy conversion by achieving higher peak-currents through enhanced charge transfer. Factoring in Speyside's annual rainfall and our resort's roof area, the model will generate about 25.39 kW annually, powering devices like thermostats and LED lighting.

### Utilization of SWEL's "WaveLength Magnet"

Additionally, we will incorporate the Waveline Magnet on the shore to harness wave energy cost-effectively. This system captures mechanical energy from waves through oscillating magnets and conductive coils; as the waves oscillate, this induces electrical currents through electromagnetic induction, allowing us to integrate this energy into the hotel's grid.[12] While one Magnet generates 100 kW in optimal conditions,[13] Trinidad's stronger tropical waves would

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[11] "Study of the enhanced electricity output of a sliding droplet-based triboelectric nanogenerator for droplet sensor design" (Science Direct)
[12] "Waveline Magnet Technology" (SWEL)
[13] "Converting wave power into electricity" (Design Boom)

increase energy production, providing significant electricity even during floods, when waves reach larger magnitudes.

## Conclusion

The proposed design for Speyside Resort provides a strong framework to address climate challenges by utilizing the principles of mechanical, environmental, and electrical engineering. However, limitations such as high implementation costs, logistical challenges in transporting technology, and maintenance requirements must be considered. Primarily, securing funding and construction permits through government and private contracts are essential. Despite these hurdles, Speyside Resort offers transformative opportunities for Trinidad, boosting job creation, tourism-driven GDP, and industry growth. In the long term, Speyside Resort may encourage further investment in resilience developments, setting the precedent for long-term growth.

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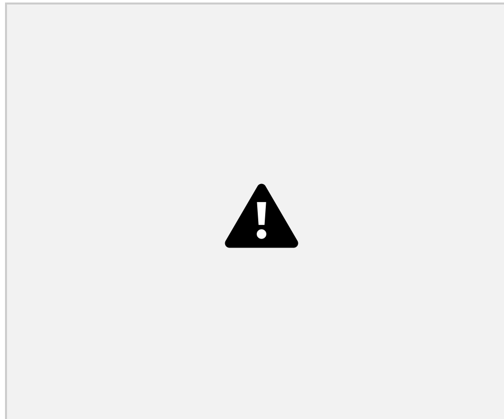
# Appendix

**Speyside Resort Location on Map**

**Waveline Magnet Model**



**8-Sided Roof Model**

## Materials and Construction Cost Analysis:

Building Speyside Resort and the surrounding watergate system requires consideration of costs for materials and structural systems to ensure a durable design. The 12-gauge steel is priced at about $3.09 per pound. With approximately 225,000 pounds needed to support the building's framework, the steel will cost about $695,250. For the exterior, fiber cement panels will cover an estimated 60,000 square feet at $10 per square foot, bringing the total cost for panels to $600,000. Interior insulation will use wood panels priced at $8 per square foot, covering an estimated 40,000 square feet for a total cost of $320,000. The insulation system, combining fiberglass insulation at $1.50 per square foot and PCMs at $3 per square foot, adds $240,000 to the overall insulation cost. The roofing system will use steel materials priced at $6 per square foot, covering an area of 10,000 square feet. This brings the roofing cost to $60,000. The watergate system, essential for flood management, will cost $250,000. The total estimated cost for constructing this 6-story Speyside Resort and its surrounding watergate system is approximately $2,165,250.

**Insulation System:**

To ensure effective thermal insulation, insulation systems will be used to maintain energy efficiency. The effectiveness of these systems can be determined with the R-value formula: (temperature difference between the warm and cold surfaces of a heat barrier)/(heat flux through the barrier). The R-value measures a material's ability to resist heat flow, and a higher value indicates greater effectiveness at slowing down the transfer of heat. For a wall without insulation, assuming an indoor temperature of 22ºC (72ºF), an outdoor temperature of 35ºC (95ºF), and a heat flux of 20 W/m^2, the R-value would be 0.65 m^2 x K/W. Adding fiberglass insulation, which has a typical R-value of 3.0 m^2 x K/W, increases the total R-value to 0.65 + 3 = 3.65 m^2 x K/W. This reduces the heat flux to 3.56 W/m^2, significantly lowering the rate of heat transfer. Incorporating PCMs, which add an additional R-value of 2.0 m^2 x K/W, further improves the total R-value to 5.65 m^2 x K/W, reducing the heat flux to 2.30 W/m^2. This represents an almost 89% reduction in heat transfer compared to an uninsulated wall. These calculations prove that using fiberglass insulation and PCMs dramatically enhances thermal resistance.

**LiDAR & AI Cost Analysis:**

The implementation of LiDAR and AI systems at Speyside Resort involves costs across hardware, software, labor, and maintenance. Each LiDAR unit costs approximately $30,000 (based on industry averages for terrestrial LiDAR systems), and 5 units will be installed to cover key areas, totaling $150,000. Data processing for creating 3D elevation maps and digital surface models (DSMs) is estimated to cost $50,000, accounting for software licenses and computational infrastructure. The AI-driven flood management system will include 80 water level sensors, priced at $150 per unit, for a total cost of $12,000. Development and training of machine-learning models for automated water diversion and overflow prevention are estimated at $100,000, based on current AI software development costs. For surveillance, 20 AI-enabled cameras at $750 per unit will monitor obstructions like debris and fallen trees, bringing the cost to $15,000. Training local operators to manage and maintain the system adds an additional $25,000. Annual maintenance and updates for the LiDAR and AI systems are projected to cost $75,000, ensuring continued functionality and reliability. The total estimated cost for LiDAR and AI integration is $427,000. This cost reflects a balanced investment in cutting-edge flood management solutions, providing long-term benefits for safety, sustainability, and infrastructure resilience at Speyside Resort.

**Drainage Systems Cost Analysis:**

Considering factors such as site assessment, materials, labor, pumping/filtration systems, maintenance costs, and storage systems, the initial installation of the drainage systems will cost around $42,000 - $90,000 while annual maintenance will cost from $1,000 - $3,000. A site assessment consisting of the analysis of soil type, topography, and environmental impacts is necessary to ensure that issues such as erosion and flooding are mitigated and that the drainage systems are efficient and sustainable. Additionally, site assessments help to predict any needed maintenance. The site assessment can cost approximately $2,000 - $5,000. The materials needed for the drainage systems include drainage pipes, filtration systems, pumps, storage tanks, and landscaping materials, which can all cost up $15,000 - $30,000. Moreover, labor will be needed for the construction of the drainage systems, which can cost $10,000 to $20,000. The filtration systems used to ensure a clean and pure source of water as well as the pumping systems for water collection will cost $5,000 to $15,000 when combined. Maintenance costs account for regular check-ins, filter cleanses, and needed repairs and can all add up to $1,000 to $3,000 a year. Lastly, the storage systems will cost $10,000 to $3,000

**Bioremediation Cost Analysis:**

Bioremediation can cost up to $65,000 with the initial investment and $21,000 for annual operating costs. The initial investment costs include those for the automated dispensing system, microorganism cultures, and pre-treatment systems. The automated dispensing system, which, when needed, automatically delivers microbial cultures, can cost up to $25,000 for the purchase of equipment, installation, and calibration. The microorganism cultures themselves can cost around $10,000 while the maintenance and storage equipment for these microorganisms cost another $5,000. Pre-treatment systems are important for optimizing conditions for microbial populations through the adjustment of factors such as pH and nutrient availability. This ensures that the microbes can effectively break down pollutants in the stormwater.

**Hydro-Electric Cost Analysis:**

The total cost of implementing both D-TENG technology and two Waveline Magnets ranges from approximately $2.5 million to $3.75 million. Installing D-TENG technology on a 50,000 sq ft roof is estimated to cost between $500,000 and $750,000, including materials, installation, and structural assessments. Adding two Waveline Magnets, with an estimated cost of $1 million to $1.5 million per unit, results in a combined expense of $2 million to $3 million for the magnets alone. This brings the overall total to a minimum of $2.5 million and a maximum of $3.75 million, depending on specific project requirements and conditions.

**Cost Analysis for Implementing D-TENG Technology**

Implementing D-TENG (Dielectric Triboelectric Nanogenerator) technology on a 50,000 sq ft roof involves estimating the costs of materials, installation, and maintenance. D-TENG devices are typically lightweight and scalable, relying on triboelectric and electrostatic induction to harvest energy from mechanical motion. Assuming a cost of approximately $10-$15 per square foot for materials and installation, the total cost would range between $500,000 and $750,000. Additional costs include structural assessments to ensure the roof can support the technology, maintenance expenses (approximately 5% of the initial cost annually), and potential integration with energy storage systems. Over time, operational savings from energy generation could offset these initial costs, depending on efficiency and energy demand.

**Cost Analysis for Implementing Two Waveline Magnets**

Installing two Waveline Magnets, which generate power by utilizing the motion of ocean waves or other mechanical forces, involves significant upfront investment in specialized technology and deployment. Each Waveline Magnet device has an estimated cost of $1 million to $1.5 million, including manufacturing, transportation, and installation. Maintenance and operational costs, including regular inspections and component replacements, would add approximately $100,000 annually per unit. If deployed in optimal conditions, these magnets could produce significant energy output, contributing to long-term savings. However, initial costs and logistical challenges, such as ensuring adequate connection to energy grids, must be accounted for in the overall cost analysis.

**D-TENG Roof Energy Conversion Calculations**

For a 50,000 sq ft roof area experiencing 1,431 mm of annual rainfall, the energy generated by the improved DLS-TENG can be calculated as follows:

Convert the roof area to square meters: 50,000 sq ft × 0.092903 = 4,645.15 sq m.

The improved DLS-TENG generates 19,676.63 joules per year per square meter. Therefore, the total energy is: Total Energy = 19,676.63 joules/sq m × 4,645.15 sq m = 91,400,897.84 joules/year.

To convert joules to kilowatt-hours: 1 kWh = 3,600,000 joules. Total Energy in kWh = 91,400,897.84 ÷ 3,600,000 = 25.39 kWh/year.

Thus, a 50,000 sq ft roof area would generate approximately 25.39 kWh annually.