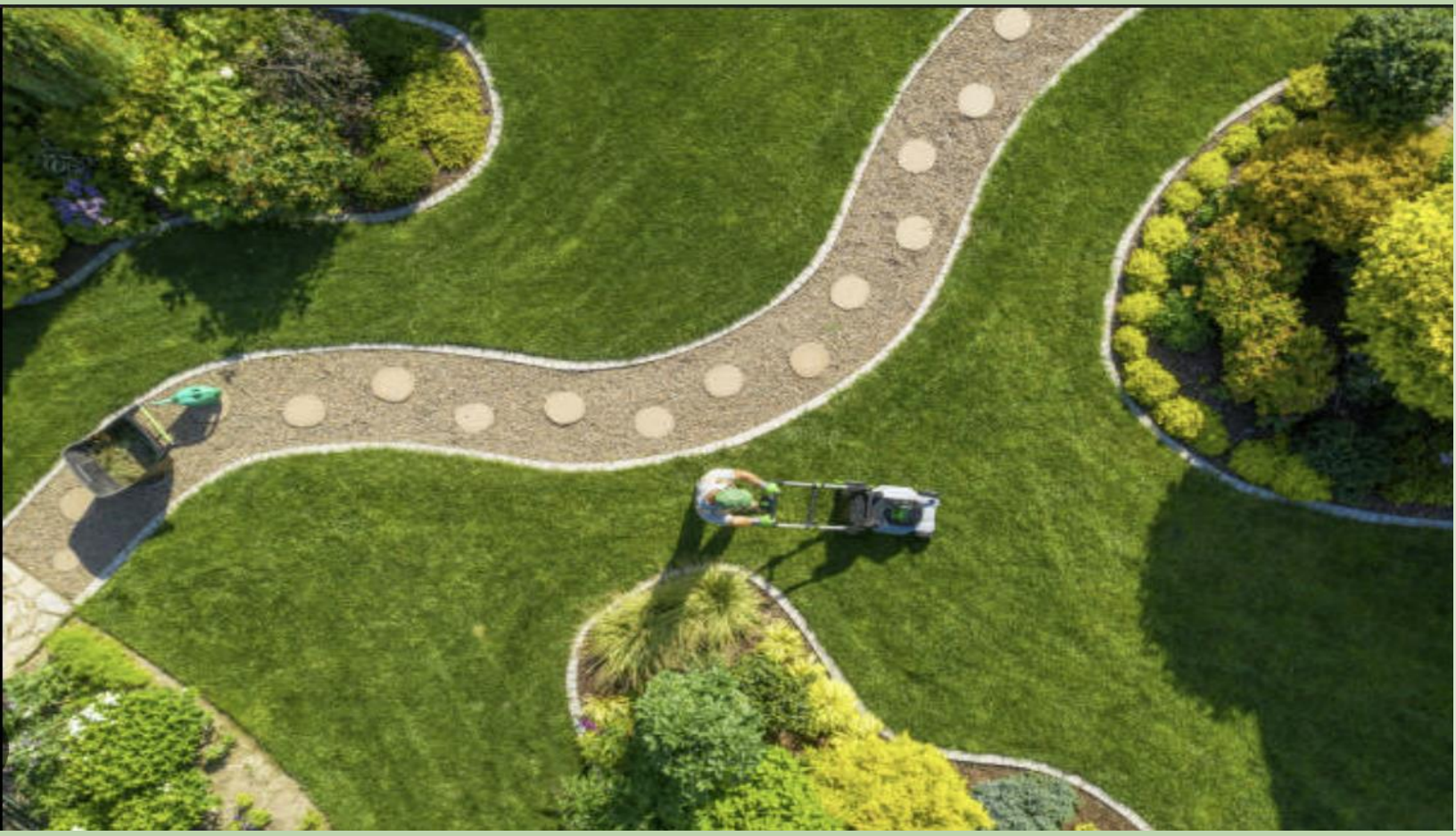
GrassGuard Smart Sprinkler Head



An Innovative Solution to Conserve Water on Landscape Irrigation

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EXECUTIVE SUMMARY

The world is moving towards a water crisis. By 2071, about 50% of the freshwater basins in the United States will not meet monthly water demands. [1] A significant contributor of wasted water is from residential landscape irrigation, where 9 billion gallons are used daily in the US alone to water lawns. [2] To make matters worse, about half of this water is wasted due to inefficient watering methods. [3] Current traditional rotary sprinklers are only able to spray in circular patterns, which inevitably leads to overlaps in water spray to cover the entire lawn. The GrassGuard Smart Sprinkler Head addresses this problem by allowing users to create custom spray patterns that fit their unique lawn shape. This sprinkler innovates on current solutions in several different ways. Other smart sprinklers on the market either are not able to provide entire zone coverage or require the homeowner to completely tear out their pre-existing sprinkler systems to install a new one. The GrassGuard sprinkler simply needs to be screwed into the adapters currently used for rotary sprinkler heads. The sprinkler can generate its own power by using energy from the water flow, which is a key differentiator in comparison to alternative products. In addition, the GrassGuard sprinkler is easily programmable through an app, making the user experience simple and straightforward. The GrassGuard sprinkler is for environmentally conscious homeowners that want to save both water and money on their irrigation. In the future, commercial buildings, parks, and golf courses will also be targeted as potential revenue streams. This white paper details Team WaterWise's solution to solving modern irrigation challenges with a robust, intelligent solution.

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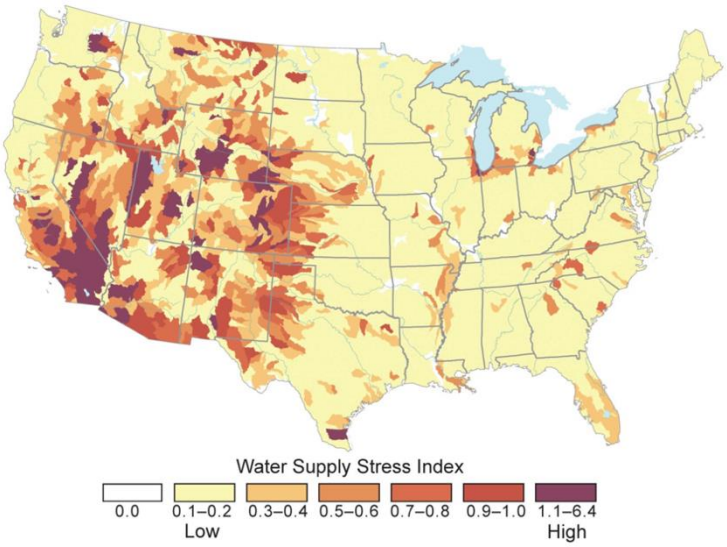
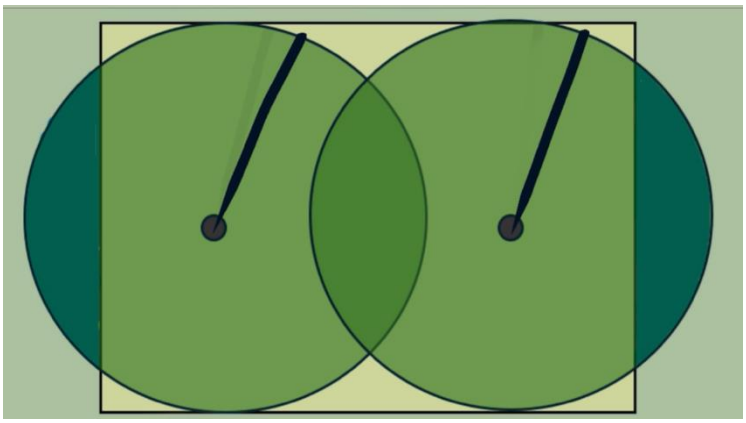
1 PROBLEM STATEMENT

Major concerns over water usage are being brought to attention across the world. According to the United Nations, three out of four people worldwide could face drought impacts by 2050. [4] The World Bank estimates that by 2030, 60% of the world population will be affected to some degree by water scarcity. [5] This global issue has also started to take effect in the United States, which is experiencing some of the consequences of unsustainable water use. In a US government-backed study, about 50% of the freshwater basins in the US are estimated to not meet monthly water demands by 2071. [1] The map shown displays the level of water stress in the US, where regions in the southwest are going to face a huge hurdle in the oncoming years with their water availability. Since the amount of water is becoming more and more limited, the cost of water has also increased for Americans. Since 2000, the cost of water for irrigation has more than doubled across the US, with even larger increases in the Midwest and Northeast regions. [7] One large contributor to the waste of water in the US concerns landscape irrigation, where 9 billion gallons are used daily, about 2.8% of overall water usage. [2],[8] 50% of this water is wasted because of inefficient patterning and evaporation [3]. Since current traditional rotary sprinklers are only capable of spraying in a circle, there will inevitably be overlaps to cover the entire lawn. This both wastes water and increases homeowners' water bills. Current smart sprinkler solutions on the market that target this problem have their own drawbacks, making them difficult to adopt. Above ground solutions don't have the range necessary to cover large zones. Below ground solutions require the homeowner to dig up their lawns to install an entirely new irrigation system. In addition, these sprinklers and systems have a high

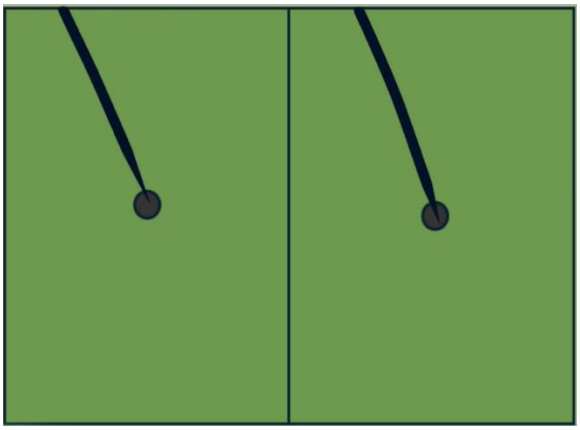




upfront cost, making them unaffordable for many homeowners. After conducting over 100 customer interviews, 97% of people reported that they are frustrated by wasteful sprinklers and 87% would consider investing in a better option. People in the age group of 50 and above were most frustrated with their sprinkler systems from a cost savings and water sustainability point of view. The current water crisis that the world now faces and widespread dissatisfaction of current sprinkler systems calls for a new innovative product that helps users save water and money.

2 PROJECT OBJECTIVES

With the current state of water resources, there is a dire need to find methods to reduce water usage. The goal of the GrassGuard smart sprinkler head is to provide an affordable, intelligent irrigation solution that reduces water waste, enhances convenience, and promotes sustainable landscaping. The project aims to integrate smart pattern capability, self-power generation, and wireless control into a compact, weather-resistant design suitable for both residential and commercial use.



Specific objectives include the following:

- Develop a fully functional sprinkler head that can produce variable spray pattern.
- Reduce outdoor water usage by up to 40% compared to traditional sprinkler systems through targeted watering.
- Design and integrate a micro-hydroelectric generator to recharge the onboard battery using water flow.
- Implement wireless connectivity via Wi-Fi or Bluetooth for remote control through a mobile app.
- Ensure the sprinkler head is universally compatible with current residential irrigation standards.
- Provide an easy installation process for the user where the sprinkler head can just be screwed onto pre-existing pipe adapters without sacrificing performance.
- Utilize waterproof, UV-resistant, and corrosion-proof materials that are suitable for injection molding and long-term outdoor exposure.
- Create a low-power system capable of operating for at least 5 eight-month seasons.

3 TECHNICAL SOLUTION

The GrassGuard is a smart sprinkler head that is capable of spraying to any lawn shape. This sprinkler head adjusts watering behavior based on pressure changes and operates independently through sustainable power generated from water flow. The entire assembly is designed to fit relative to the form factor of a standard popup sprinkler head, enabling easy integration into existing irrigation infrastructure.

3.1 KEY COMPONENTS

3.1.1 Pop-up

A dual-stage pop-up mechanism allows the sprinkler nozzle to extend beyond the height of the grass, allowing the water to spray freely. The stages are fit with springs that allow the pop-up to rise during operation and retract when not in use. The nozzle geometry is the same as traditional sprinkler heads and provides uniform spray onto the lawn. A gear at the bottom of the pop-up connects through a gear train to a servo motor, which is responsible for the angular adjustment of the pop-up.

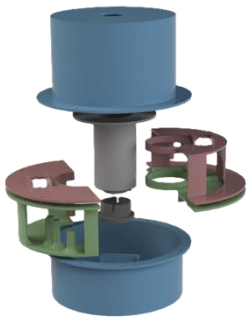
3.1.2 Power Generation

Inside the water path is a miniature hydroelectric turbine generator that spins as water flows, producing the electricity that powers the sprinkler head. This closed-loop energy harvesting design ensures that the system remains self-powered with no need for extra wiring to external power sources. The turbine generator connects to a boost converter that steps up the voltage, which then connects to the battery that powers the rest of the electronics.

3.1.3 Valve

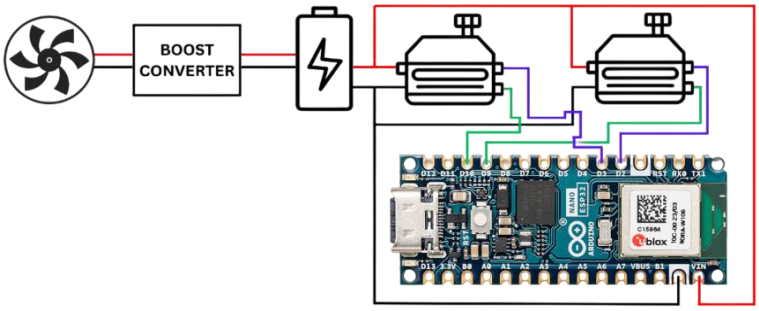
A mechanical ball valve allows the system to regulate the pressure of the water flow, changing the distance of the water spray. The ball valve is connected through a gear train to a servo, which controls the opening of the valve. The more open the valve is, the farther the spray distance.

3.1.4 Housing



The housing is responsible for protecting the internal components of the sprinkler head from weather, sunlight, and impacts, as well has holding the electronic components in place. The sprinkler head's housing is made from ABS plastic, and all designs are optimized for injection molding.

3.1.5 Electronics



The electronics control the valve and pop-up subsystems. A continuous rotation servo connects to both the ball valve and pop-up through a gear train. These servos have built-in hall effect sensors that allow PWM and feedback control to be utilized to achieve precise angle adjustments. The servos are controlled through an Arduino Nano ESP32 microcontroller, which has built-in Wi-Fi and Bluetooth capabilities that allow the user to connect through their phone.

3.2 System Operation

During irrigation, water pressure causes the sprinkler head to pop up and initiate power generation through the internal turbine. Through the lawn pattern that the user programmed through the app, the sprinkler pop-up will constantly rotate as the spray distance is continuously adjusted by the ball valve. Once the irrigation cycle ends, electronics power off and the pop-up mechanism retracts.

To install the GrassGuard, the user removes their existing sprinkler head and screws on the smart sprinkler head just like a standard rotary model. Once installed, the user connects the sprinkler to the mobile app for setup. Upon running the sprinkler for the first time, the system emits a stream of water corresponding to a certain angle within the app. The user can then fine-tune the spray distance for that specific angle using a slider interface. This process continues until the user has programmed a complete watering

pattern tailored to the shape of their lawn. After setup, the smart sprinkler operates autonomously based on the programmed pattern.

3.3 Innovation and Engineering Challenges

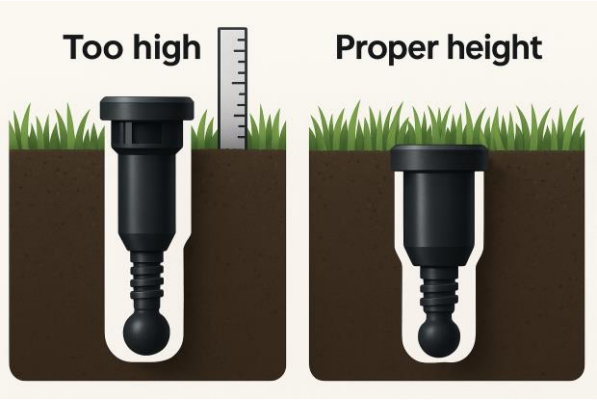
One of the GrassGuard's key innovative features is its self-sufficiency. GrassGuard is the first smart sprinkler head of its kind that can generate its own energy without relying on external power sources. Also, the GrassGuard sprinkler head utilizes a completely new and innovative design to control the spray angle and distance of the water.

Waterproofing was a key factor to many design considerations and posed many challenges. Multiple methods were used to create a prototype that was watertight and kept all the electronics dry. Fitting all the components inside a compact sprinkler housing required creative space management and thoughtful mounting solutions. Ensuring consistent pressure and spray performance while harvesting energy was a difficult process but was addressed through iterative prototyping and testing.

4 DESIGN CONSIDERATIONS

The design of the GrassGuard sprinkler head was guided by a balance of functional performance, environmental durability, user accessibility, and manufacturability. Every component and subsystem were selected and configured with the goal of creating a reliable, energy-independent, and user-friendly irrigation solution that easily integrates into pre-existing systems.

4.1 Form Factor and Physical Constraints



One of the primary challenges was fitting all critical subsystems — including a power-generating turbine, electronics, valve, and rotating pop-up — within a small body of a sprinkler head. The size of the head must be comparable to that of traditional rotary sprinklers and cannot surpass a certain height to where the head protrudes too high into the grass. The design must allow for smooth vertical motion during pop-up and retraction while avoiding interference between moving parts. To achieve this, a compact vertical layout was chosen with electronics housed around the central water path.

4.2 Material Selection and Durability

Because the device will operate outdoors year-round, material selection was critical. The outer housing material chosen was Cycolac MG47U, a UV-resistant and corrosion-proof ABS plastic suitable for injection molding. This outer material ensures both weather resistance and long-term durability. The internal housing is made of Cycolac MG47, which has the same durability as its "U" counterpart but without the UV resistance. All relevant components must be sealed to at least IP65 standards to prevent intrusion from water, dust, and soil. The enclosure also must withstand constant pressure changes and mechanical stress from water flow, as well as repeated pop-up actions.

4.3 Power Generation and Energy Management

Energy generation through a micro hydroelectric turbine presented both opportunities and constraints. The system must harvest sufficient energy from variable water pressures without introducing significant pressure drop. At first, a turbine like those in traditional rotary heads combined with a DC motor generator was considered for power generation. This method did not work as the water flow could not produce enough torque to turn the DC generator at the rate needed to meet energy generation requirements. An off-the-shelf high-efficiency micro-turbine was then considered, which adequately produced the energy needed with negligible pressure drop. Power management protocols were also developed to ensure the safety of the electronics and reduce energy requirements.

4.4 Valve and Spray Control

The spray control mechanism is a critical component to the sprinkler head and must function correctly to ensure variable spray pattern capabilities. Initially, a saltshaker design was considered. Challenges arose because of interfacing difficulties. Water leaking through the different levels of the shaker design, which ended up pouring out of the sprinkler head interfaces. This led to the transition to a ball valve, a pre-existing method that has been proven to work. Integrating a ball valve

allowed the system to dynamically adjust spray distance in real time. This required precise control of the valve mechanism while maintaining water-tight seals and quick responsiveness to user commands. Position feedback from the servos ensures repeatable spray distance control across multiple zones.

4.5 Manufacturability and Cost

To ensure scalability, all structural components were designed with injection molding in mind, minimizing complex geometries and the need for post-processing. High volume off-components were used where possible to reduce prototyping costs and simplify sourcing. The overall bill of materials (BOM) was kept under certain targets to ensure a smooth transition to mass manufacturing costs, making the product viable for commercial markets.

4.6 User Interaction and Setup

The system was designed to be installed with minimal user effort. It screws into existing standard sprinkler fittings without additional tools, and setup is completed through a mobile app interface. After the initial set up of the sprinkler heads, users do not have to do anything further. The goal was to make customization simple for any type of user.

5 SYSTEM ARCHITECTURE

The GrassGuard sprinkler system is designed as a fully self-contained unit that activates, controls, and powers itself during each irrigation cycle. Its operation begins the moment water flows into the system.

As water enters through the base adapter, it passes through the mini turbine embedded in the flow path. This turbine spins with the water pressure and generates electricity, which is routed through a boost converter to step up the voltage. This power charges a small 6V NiMH battery, which acts to stabilize, store, and distribute the power. Initially the battery powers on the main control board — an Arduino Nano ESP32. At around the same time, the water pressure in the sprinkler head will cause the pop-up stages to activate and extrude above the grass.

The ESP32 reads the user's programmed lawn pattern from onboard memory — settings that were uploaded via Wi-Fi or Bluetooth through the mobile app. For each programmed angle, the ESP32 sends PWM signals to the servo responsible for spray direction, adjusting the rotation in precise increments through the gear train connected to the base of the pop-up. At the same time, another servo, also connected via gear train, adjusts the opening of a

mechanical ball valve. The valve modulates water pressure to control spray distance, which the user has fine-tuned through the app.

All motion is closed-loop. The servo motors include built-in Hall effect sensors, which report angular position back to the ESP32. This enables precise control over both direction and valve positioning, even under varying water pressure conditions.

Once the cycle ends, the nozzle retracts and the electronics power down, stopping the pop-up rotation and valve adjustment. The turbine also stops spinning, halting further energy production until the next cycle begins.

All these components are compactly arranged within the sprinkler head's ABS housing. Wiring is routed through the internal electronics housing to ensure waterproofing, and all components are fixed into position using internal mounts designed for injection molding.

The result is a compact, responsive system that operates autonomously and harvests its own energy.

6 FINANCIAL PROSPECTIVE

6.1 MARKET OPPORTUNITY

The smart irrigation market in the United States is currently valued at $2.4 billion and is growing at over 12% annually. This fast growth has been stimulated by government programs and incentives like WaterSense, that give re bates for using water efficient devices, as well as local regulations and restrictions that are being placed on water usage. WaterWise will beachhead to upper-middle class homeowners in the Southwest of the U.S., where water stress is at its highest, who value sustainability.

6.2 COMPETITIVE ADVANTAGE

Unlike all other smart sprinklers with controllable flow patterns, the GrassGuard Smart Sprinkler is compatible with existing systems and is designed to replace existing sprinkler heads. This eliminates all setup costs that typically come with a smart sprinkler system as well as the headache of tearing up one's yard to install a new system. Whereas other smart solutions can take thousands of dollars to implement, the GrassGuard is free of additional installation costs, reducing the barrier to entry.

6.3 Customer Benefit

Customers will purchase the GrassGuard sprinkler for $100. The average homeowner who purchases the GrassGuard Smart Sprinkler will be able to save up to $10/month on their water bill with an expected payback time of about a year. The average family of four can expect to save up to 1440 gallons of water per month.

6.4 Business Model

WaterWise will begin by selling the GrassGuard Smart Sprinkler to homeowners through online direct-to-customer sales. Once a reputation is established and demand is proven, WaterWise will expand to commercial buildings, landscaping companies, golf courses, and parks. After this, WaterWise plans on partnering with large retail stores like Home Depot and Lowe's to begin selling the GrassGuard on their shelves.

7 SUSTAINABILITY IMPACT

Sustainability is the primary focus of the GrassGuard sprinkler head's design. This sprinkler head is a solution that saves water and lessens landscape irrigation's impact on the environment.

Because of spray overlaps, traditional irrigation systems frequently overwater. By enabling users to alter the spray patterns to suit their unique lawn, GrassGuard addresses this problem and ensures that water only gets used on the areas that need it. This solution will cut down on water use for lawns, which is crucial in areas experiencing water scarcity.

GrassGuard's self-power generation is one of its most innovative sustainability features. The system eliminates the need for an external power source by harnessing the energy of the water flow itself. This guarantees that every sprinkler runs independently and eliminates the need for outside electricity from the grid.

GrassGuard's ABS housing can be mass produced with minimal material waste by utilizing injection molding. The ABS's high durability also helps extend the product's lifespan. This lessens the environmental impact and replacement frequency.

By combining water efficiency, self-energy production, and durability, GrassGuard provides a sustainable alternative to traditional sprinklers. It supports homeowners in making greener landscaping decisions, especially in water-stressed communities.

GrassGuard reflects a shift toward smarter, greener infrastructure, a much-needed change with the current state of the climate.

8 CONCLUSION

The GrassGuard smart sprinkler head represents a significant innovation in smart irrigation technology. Developed in reaction to the inefficiencies and environmental costs of traditional sprinkler systems, GrassGuard provides homeowners with a sustainable alternative to reduce water waste while increasing control and convenience.

The GrassGuard introduces a few key innovations that set it apart from other solutions on the market. This sprinkler head dynamically manages the direction and distance of water spray, all from a user-defined pattern using a smartphone app. Its onboard power design — fueled only by hydroelectric power harvested while watering — eliminates the need for external wiring, making it sustainable and simple to install. By plugging directly into existing irrigation systems, GrassGuard is a plug-and-play system without requiring an overhaul of large systems.

In addition to offering real-world functionality and value in sustainability, GrassGuard also symbolizes an even broader trend toward more intelligent, responsive environmental technologies. With municipalities and communities increasingly being compelled to conserve water and maximize the use of resources, solutions such as GrassGuard provide low-impact, scalable solutions that satisfy the needs of the modern world.

In the future, ongoing innovation will be focused on developing a smartphone app, reducing the sprinkler's form factor, enhanced wireless controls, and beginning mass manufacturing processes to start selling the product. By having the ability to optimize water usage in irrigation, GrassGuard is more than an intelligent sprinkler — it's a smarter way to care for the environment.

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