UV Pulse Bulb Agricultural Treatment System Against Fungal Pathogens

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BREE 495 Final Report

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Abstract

As pulse bulb ultraviolet (UV) light treatment system is proposed for application on grape vines. The pulsing UV-C light treats fungal diseases which commonly occur on grape leaves. It is an automated system which provides a wavelength of 275 nm and requires an input voltage of 24V. The radiation intensity is 50 W/m^2 with an exposure time of 1 second. The system consists of a steel frame, enclosed with aluminum panels for support. The panels house UV light strips. The entire system is enclosed in a reflective aluminum lining which keeps harmful UV light inside, redirecting it onto the leaves, ensuring operator safety. The system is intended for use with a tractor. Attachment to the tractor will allow the system to travel over each row of grape vines. As the vines pass through the enclosed system the pulsing UV light will treat the leaves, preventing fungal disease infections and associated crop losses. The structure of the system is fully adjustable. The height and width of the system may be adjusted to allow for various vineyard sizes and layouts. In addition, this allows for compatibility with various tractors. The width adjustability also increases treatment efficiency by allowing accurate distance from lights to leaves for various life stages of the grape vines. This project outlines the complete engineering design of this UV pulse bulb treatment system, including all system design aspects, environmental, social, and economic considerations. In addition, a case example is outlined to help explain the systems integration and application within a vineyard.

This report was written for BREE 495 an undergraduate Capstone Design Project at McGill University in the Bioresource Engineering Department. Our team worked under the supervision of Dr. Mark Lefsrud.

As part of the design team process, we developed the following statements:

Vision Statement: Using ultraviolet light to improve agricultural disease management sustainability.

Mission Statement: Transforming agricultural practices for a safer present and a brighter tomorrow.

Table of Contents

Introduction

In an industry as high value as the grape industry producing a high-quality fruit is key for a successful business. One of the major problems that grape growers encounter is fungal diseases (AAFC, 2018). These fungal diseases infect the grape plants and can reduce yields by killing plant cells and/or by putting the plant under stress (AUSVEG, 2022). Fungal diseases most often affect the leaves of plants; therefore, preventative measures and treatments are applied to the leaves of plants. The most effective way to treat the leaves, according to traditional agricultural practices, is by spraying chemical fungicides onto the leaves. A fungicide is a fungal specific pesticide which kills and prevents the growth of fungi and their spores (NPIC, 2022). The problem arises that fungicides may not just be killing their target fungal diseases. The harsh chemicals in fungicides can be washed away by rain, ending up in water systems near application sites (Schilder, 2010). Concentrations of chemicals can be found in many aquatic species, posing a serious threat to species diversity but also to human beings through paths such as bioaccumulation, and direct inhalation for producers (Lorenz, 2022).

There is a clear market for an environmentally conscious treatment for fungal disease. This paper proposes a complete engineering design to solve the problem of fungal diseases in grape vineyards, without the use of harmful fungicides. This design is an agricultural attachment for a tractor which uses pulse bulb ultraviolet (UV) light technology to treat the grape leaves. The pulses of UV light kill the fungal disease and preventing yields losses. Pulse bulb UV lights are both an environmentally friendly and energy efficient design. The pulse bulb feature allows for minimum energy use while still delivering effective disease treatment to the crop. In addition, the implementation of UV light treatment eliminates the need for chemical fungicide application. This reduces environmental concerns surrounding leaching and bioaccumulation. It also improves human health and safety with regards concerns surrounding fume inhalation and chemical ingestion.

A mobile steel structure which can connect to a tractor has been designed to carry the UV lights overtop of grape vines delivering UV light to the foliage. The system travels on wheels, while being propelled by a tractor driven parallel to the vine rows. Protective measures were implemented, including reflective lining, which ensures that the UV light is contained within the system. This both maximizes treatment efficiency as well as ensures that the UV light is not coming in contact with the producer. The design consists of several sizing options. It is fully equipped with both height and width adjustments to allow for use on a variety of crop systems, styles, and sizes. The system carries LED UV light strips which line the inside of the structure. The producer has the ability to control the lights as they deliver pulses of UV light to the crop as the system travels over top.

In addition to safety and efficiency this system was engineered for low maintenance, ease of use and longevity. Design decisions were made with these criteria in mind. Many integral parts of the design were included to ensure that these were met. This included materials choices, structural design choices and user interface integrations. The importance of creating a low-cost system was also a key aspect of this design. Encouraging producers to make the switch to a more sustainable, efficient fungal disease treatment is key for advancing. Cost efficient equipment is a key part of this process.

The proposed design is a fully integrated fungal treatment system that is vineyard ready with adjustable dimensions which puts the producer's safety first while protecting yields by ensuring that fungal diseases are not an issue for the grapes.

Design Overview

PART A: Overall Rendering of System

I. Diagram with General Dimensions

The following Figures 1, 2 and 3 represent the Solidworks rendering of the final system design metallic structure, including the LED layout and the wheels.

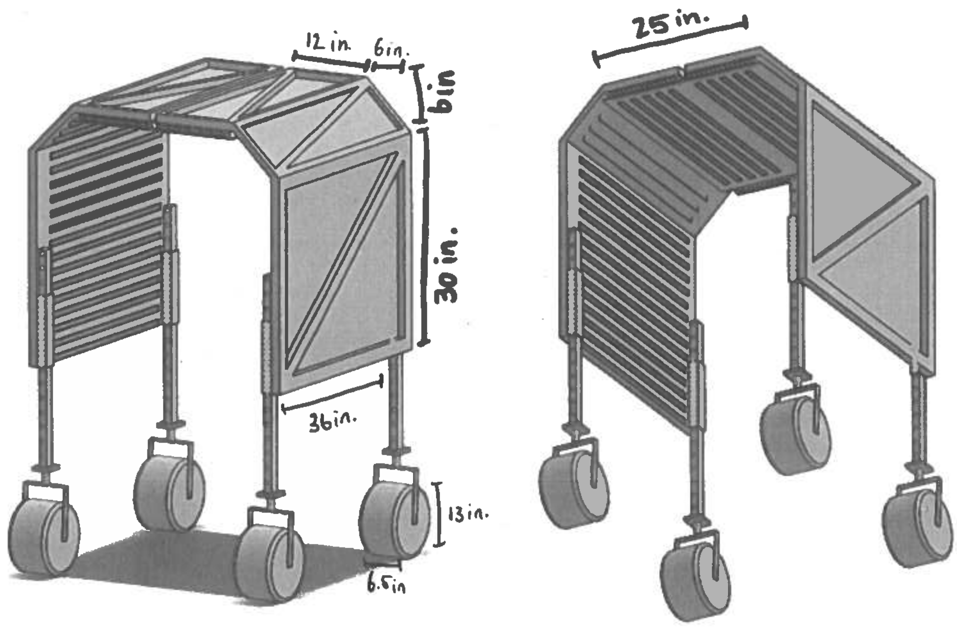

Figure 1: SolidWorks rendering of final design structure

Figure 2: View of top and underneath top of UV-C treatment system structure with width adjustment mechanism.

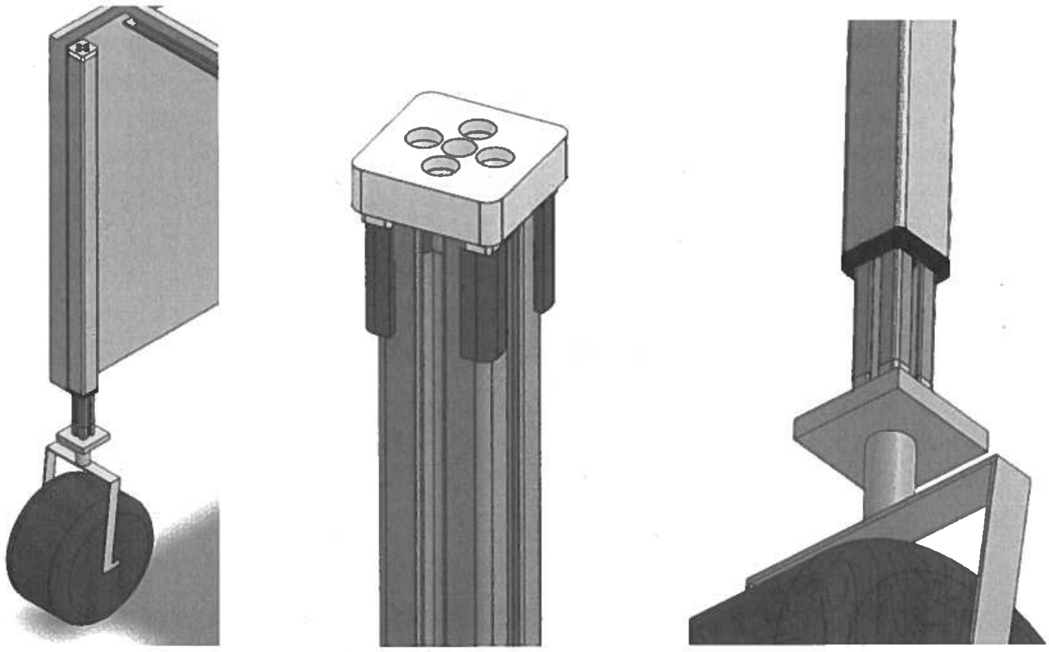

Figure 3: Height adjustment telescopic mechanism

II. Specific Characteristics of Design

To ensure this system was the best that it could be there were several specific design criteria that the final design had to meet. There are many aspects of the treatment system which were carefully designed to meet the design's needs. The two most important aspects of this design were high disease killing efficiency and human health and safety. The risks associated with UV light are serious and cannot be ignored. This system takes every precaution to ensure that the operator and bystanders are completely safe. The reflective lining and control panel location were specifically chosen to ensure maximum safety.

In the design process it was also important that this system be low maintenance with easy installation and use. This design criteria were extremely important to ensure that the consumer would be able to get maximum longevity out of their purchase. The choice of materials and structural design were done with these criteria in mind. The implementation of fully adjustable structure was introduced to ensure that this system is adaptable to a variety of agricultural operations, layouts, and tractor sizes. The sizing in terms of vertical height (crop height) and horizontal width (perpendicular to direction of travel) are all easily adjustable. These easy-to-use adjustable components also allow the system to be efficient in treating a variety of crop ages, from young/juvenile all the way to full grown, mature vines. In addition, it was important to ensure that the final system would be available to producers at a reasonable price. This was honored with a detailed economic analysis, which will be outlined below.

The final criteria which were fully integrated into this system were the environmental aspects. This system in and of itself was engineered to reduce pesticide usage. In addition, the pulse bulb component ensures that power usage is efficiently conserved. Material selections were done with end of life, longevity, and material reuse in mind.

III. Constraints: Boundaries of the Design

i. Light Parameters

The authors did not determine specific light parameters for this study, but instead used values from the literature or based on novelty of treatment, as determining optimal parameters would require extensive research over years. Instead, the design focused on developing an adaptable and adjustable system to the many shapes and sizes of vineyard system in Québec, that would incorporate updated optimal light parameters, as the research in this area advances. The light parameters chosen to use in our calculations on were based on a study by Gadoury et al. in 2022, which included UV-C radiation with a wavelength range of 254 to 283 nm, radiation intensity of 50 W/m^2 during nighttime with an exposure time of 1 seconds, dosage of twice weekly with a light energy of 50 J/m^2, distance between plants and light of 45 cm, and a pulsing frequency of 15 Hz. It is important to note that these are base values and can be adjusted using a control board to adapt to specific needs.

ii. Tractor Attachment System and Beam Length

The authors did not incorporate a tractor attachment system for their pulsing UV-C light fungicidal system in their study, as the type of tractor used would vary depending on the specific agricultural vineyard system being utilized. Instead, suggestions were made for the type of PTO generators that would fit the design presented here. Indeed, the attachment system would need to be custom-built to fit the particular tractor and the UVC light system. Similarly, the length of the beam connecting the tractor to the UVC light system was not determined, as it would depend on various factors such as row widths, spacing, and tractor dimensions specific to the agricultural vineyard system being used. Hence, the beam would either need to be custom-built to ensure it fits both the UVC light system and the tractor being used or have a modulable length. In order to facilitate universality of this system, the authors decided to design a beam with modulable length to expand the possible applications and fields for this system.

PART B: Precise Description of Each Component

I. Aluminum Sheeting

Aluminum alloy panels 6061 were chosen as the material for the protective housing of the system because they are commonly used in agricultural machinery due to their excellent strength-to-weight ratio, corrosion resistance, and weldability. These panels are ideal for applications that require structural integrity, durability, and resistance to environmental factors such as moisture, chemicals, and UV exposure (ASM Material Data Sheet, n.d.). As such, this type of aluminum was chosen for this design since the system must be strong, durable, lightweight, resistant to various weather conditions, and be able to withstand UVC radiation exposure without affecting its durability (Jon, 2021). An example of such a 6061-aluminum alloy panel is represented in Figure 4. This sheet, measuring 12 in by 12 in and ¼ in thick, would be ideal for this design. The panels can be cut to fit the exact measurements of the top, slanted, and side panels of this system. Since these panels will be supported by steel structural support beams (discussed in the following section), they will not undergo excessive loads/forces/stresses. As such, a structural analysis was not performed on these panels.

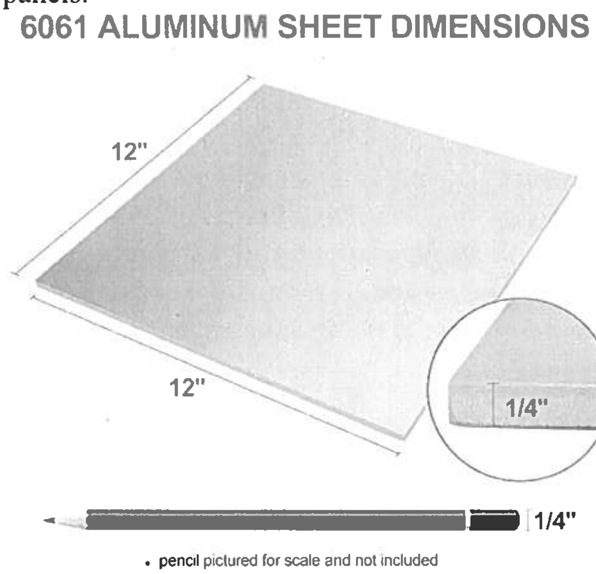

Figure 4: 6061 Aluminum Sheet Panel for Protective Housing (Amazon, 2023)

The aluminum housing is comprised of seven panels made of aluminum, with each side consisting of one panel, resulting in a total of two panels. Each of these side panels measures 3 feet (36 inches) in depth and 2.5 feet (30 inches) in height. Each aluminum panel is 0.25 inches thick.

The top part of the object is made up of multiple panels. In the middle, there is a panel that can be extended to its maximum length, measuring 2 feet (24 inches) in width and 3 feet (36 inches) in depth. Above this middle panel, there are two additional panels that hover over it, with each panel measuring 11.5 inches in width and 36 inches in depth. There is a 1 in gap separating these two panels to allow for extension. These top panels are positioned at an angle, slanting downwards towards the sides at a 45-degree angle.

There are also two slanted side panels that connect the top panels to the sides of the object. Each of these slanted side panels measures 0.707 feet (8.5 inches) in width and 3 feet (36 inches) in height. They are positioned at a 45-degree angle, forming a triangular shape between the slanted side panels and the top panels.

In summary, the object has a rectangular shape with two aluminum panels on each side, a middle panel at the top that can be extended, two top panels hovering over the middle panel, and two slanted side panels connecting the top panels to the sides. The dimensions of the structure, outlining each panel, are provided in Figure 5, including their width, height, and angle of inclination. The maximum width at full extension is 5 feet (60 inches).

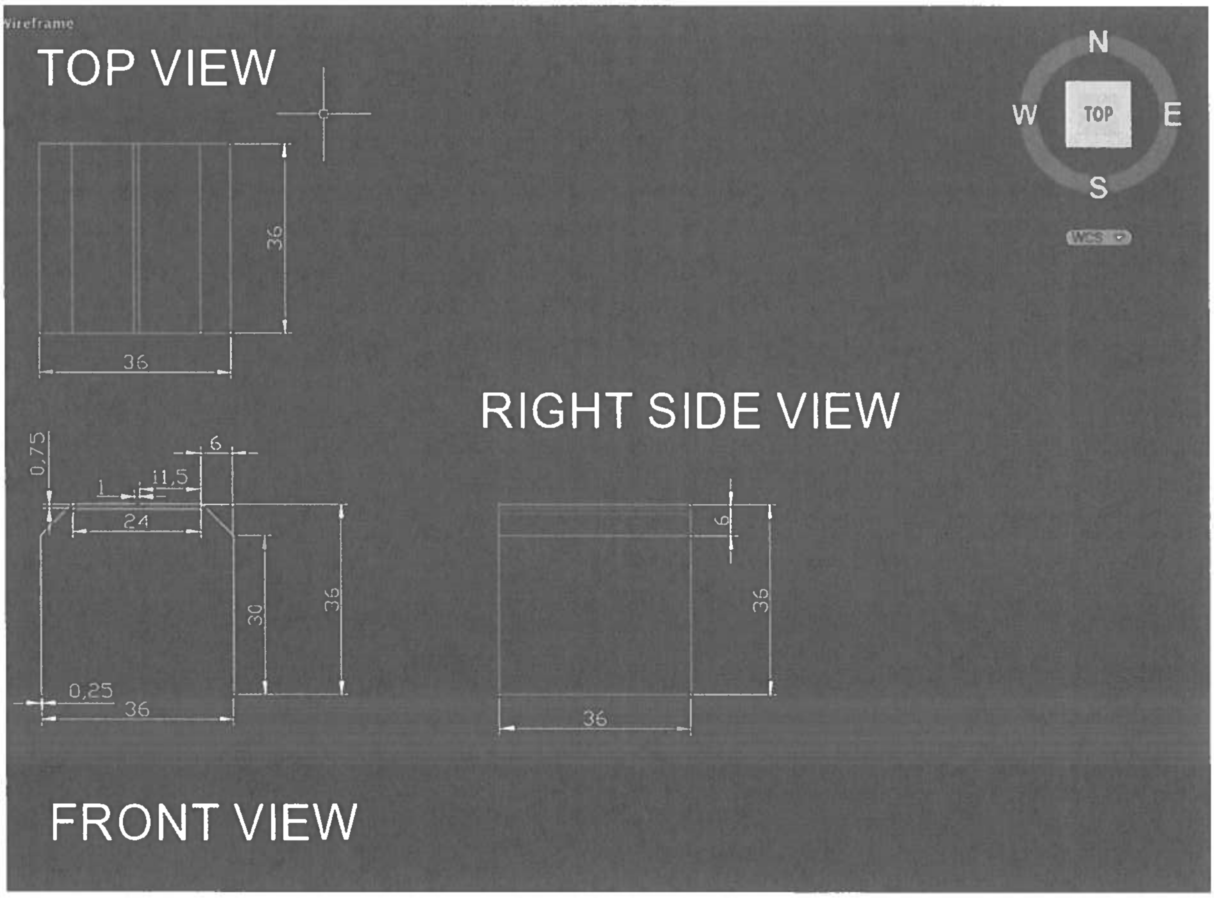

Figure 5: Top, Front, and Right Side View illustrating dimensions of aluminum panels (inches)

Total surface area needed:

To calculate the total surface area needed for the object, we can break it down into its different components.

For the sides, there are two aluminum panels, with each panel measuring 36 inches in width and 30 inches in height. To find the total surface area of the sides, we multiply the width and height of one panel and then multiply by 2 to account for both sides. This gives us a total surface area of 2160 square inches (36 in * 30 in * 2 panels = 2160 in^2).

Next, for the top of the object, there are several panels to consider. The middle panel measures 24 inches in width and 36 inches in height, resulting in a surface area of 864 square inches (24 in * 36 in = 864 in^2). Additionally, there are two hovering panels positioned above the middle panel, with each panel measuring 11.5 inches in width and 36 inches in height. Multiplying these dimensions by 2 to account for both hovering panels, we get a total surface area of 828 square inches (11.5 in * 36 in * 2 = 828 in^2).

Lastly, there are two slanted side panels that connect the top panels to the sides. Each slanted side panel measures 8.5 inches in width and 36 inches in height, resulting in a surface area of 612 square inches for both panels (8.5 in * 36 in * 2 = 612 in^2).

To find the total surface area needed for the object, we add up the surface areas of all the components calculated above: 2160 in^2 (sides) + 864 in^2 (middle panel) + 828 in^2 (hovering panels) + 612 in^2 (slants) = 4464 in^2. Therefore, the total surface area needed for the object is 4464 square inches.

I. Metal Structure

The structural base of the system is a steel framed skeleton. Steel such as AISI carbon steel is commonly used steel for agricultural equipment (Reed, 2021). This type of steel is easy to machine, weld and therefore will be good for the production process of the pieces for this system (Engineering Toolbox, 2009). Based on this to build the skeletal frame for given dimensions, as outlined above, steel of a hollow rectangular cross section of dimensions 3in by 1.5in by 0.125in is selected (see Figure 6) (Millennium Alloys, 2023). Given the nature of the design the steel will be constructed using welding to create the designed structure. Based on the above outlined dimensions of the frame it was determined that approximately 75 ft of steel would be needed to construct one frame. As the top aluminum panels have a much smaller load, due to less weight, than the bottom side panels, the top panels will have thinner carbon steel structural supports, as illustrated in Figure 7 below. The dimensions of the top supports will measure ¾ in. in width by 48 in. in length and are 1/16 in. thick.

To reinforce the structural integrity of the design it was necessary to engineer a safe and sound skeletal frame. To ensure this was the case diagonal pieces were added on each side of the frame for extra structural support and rigidity (see Figures below). This is key because the frame will be supported by the tractor attachment beam, but this beam was not designed, nor was it intended, to support the full weight to the system. The legs of the frame will also be on wheels, which rest on the ground. Therefore, these additional structural aspects will ensure that the full system is structurally sound and can support itself full under the weight of the materials, as well as additional stresses applied from movement and vibrations produced from movement traveling through vineyards during treatment operations.

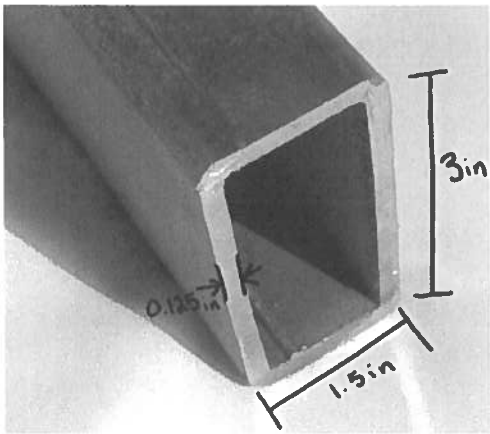

Figure 6: Cross sectional view of chosen steel beams for structural frame construction (Millennium Alloys, 2023).

Figure 7: Carbon Steel Beam measuring ¾ in W by 48 in L by 1/16 in T (Rona, 2023)

It is also important to note that, as in most agricultural implements, a protective rust coating would be implemented on the finished product. This coating will increase the system's lasting structural integrity and longevity of life. Commonly paint is used to provide this protection (Steele, 2022). This coating will also protect from harsh weather elements which will inevitably be encountered during field usage. This is especially important due to the fact that steel rusts over time. The simple solution of paint will help prolong the life of the steel.

Figure 8 below depicts the dimensions of the steel structural supports used in this design. The sides of the structure are supported by four steel beams, each measuring 3 inches in width and 1.5 inches in thickness. These beams have a height of 66 inches each. The 2 diagonal beams along each of the side aluminum panels measure 72 inches in length. The resulting length for these wider steel beams is therefore 336 inches, or 28 feet.

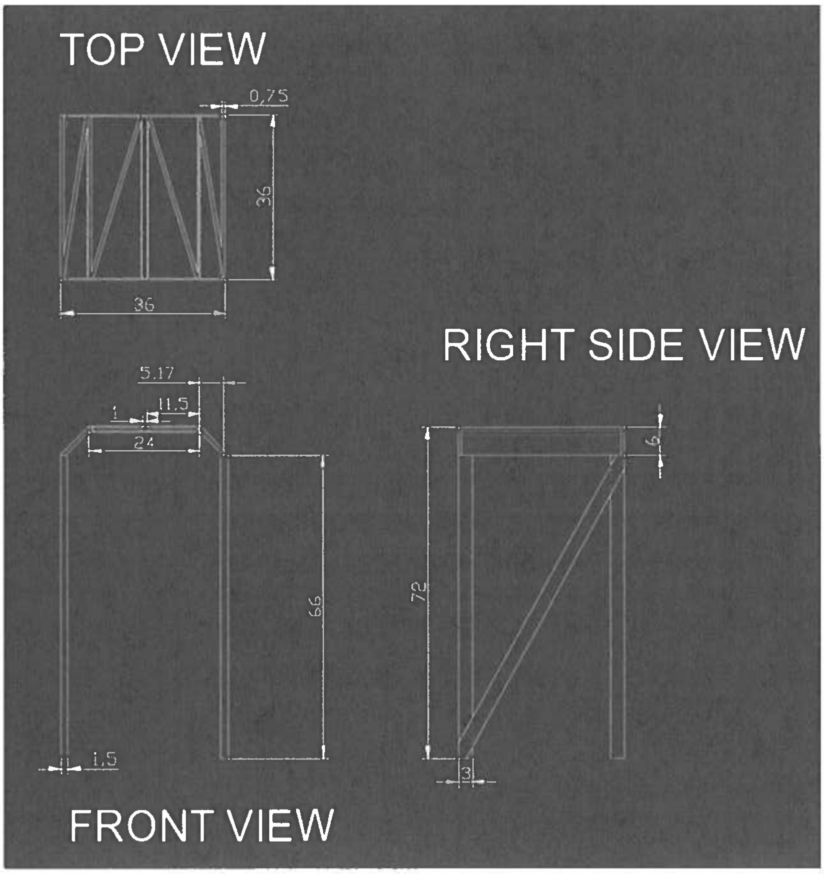

Figure 8: Top, Front, and Right-Side View of steel structural supports

(Legend: contour lines, hidden lines)

On the top of the structure, thinner steel supports are used, measuring 0.75 inches in width. There are four supports that are 6 inches in length each, eight supports that are 36 inches in length each, four supports that are 11.5 inches in length each, two supports measuring 34 inches in length (diagonals), and two supports measuring 30 inches in length (diagonals on slants). When calculating the total length required for these thinner 0.75-inch supports, it amounts to 486 inches or 40.5 feet.

In summary, the steel structural supports in the diagram consist of four 3-inch by 1.5-inch supports for the sides with a total length of 22 feet, and various thinner 0.75-inch supports for the top with a total length of 41 feet. These supports play a critical role in providing stability and strength to the structure, ensuring its structural integrity and safety.

II. UV lights and Electronic Components

i. System Power Source

As mentioned previously, the design was limited to the UV-C system itself, and does not include the link to the tractor, both mechanically and energetically. However, the system still requires a power source that is adapted to the needs of the UV-C lamps, while being similar to those found in vehicles such as tractors. Typically, tractors use 12V DC lead-acid batteries (Sauer, 2022), therefore this voltage will be chosen for our power source to allow the user to easily switch the power source from an external battery (such as in our design), to the battery integrated in the agricultural vehicle.

Another advantage to the 12V battery compared to a 24V one is they are more common, are usually cheaper, and tend to be safer for DC circuits (Reed, 2011). of if the tractor is equipped with a PTO generator and a voltage converter (to convert 120V to 12V),

However, in the case where the lights have the same power rating (for example 10W), using a 12V battery instead of a 24V draws twice as much current to achieve the same power output, as seen in the equations below:

$$P = V * I$$

For 12V:

$$I = \frac{10W}{12V} = 0.833\ A$$

For 24V:

$$I = \frac{10W}{24V} = 0.416\ A$$

In consequence, opting for a 12V power source implies that the wires in the system need to be larger to carry more current, thereby increasing the overall wiring cost (Battery University, 2020). However, one can assume this is compensated by the reduced price of 12V batteries compared to 24V. In addition, drawing more current generates more heat, which can impact the system performance (Battery University, 2020). Therefore a heat dissipation unit was included to increase the system performance and safety. Additionally, a fuse would be installed between the lights system and the battery to reduce the risks of accidents and damaging the system (fuse is integrated in the power source converter).

The user may also use a rolling PTO generator behind the tractor as a power source. The generator would need to have a power output of at least 1 kW (2HP), and if the output is 110V, the user would need to use a power supply converter (110V to 12V, 75Amps - 280 CAD (Amazon, n.d.)).

Small PTO generators usually produce 10-15 kW, 30-60 A (AP Electric & Generators LLC, n.d.), which is more than enough to operate the pulsing UV-C treatment system, as seen in the Power Consumption section of this report.

Finally, an independent battery can be used as a power source. The recommended specifications would be a 12V, 300 Ah, Lithium battery, allowing 5 hours of autonomy for treatments (see power consumption calculations section) (CANBAT, n.d.).

The UV-C lights were chosen according to the 12V specification of the battery, to ensure optimal performance of the system, as discussed in the following section.

ii. UV Light Strips

The chosen UV-C lights for this system are the cleanUV™ UV-C LED light strips offered by the company "Waveform Lighting" (Figure 9). The general specifications related to these lights seen in Table 1, and the detailed specification sheet can be found in Appendix A.

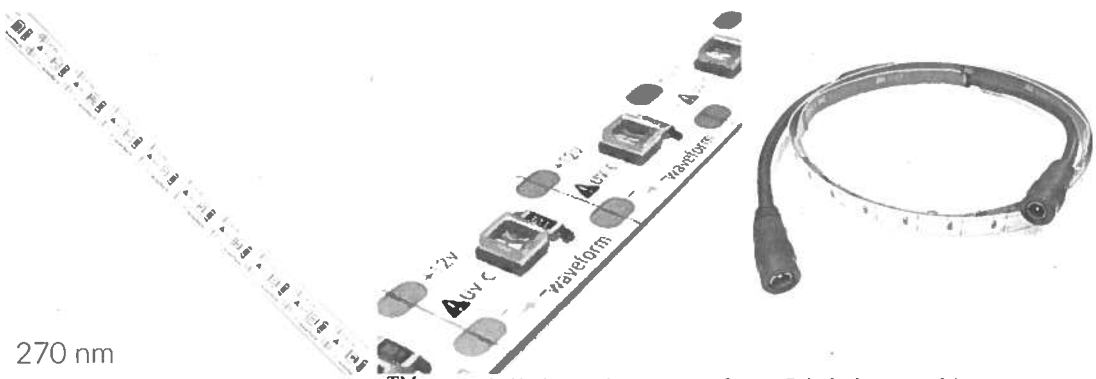

Figure 9: Images of a cleanUV™ UV-C light strip (Waveform Lighting, n.d.)

Table 1: Specifications for one UV-C light strip unit

Wavelength	270-275 nm
UV Output (per reel)	0.13 – 0.14 W
UV Irradiance 6" (15 cm)	40 μW/cm²
Voltage / Current	DC 12V / 1200 mA
Dimensions	0.39 x 39.4 in (10 mm x 1000 mm)
LED Quantity	60 x SMD 3030 LEDs
Power	14.4 watts
Connection Style	Female DC Connector (Both Ends)

Each LEDs are spaced 0.656 inches apart on the strip, and the strip bars are spaced 2 inches from one another (vertically) (Figure 10). The entire system includes 50 strips in total, i.e., 25 on each side.

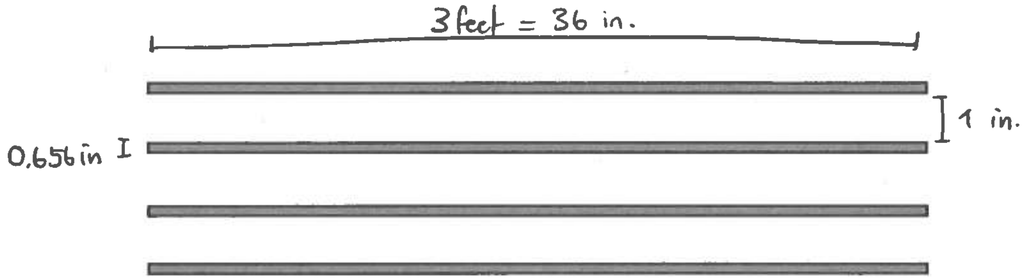

Figure 10: LED Bar Layout Example

The UV-C lights will be connected in a series configuration to avoid high voltage fluctuations. Heat dissipation units are placed on the back of each light strips to prevent system overheating while the treatment is being applied (Figure 11).

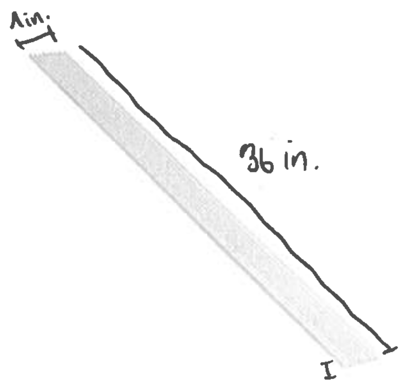

Figure 11: Heat dissipation blocks on the back of the UV-C light strips (Digi-Key Electronics, n.d.)

The light strips have pre-mounted female DC cables on each end to allow quick and easy set up and part replacement. Each strip are connected to one another using solderless gapless connectors (Figure 12(a)). The overall lighting system is electrically connected to the power source (battery, or PTO generator) using a 16 AWG wire (Figure12(b)) and a male DC barrel jack plug adaptor (Figure 12(c)) (Waveform Lighting, n.d.).

Figure 12: (a) solderless gapless connectors; (b) 16 AWG wire ; (c) male DC barrel jack plug adaptor (Waveform Lighting, n.d.).

III. Reflective Lining

To maximize light efficiency and safety of the system a lining will cover the entire exterior of the system. The lining will keep the UV light inside the system. This serves both safety and light usage efficiency purposes. In terms of safety the lining will protect the producer from being exposed to harmful UV light during treatment.

In terms of light efficiency, this related to maximizing light distribution within the system helping to maximize the amount of light that comes in contact with the grape leaves. When it comes to light distribution, reflective and white lining can both be effective in their own ways. Reflective lining is made of materials that reflect light, such as aluminum or mylar (Torpey, 2021). When used as a lining in a space, it can help to evenly distribute light by reflecting it throughout the area. Reflective lining is often used in indoor gardening to maximize the amount of light that reaches plants, and it can also be used in photography or film sets to create even lighting (Gardener's Supply Company, 2023). White lining, on the other hand, absorbs some light but reflects the rest, which results in a more diffused and softer light. When used in an enclosed space, it can help to reduce harsh shadows and create a more even distribution of light (Sargent, 2022). White lining is often used in photography and film sets as well, especially for portrait or product photography, to create a soft and even light. Overall, the choice between reflective and white lining depends on the specific use case and the desired outcome. For this project, aluminum lining was chosen as it can be more effective in maximizing light output.

Figure 13 shows the aluminum reflective lining which was selected for this design system. The lining is strong and durable. These are important characteristics because it must withstand brushing the grape vines and will sustain general wear-and-tear. In addition, it must be flexible so that it can be rolled, as discussed below. This aluminum lining is also waterproof which is an advantage for expended longevity and will also help protect the lights inside for the weather elements. Based on the previously discussed structural frame dimensions it can be estimated that approximately 40 square feet of reflective lining will be required to cover the whole system fully.

Figure 13: Chosen Reflective Lining (MWS, 2023).

Due to the fact that the system is vertically adjustable in terms of height, it was necessary to account for that in the sizing and design of the reflective lining. Therefore, the reflective lining will travel all the way down the sides of the system, at its maximum vertical height of 7ft. When the system is not fully extended vertically the lining can easily be rolled up and secured with ties (see Figure 14). This will allow the user to adjust the height of the system while the lining will still provide them with safety protection.

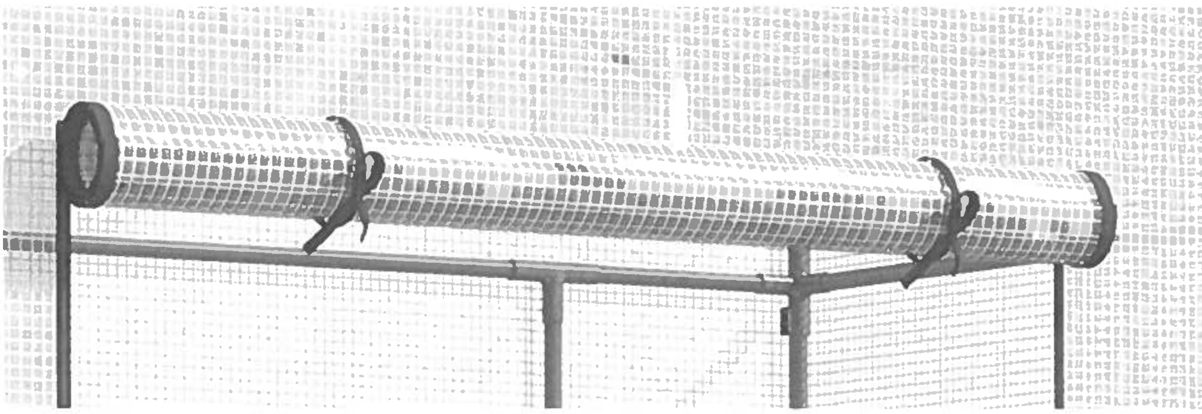

Figure 14: Example of how the reflective lining rolls up will operate (Out Sunny, 2023). Note this is not an example of the material that will be used for the lining, but simply an example of the mechanism that will be used.

The lining will also cover the ends of the system, the side through which the grape plants pass through. To ensure the vines can pass through easily, without any damage, while keeping the UV light inside the system, vertical strips of lining will be used (see Figure 15). The vertical strips will overlap, ensuring that the UV light is kept in, while the actual strips will easily allow the vines to pass through without damage.

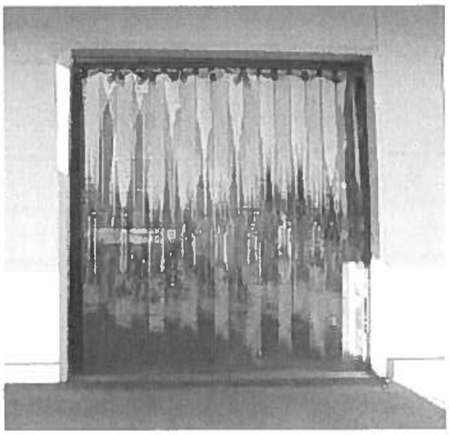

Figure 15: Mechanism of design for strips of reflective lining that the vines will pass through (AKON Curtain & Divider, 2023). Note this is not an example of the material that will be used for the lining, but simply an example of the mechanism that will be used.

IV. Support Castor Wheels

Support wheels are needed on the bottom of the structure to support some of the weight from the body of the equipment. In addition, the wheels will allow for travel over various types of terrain and provide stability to the structure. Therefore, the wheels needed to be structurally sound but also functional. The selected wheels will provide support from the ground up to carry a percentage of the total system weight. The wheels will act as a guide on the ground for the structure as it passes over the grapes. Caster wheels were chosen for this design (pictured below Figure 16). The chosen wheels do not support all the weight of the system, they are not structural wheels. The wheels have a max capacity of 213 kg (470 lbs) (Uline, 2023).

System weight calculation:

The weight of the system was calculated to ensure that the chosen wheels could support the system. Given ~75 ft of steel, at the above cross section and a steel density of 490 lbs/ft^3 (Kloeckner Metals, 2021) the weight of the system frame can be approximated to 270lbs. The other heavy part of the system is the aluminum panels. Given 4464 in^2 of quarter inch thick aluminum panels at a density of 169.18 lbs/ft^3 (Thyssenkrupp Materials, 2022) the weight of the aluminum panels can be approximated to 110lbs. This gives a total system weight of 380lbs. this is well within the max capacity of the selected wheels. Therefore, the wheels are an acceptable choice for this design.

Another advantage of the chosen wheels is that they do not require maintenance. The wheels also have some tread which will help the system with grip and stability while traveling in various conditions and terrain. These tires have a 10-inch diameter and are 4 inches thick.

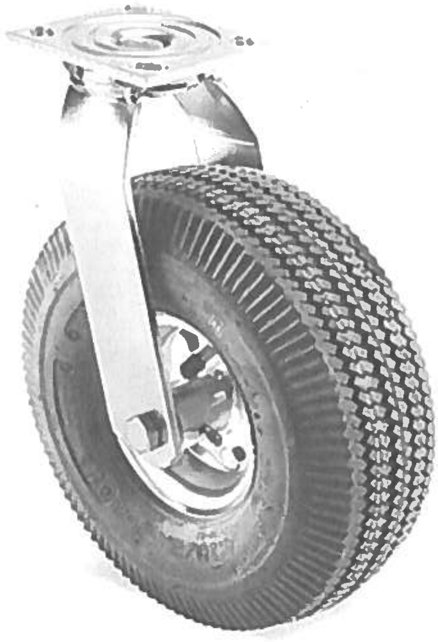

Figure 16: Image of castor wheels (Unline, 2023).

V. Extension/ Expansion Components

For both adjustment mechanisms, the choice of a manual adjustment system was made rather than an automated system for the following reasons:

- Reliability and durability: an automated sliding mechanism has more risk of failing, such as a motor failure, or electrical wiring damage, or there could be a control board malfunction. Using a manual system reduces the risk of failure to adjust width and therefore reduces the risk that the user needs to interrupt treatment to repair le system.
- Cost: the automated system would include more components, some of which would be electrical, and thus would cost more than a simple stop handle.

i. Width Adjustment Component

As previously mentioned, the system is adjustable to increase the width up to 2 feet in additional width (5 feet total max width) to adapt to the maturity of the vineyard and to the foliage density at a given time of year. In this design, we opted for T-slot Aluminium extrusion profiles (Figure 17, left) with a T-slot linear slider mechanism including a stop handle (Figure 17, right) as they are common, low cost and thus easily replaceable.

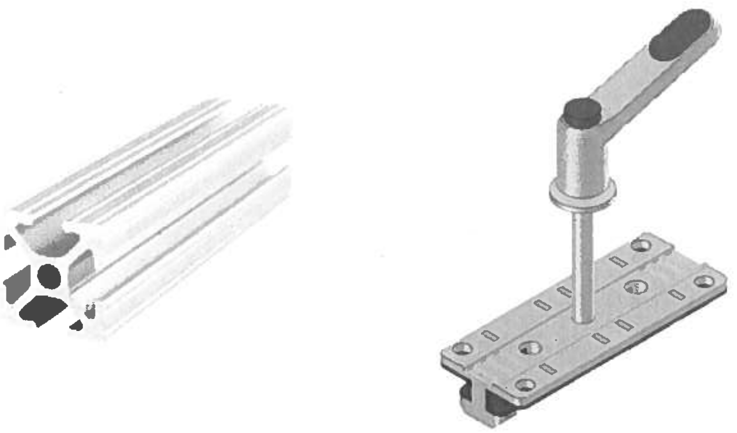

Figure 17: T-slot Aluminum extrusion profile (1.5"x1.5") (left) and T-slot linear slider mechanism with handle (1.5"W X 3.1"L) (Modular Components & Automation, 2018).

ii. Height Adjustment Component

Similarly to the width adjustment mechanism, the height adjustment component chosen is a telescopic profile system (Figure 18) as they offer several advantages that fit our design objectives for the overall design: easy to install, maintain and is low cow and durable (and easy part replacement). Indeed, telescopic length adjustment mechanisms are highly versatile as they can be used in a wide variety of applications, and withstand heavy loads over long periods of time (Modular Components & Automation, 2018).

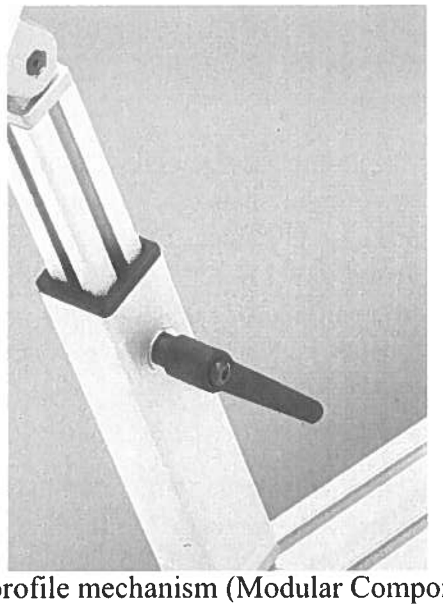

Figure 18: Telescopic T-slot profile mechanism (Modular Components & Automation, 2018)

VI. Tractor Attachment Beam

When considering an appropriate tractor attachment beam to use for the UV-C pulsing light fungicidal system, there are several options to consider, outlined below.

Three-Point Hitch (3PH) Attachment Beam: A three-point hitch attachment beam is a common type of tractor attachment that provides stability and control for implements. It consists of two lower arms that connect to the tractor's rear axle and an upper link that connects to the tractor's top link point (Meyer, 2022). This type of attachment beam is widely used for various agricultural implements and provides good stability and maneuverability for towing a UVC pulsing light fungicidal system on wheels in a vineyard (Meyer, 2022).

Drawbar Attachment Beam: A drawbar attachment beam is a simple attachment that connects to the tractor's drawbar, which is a horizontal bar located at the rear of the tractor (Woodlot Management, 2022). It provides a basic connection for towing implements and is suitable for light to moderate loads (Woodlot Management, 2022). However, it may not provide the same level of stability and control as a three-point hitch attachment beam, especially for heavy or bulky implements like a UVC pulsing light fungicidal system on wheels.

Custom Attachment Beam: Depending on the specific requirements of your UVC pulsing light fungicidal system, consider a custom attachment beam that is designed specifically for your system and tractor may need to be considered. This could involve designing and fabricating a specialized attachment beam that takes into account the weight, size, and configuration of the UVC system, the type of cropland, as well as the type of tractor being used.

As such, the most appropriate tractor attachment beam for this is a three-point hitch attachment beam since it is more stable. The 3PH attachment beam used for connecting the light system is Sulythw 3 Point Tractor Hitch Receiver for Cat 1 with 2 Balls. The dimensions of the attachment beam are shown in Figure 19, and the item weight is 29.2 lb (Sulythw, 2023). The towing capacity of the attachment beam is up to 8000lb, while the weight of the UVC pulsing light fungicidal system is 380lb. This indicates that our system can be towed with ease and stability. In addition, the attachment beam is made of heavy-duty steel with black powder coated, which is durable and resistant to rust and corrosion (Sulythw, 2023). Finally, the attachment beam is easy to install and has high compatibility with attachments and tractor models, further enhancing the sustainability and versatility of the design.

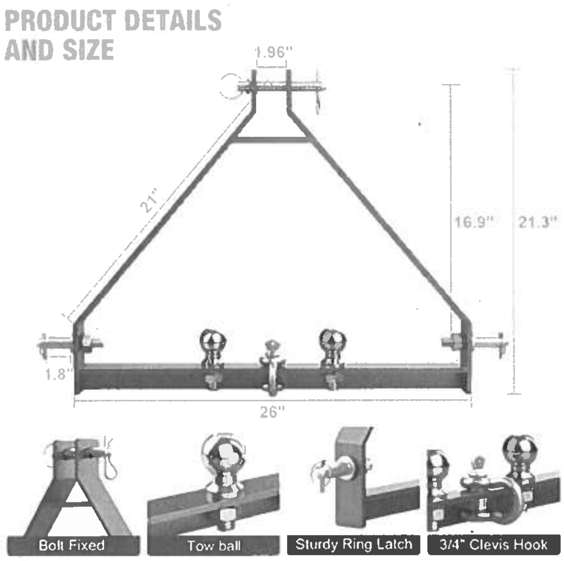

Figure 19: Dimensions and details of the 3PH attachment beam (Sulythw, 2023)

VII. Energy Analysis

If the system uses the independent battery unit as a power source (lithium battery), the battery life can be determined using the lights and battery specification (Table 2).

Table 2: Battery and Lights Specifications

BATTERY (CANBAT, n.d.)			
Parameter	**Value**	**Unit**	**Equation used (if applicable)**
Voltage	12	V (DC)	
Amperage	200	A	
Capacity	300	Ah	
UV-C LED LIGHTS			
Parameter	**Value**	**Unit**	**Equation used (if applicable)**
Voltage	12	V (DC)	
Power	14.4	W	
Number of LED strips/battery unit	50	-	
Total Power	720	W	14.4W * 50 strips
Total current draw	60	A	720W/12V

Battery Life:

$$\frac{\text{Battery capacity}}{\text{LED total current draw}} = \frac{300Ah}{60A} = 5 \text{ hours of autonomy}$$

If the batteries are used independently from the tractor, they can perform UV-C treatments for 5 hours without the need to recharge. However, if the tractor battery is used directly, the battery would be recharged while the tractor is in motion. Otherwise, as previously mentioned, the PTO generator could power the UV-C treatment system, consuming approximately 2.09 gal/hour of fuel to produce 2 HP, or 1 kW of electricity (Grisso , 2020). For a 5 hour treatment session, running the overall fungicide treatment would require:

Pulsing bulb system:

5 hours x 2.09 gal/hour = 10.45 gal of fuel

Tractor consumption:*

Speed = design structure coverage length/exposure time = 3ft/1s = 3 ft/s = 0.682 mph

For the 5075EN tractor model, and according to *ASABE Standards* the formula* below is the most widely used to estimate fuel consumption (Grisso, 2020) is:

$$Q_F = (0.043X + 0.019) \cdot P_{PTO} = (0.043(2hp/60hp) + 0.019) \cdot 60 \text{ hp} = 12.26 \text{ gal/hour}$$

Where,

Q_F = diesel fuel consumption at partial load and full throttle (gal/h),

X = fraction of equivalent PTO power available (decimal).

$$X = P/P_{RATED}$$

Where,

P = equivalent PTO power required by current operation (hp),

P_{PTO} = rated PTO power available (hp).

$$Q_R = Q_F \cdot [1 - (N - 1) \cdot (0.45X - 0.877)]$$

Where,

Q_R = diesel fuel consumption at partial load and reduced throttle (gal/h),

N = ratio of reduced- and full-throttle engine speeds at operating load (decimal).

$$N = RPM_{PT} / RPM_{FT}$$

Where,

RPM_{PT} = engine speed at partial throttle at reduced engine speed (rpm),

RPM_{FT} = full-throttle engine speed (rpm).

Therefore, to simulate the "worst case" scenario, i.e. the tractor being at full throttle, the fuel consumption is 12.26 gal/hour of diesel fuel. Total fuel consumption for treatment is thus 10.45 + 12.26 gal/hour. The fuel consumption when the tractor is at partial load and reduced throttle (QR) can be calculated using the above formulas, and depends on the type of tractor and speed of treatment.

Environmental, Social, and Economic Sustainability

PART A: Environmental

As previously mentioned, the use of UV-C light as a fungicidal treatment for crops, such as vineyards, has gained increasing attention in recent years as a potential alternative to conventional chemical fungicides. UV-C light, a type of ultraviolet light, has been shown to effectively control fungal diseases in crops through its germicidal properties (Janisiewicz et al., 2016). However, like any agricultural practice, there are both positive and negative environmental impacts associated with the use of UV-C light as a fungicidal treatment compared to conventional chemical fungicides.

One of the positive environmental impacts for farmers in vineyards using UV-C light as a fungicidal treatment is its non-toxic nature. Unlike conventional chemical fungicides, which are often made from synthetic chemicals that can persist in the environment and accumulate in soil and water, UV-C light is a physical treatment that does not leave any harmful residues (Komarek et al., 2010; Urban et al., 2018). This means that UV-C light does not contribute to soil or water pollution, nor does it pose a risk to non-target organisms such as beneficial insects, birds, or mammals (Urban et al. 2016). It also does not result in the development of resistance in fungi, as UV-C light disrupts the DNA of the fungal pathogens, making it difficult for them to develop resistance (Allende et al., 2006). As the crops would not develop resistance, the farmer would lose less crops due to fungal resistance if they were to use this UVC fungicidal system versus chemicals.

Furthermore, UV-C light has a shorter residual effect compared to conventional chemical fungicides. Chemical fungicides may persist in the environment for days or even weeks, posing a risk of contamination to other crops, nearby water bodies, and wildlife (Zubrod et al., 2019). In contrast, UV-C light has a very short residual effect, as it degrades quickly and does not persist in the environment, reducing the risk of unintended exposure (Narita et al., 2020).

Another positive environmental impact of using UV-C light is its potential to reduce the use of chemical fungicides. Conventional chemical fungicides are typically applied in large quantities and may require multiple applications throughout the growing season, contributing to the risk of environmental contamination and the development of fungicide resistance. By incorporating UV-C light as a part of an integrated pest management strategy, farmers may be able to reduce their reliance on chemical fungicides, leading to a decrease in chemical inputs and potential environmental impacts (Ferreira et al., 2021).

However, there are also negative environmental impacts associated with the use of UV-C light as a fungicidal treatment. One of the primary concerns is the energy consumption associated with UV-C light systems. UV-C light requires a significant amount of energy to generate and maintain, and this energy may come from fossil fuels, contributing to greenhouse gas emissions and climate change. The production, installation, and maintenance of UV-C light systems also require resources, such as raw materials and water, which may have environmental impacts during their extraction and production processes (Darre et al., 2022). A brief Life Cycle Analysis (LCA) will be performed in the following section in order to further examine the sustainability of the design.

Another potential negative environmental impact is the potential for unintended effects on non-target organisms. While UV-C light is generally considered safe for humans and animals, there may be risks associated with direct exposure to the light, such as skin and eye damage, and indirect effects on non-target organisms (U.S. Food and Drug Administration, n.d.). For example, UV-C light may also affect non-pathogenic microorganisms, such as beneficial microorganisms in the soil, which play a crucial role in maintaining soil health and fertility (Dai et al., 2012).

Additionally, the implementation of UV-C light systems may require changes in farming practices and infrastructure, such as the use of specialized equipment and installation of UV-C light sources in fields or greenhouses. This may result in additional resource use, such as manufacturing and transportation of equipment, and may have associated environmental impacts.

In conclusion, the use of UV-C light as a fungicidal treatment for crops has both positive and negative environmental impacts. On the positive side, it is non-toxic, has a short residual effect, and has the potential to reduce the use of chemical fungicides. However, it also has negative impacts related to energy consumption, potential unintended effects on non-target organisms, and changes in farming practices and infrastructure. Further research is needed to fully understand the environmental implications of using UV-C light as a fungicidal treatment.

PART B: Life Cycle Analysis (LCA) of UVC Fungicidal System for Vineyards

The UVC fungicidal system for vineyards is an innovative technology designed to mitigate the spread of fungal diseases in vineyards, thereby reducing the need for chemical pesticides. A brief life cycle analysis is outlined below, focusing on the resources used and waste products generated at each stage of its production.

<u>Raw Material Extraction:</u> The production of the UVC fungicidal system requires several raw materials, as previously discussed. The carbon steel beams, aluminum sheeting (6061), and aluminum reflective lining are commonly extracted from mines through energy-intensive processes such as mining, smelting, and refining (U.S. Energy Administration, n.d.). The extraction of these materials may result in habitat destruction, soil erosion, water pollution, and greenhouse gas emissions (U.S. Energy Administration, n.d.).

Manufacturing and Production: The raw materials are then processed and manufactured to create the various components of the UVC fungicidal system. The manufacturing processes involve cutting, bending, welding, and painting of the carbon steel beams, aluminum sheeting, and reflective lining. The manufacturing of UVC light strips involves assembling electronic components, which require energy and raw materials. The use of electricity and fossil fuels during manufacturing may further contribute to air pollution, water pollution, and carbon emissions.

Assembly and Packaging: Once the components are manufactured, they are assembled to create the UVC fungicidal system. The battery, castor wheels, antirust paint, and other miscellaneous components are also integrated into the system. Packaging materials such as plastic wraps, foam, and cardboard may be used for transportation and storage, resulting in waste and potential environmental impacts.

Transportation: The UVC fungicidal system is transported from the manufacturing facility to the vineyards. The transportation process itself consumes energy, typically in the form of fossil fuels due to gasoline/ internal combustion engines being most modern vehicles, and therefore contributes to greenhouse gas emissions. Additionally, the weight and size of the system may require special transportation considerations, such as oversized load permits or additional handling equipment, which can further impact the environment (Canada Cross Border Freight, 2020).

Use Phase: The UVC fungicidal system is used in vineyards to emit UVC light that helps control fungal diseases. The system requires energy to power the UVC light strips, which may come from a battery or an external power source. The battery used in the system may have a limited lifespan and will eventually need to be replaced, resulting in waste and potential environmental impacts associated with battery disposal (Gallegos Sanitation/ Republic Services, 2020).

End of Life: At the end of its useful life, the UVC fungicidal system may be disposed of or recycled. The carbon steel beams, aluminum sheeting, and reflective lining can be recycled (Recycling Center Near Me, 2022). However, recycling processes also require energy and may generate waste and emissions. The UVC light strips may contain hazardous materials, such as mercury or other electronic waste, which require proper disposal or recycling to prevent environmental contamination.

In summary, the production of the UVC fungicidal system for vineyards involves the extraction of raw materials, manufacturing and production, assembly and packaging, transportation, use phase, and end of life considerations. Throughout the life cycle, there are potential environmental impacts associated with resource extraction, energy use, waste generation, and emissions. Therefore, it is essential to carefully manage the resources used and waste products generated at each stage of the system's life cycle to minimize its environmental footprint and promote sustainability.

PART C: Social - User Safety

a. What are the laws and regulations in Quebec regarding the use of UV-C light

In Quebec, the use of UV-C is governed by the Quebec Occupational Health and Safety Act, which sets the rules for ensuring workplace safety. There are no special laws or regulations governing the use of UV-C, however it is critical to follow the standard workplace safety criteria.

Companies are expected to identify and control potential dangers in the workplace, including radiation exposure. The legislation states that "an employer shall take the appropriate precautions to guarantee that every worker is safeguarded against the risk of ionising radiation exposure." (RLRQ c S-2.1, r 13, s. 13.3)

Companies must also supply workers with proper personal protective equipment (PPE) to safeguard their safety. (CCOHS. 2021). It is also crucial to remember that the usage of UV-C must be done in compliance with manufacturer specifications and suitable safety practices to avoid injury to workers and others in the area.

b. What PPE (personal protective equipment) would be needed for the user of our system (protection against UV-C)

UV-C radiation can be damaging to human skin and eyes, so when working with UV-C lamps or other UV-C sources, it is critical to wear protective equipment.

UVC-protective clothing is intended to keep the wearer safe from UV-C radiation. Full-body suits, aprons, and lab coats composed of UVC-absorbing or reflecting fabrics are examples of such clothing. UV-C-protective clothing prices vary depending on quality, material, and level of protection, but a basic UV-C-protective suit can cost roughly $50. However, the tractor driver may not always require wearing the suit, depending on the vineyard row width, as the design was built to limit the UV light leaving the system. The suit would however be mandatory during testing and maintenance of the system, or when they are nearby the system.

UV-C-protective gloves are another important piece of safety equipment. These gloves are composed of UV-C-resistant fabrics and are intended to provide protection for the hands and wrists. UV-C-protective gloves (Figure 20) can cost anywhere between $5 and $30 per pair, depending on quality and level of protection.

Figure 20: UV protective gloves

When working with UV-C lamps or other UV-C sources, it is also critical to wear protective eyewear. UV-C-protective eyewear could include goggles or glasses constructed of UV-C-absorbing or reflecting materials. Prices for UV-C-protective eyewear vary according to style and amount of protection, but a basic pair of UV-C-protective glasses (Figure 21) may be found for roughly $10. (CCOHS. 2021).

Figure 21: UV protection safety glasses (CCOHS, 2021)

It should be noted that the costs listed above are simply estimates and may vary depending on your region and supplier. Furthermore, the level of protection supplied by UV-C-protective equipment varies depending on the product and its intended use. It is recommended that you contact a safety specialist or supplier to ensure that you are utilizing UV-C-protective equipment that is appropriate for your individual application.

PART D: Economic Analysis

A cost estimation analysis was completed to determine how much this system would cost to produce. In addition to the cost estimate a brief market assessment was done to help understand where this system would fit into currently available machinery. In addition, it helped justify the cost and ensure that the system was one that producers could afford. In addition, it was in the interest of this project to ensure that this system could be financially stable. Meaning that it has the ability to generate actual income.

Below in Figure 22, the detailed material cost analysis is shown. Based on the given dimensions of the design, materials costs were estimated for the reflective lining, steel for the structural frame, aluminum sheeting and lights. Costs were also estimated for the wheels and battery. Finally, some very rough estimates were included for completeness to consider labor, welding, and electrical assembly. Based on the cost analysis the UV Pulse Bulb Treatment system would cost ~$11 000 to manufacture.

Materials	Unit Price($)	Quantity	Total	Source
Reflective lining (~40ft^2)	0.36/sqft	40sqft	14.40	(MWS, 2023)
Wheels	94	4	376.00	(Unline, 2023)
3in by 1.5in Steel supports	8.70/ft	22 ft	191.40	(Millennium Alloys, 2023)
0.75in by 0.75in steel support	4.75/ft	41 feet	194.75	(Rona, 2023)
Lights	190.99/m	50 @ 0.5m length	4774.75	(MOSS LED, 2023)
1/4 inch Aluminium sheeting	0.38$/in^2	4464	1696.32	(Amazon, 2023)
Anti-Rust Paint	72.94/gallon	1	72.94	(POR-15, 2023)
Battery	329.99		329.99	(RENOGY, 2023)
Electrical	~1000		1000.00	Estimate
Welding	42/hr	8 hours	336.00	(GC Job Bank, 2022)
Labour	46.56/hr	1 week =40hr	1862.40	(Stats Canada, 2022)
		Total	**10848.95**	

Figure 22: Detailed Material Cost analysis

A brief agricultural equipment market analysis was conducted. This yield that generally agricultural equipment is retailed at 12% mark up (Schmidt, 2015). Meaning that the UV Pulse Bulb Treatment System would retail to farmers for ~$12 320.00. The next step in the market analysis was to compare this to other agricultural equipment. This was focused specifically the conventional method of treating fungus, spraying fungicides. It was found that fungus treatment is applied in a variety of ways. On small scale operations it could be applied with a hand sprayer, retailing for $170.00 (Uline, 2023). Whereas larger operations would require a larger sprayer. Top of the line sprayers could be of the order of $10 000 (Market Book, 2023). In addition to the initial investment for equipment, conventional fungal disease treatment requires the purchase of the fungicides. It is estimated that producers spend $600/ac every year on fungicides to treat fungal diseases in grapes (ON Ministry of Agriculture, Food and Rural Affairs, 2019). Based on this a simple cost comparison between this design and the conventional solution was done. An average initial investment for fungicide spraying equipment (~$5000) was subtracted from the cost of the UV Pulse Bulb System (see calculations below).

Cost Analysis Comparison Calculations:

Retail Price of UV Pulse Bulb System = $12 320.00

Average Retail price of Fungicide Sprayer = $5000.00

Difference in initial investment = Retail Price of UV Pulse Bulb System - Average Retail price of Fungicide Sprayer

= $12 320.00 – 5000.00

=$7320.00

This indicated that the initial investment of the UV Pulse Bulb System would be roughly ~$7500 more than that of conventional solutions. However, the advantage of the proposed system is that there are no additional yearly purchases associated with it. Whereas conventionally the producer would buy fungicide every year, the pulse bule system is fully inclusive upon initial purchase.

Therefore, an economic analysis can be done to relate yearly fungicide expenses. See calculations below.

Yearly Fungicide Expenses Estimation:

Average size of Quebec vineyard = 15 acres (BC Wine Grape Council, 2021)

Average Fungicide cost = $600/acre

Average Yearly Fungicide Investment = Average size of Quebec vineyard * Fungicide Cost

= 15 acres * $600/acre

= $9000

From this a basic conclusion can be reached that the pulse bulb system may have a larger initial investment, but on an average sized vineyard the system becomes the cheaper system withing the first year of use. Comparing $7500 large initial investment to $9000 in fungicide.

There is one additional aspect that is assumed for this analysis. It was assumed that the length of time spent spraying was equal to the amount of time that would be spent treating vines with UV light. Due to lack of data availability this assumption was made. This is a confident assumption because it leaves room for $9000 in labour every year. As long as the labour values are below this for the UV system, it will remain the more economical system. It would still be the more economical system even if the labour cost went up when comparing conventional vs. UV system. Another assumption that was made was that the life span of the two machineries would be similar. This is also a safe assumption due to the similarity in structural components, steel frame etc. This would indicate that both would have a similar life span, therefore eliminating that as a factor within the economic analysis.

Furthermore, according to market research, the average sale price for wine grapes in the Quebec vineyard farming system is approximately $1,800 per ton (Rimerman, 2017). Assuming a low-yielding vineyard that produces only 2 tons of grapes per acre and considering the average vineyard size of 15 acres in Quebec, the total yield of the vineyard would be 30 tons (Wine Spectator, 2007). Therefore, the potential revenue from the sale of wine grapes would be 30 tons x $1,800 per ton = $54,000. This indicates that even a low-yielding vineyard can generate enough revenue to cover the initial cost of a UV system. Furthermore, since the size and light parameters of the UV system can be adjusted to suit the specific characteristics of different farming systems, it can be shared between neighboring vineyards to further reduce initial costs and increase economic sustainability.

"Real Life" Case Study in Vineyard

A simulated "real-life" case study, was performed to demonstrate the parameters of a typical Pulsing Bulb Fungicide Treatment. For our calculations, we assume a vineyard size of 15 acres, which is the average size of vineyards in Quebec (BC Wine Grape Council, 2021). Each block within the vineyard is rectangular with the same size of 2.5 acres and same dimensions to ensure more crops can be planted and reduce turnaround time (Kurtural, n.d.). The length of each block will be 481 feet and the width will be 226 feet. The vineyard has a vine spacing of 8 feet and 9 feet between rows, which is an ideal spacing for American and French-American vineyards with 605 vines per acre (Kurtural, n.d.). The width of the headland will be 30 feet and the width of the alleyways will be 20 feet to ensure adequate space for agricultural machinery operation and air circulation (Kurtural, n.d.). The figures below represent the top view of the vineyard in the case study, which is the vineyard layout that is used as a basis for the subsequent UV treatment analysis.

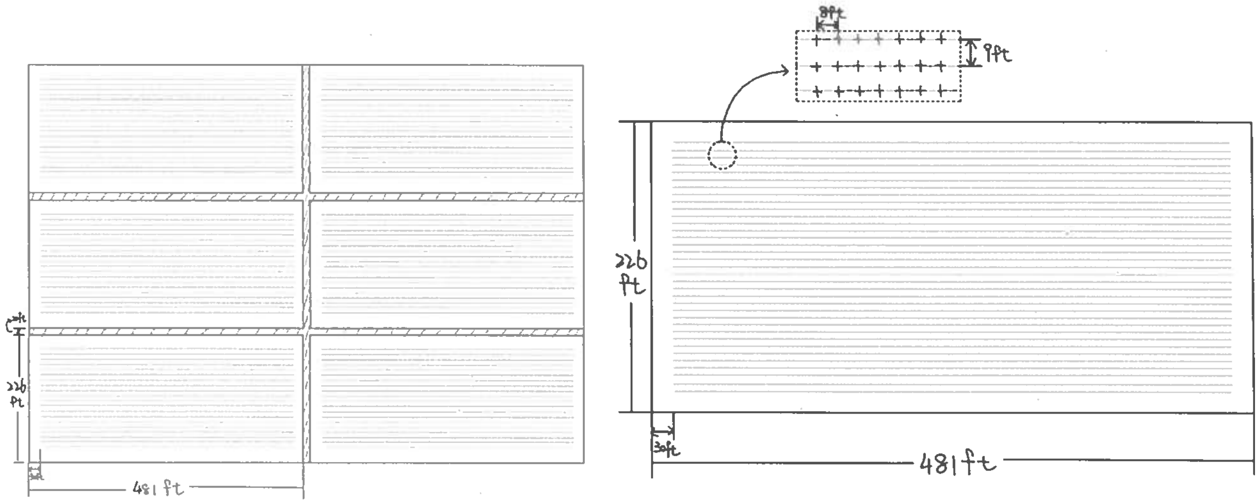

Figure 23. Layout of vineyard for case study

The type of tractor used in the case study is 5075EN, which is suitable for the relatively narrow operating environment of the vineyard. Equipped with front and rear hitches and a mid-selective control valve, it is highly compatible with different tools and is suitable for connection to our attachment UV system (Kan, 2022). The tractor's working width is 51 inches with 75 hp engine horsepower (Kan, 2022).

As mentioned above, the UV pulsed bulb used in the treatment was a UVC strip with a pulse frequency of 15 Hz and a wavelength of 275 nm, and an input voltage of 24V.

Treatment during nighttime: The radiation intensity was 50 W/m^2, exposure time was 1 seconds. The dosage will be 50 J/m^2 twice a week.

Speed of tractor = design structure coverage length / exposure time = 3ft/1s = 3 ft/s = 0.682 mph

Time for treating one row = length of the block/speed of tractor = 481 ft / (3 ft/s) = 160.33s

Number of rows in each block = [width of block – (headland width)]/ row space

= [226 ft – (30ft+30ft)]/9ft = 18 rows

Time for treating one block = 18 * 160.33 = 2957.2 s = 0.82 h

Time for treating the whole vineyard = 0.82 h x 6 blocks = 4.93 h

Consider time for turning, we round up to 5h.

Maximum coverage area of the UV system = 3ft L x 5ft H = 9 ft^2 = 1.39 m^2

Energy use for treating the whole vineyard once = 50W/m^2 x 1.39m^2 x 5h = 0.348 kWh

Total energy use per week = 0.348 kWh x twice a week = 0.695 kWh

In the case where the vineyard uses a more powerful tractor, it would be possible to attach two pulsing bulb systems together, in a row, to increase UV-C coverage length to 6ft, allowing an increased treatment speed to 1.364 mph, and a total treatment time of 2.405 hours (rounding up to 2.5 hours) for the same vineyard surface (15 acres).

Conclusion

This report outlined a design for the implementation of such technology for vineyard systems in Quebec, showing a design that is adaptable, relatively low cost, easy to maintain and competitive compared to conventional treatments. An environmental analysis that compares the localized environmental impacts of applying UV-C light in vineyards, compared to the more diffuse yet dispersed impact of applying fungicides would be beneficial to truly determine the trade-off of using one technique rather than another. The full potential of this treatment technique has yet to be determined, however it shows great promise, and requires further research.

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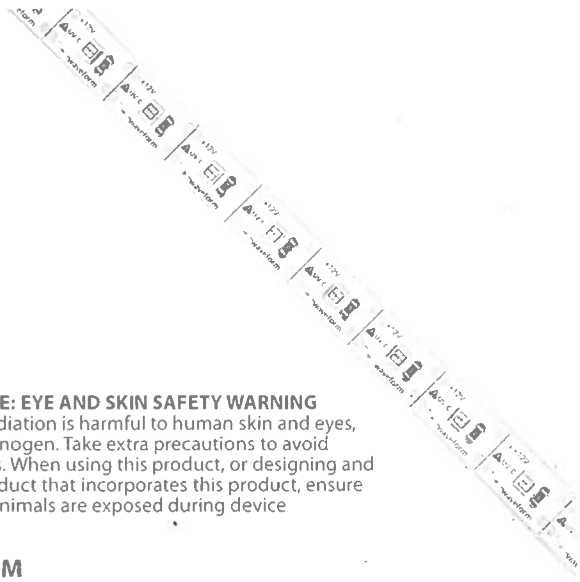
eanUV™ UV-C LED Flex Strips

: 7026.270



ıveform Lighting's cleanUV™ LED flex strips operate at 270 nanometers, an optimal ıvelength for sterilization and disinfection applications. Each LED strip reel includes 60x gh efficiency, high reliability 270 nm UV-emitting LEDs mounted on a flexible cuit-board.

e back side of the LED strip includes pre-applied 3M VHB® double-sided tape, which ɔvides a simple but extremely strong adhesive mounting method for all of your projects.

e LED strips are 39.4 inches in length (1.0 meters), and are conveniently reeled for quick d easy application, and can be cut to length every 0.7 inch (17 mm) with just a pair of ssors.

ꓤODUCT AND FEATURES

- 270 nanometer peak wavelength for UVGI efficacy
- 39.4 inch reel (3.2 ft / 1.0 meter)
- 12V DC input
- Power consumption of 14.4 watts
- For indoor use only

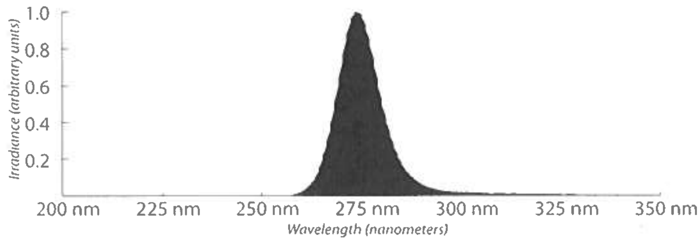
IMPORTANT NOTICE: EYE AND SKIN SAFETY WARNING
UV-C wavelength radiation is harmful to human skin and eyes, and is a known carcinogen. Take extra precautions to avoid exposure at all times. When using this product, or designing and implementing a product that incorporates this product, ensure that no humans or animals are exposed during device

HOTOMETRIC SPECIFICATIONS

/-C output per reel:	130-140 mW
ak wavelength:	270-275 nm
ectrum FWHM:	10 nm
nission angle:	120 deg

wnload full photometric reports at https://www.waveformlighting.com/photometrics

TYPICAL EMISSION SPECTRUM



LECTRICAL SPECIFICATIONS

put type:	Constant Voltage
put voltage:	12V DC
ırrent draw:	1.2 A @ 12V DC
ɔwer draw:	14.4 W @ 12V DC
ax run:	16.4 ft (5 meters)

MECHANICAL SPECIFICATIONS (FULL REEL)

Length:	39.37 in (1000 mm)
Width:	0.394 in (10 mm)
Height:	0.067 in (1.7 mm)
LED spacing (OC):	0.656 in (16.67 mm)
Cut-line spacing:	0.656 in (16.67 mm)
PCB copper thickness:	3 oz
Connection (both ends):	Female DC 2.1 x 5.5 mm

OWER SUPPLY SELECTION

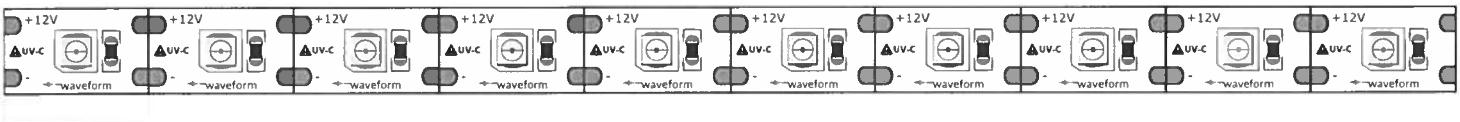
ɔmpatible with Waveform Lighting PN 3091 or third-party 12V DC constant voltage power supply. If ıu choose to utilize a third-party power supply unit, you will need to ensure that the power capacity of e power supply is sufficient for the length of LED strip being connected. Use the table below to etermine if the power supply is sufficient for your project.

ENGTH	MINIMUM POWER SUPPLY CAPACITY
ft:	600 mA / 7 W
ft:	1.8 A / 22 W
ft:	3.6 A / 43 W
ft:	5.4 A / 65 W
2 ft	7.2 A / 86 W
5.4 ft	9.0 A / 108 W

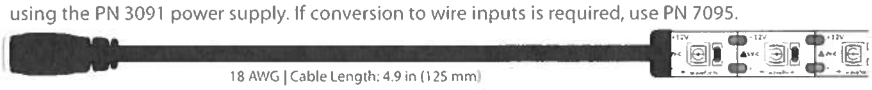
LENGTH	MINIMUM POWER SUPPLY CAPACITY
0.5 m:	900 mA / 11 W
1.0 m:	1.8 A / 22 W
2.0 m:	3.6 A / 43 W
3.0 m:	5.4 A / 65 W
4.0 m:	7.2 A / 86 W
5.0 m:	9.0 A / 108 W

ꟽECHANICAL DRAWING & DIMENSIONS

This drawing is an excerpt that shows just ten complete, cuttable sections. Each reel consists of 60 of these sections with female DC plugs mounted on each end.



Female DC cables (5.5 x 2.1 mm) are pre-mounted on both ends of the reel for quick and easy set up using the PN 3091 power supply. If conversion to wire inputs is required, use PN 7095.



18 AWG | Cable Length: 4.9 in (125 mm)

ART NUMBERS AND ORDERING

70 nm:	7026.270

waveform lighting

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https://www.waveformlighting.com | support@waveformlighting.com