Graduation Project

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Design and Development of an Automated Vertical BSF Breeding System

Food waste management is a pressing global challenge, with millions of tons of waste generated daily, contributing to environmental degradation and greenhouse gas emissions. A sustainable solution lies in utilizing black soldier fly (BSF) larvae, which efficiently process organic waste while producing high-value biomass for animal feed and other applications. This project aims to design an automated vertical BSF breeding system to streamline larvae production for waste processing, ensuring space efficiency, environmental control, and scalability. By harnessing the BSF's natural ability to recycle nutrients, the system promotes sustainability and contributes to reducing waste-related environmental impacts.

BSF Lifecycle Overview: Explain the stages and requirements (use visuals).

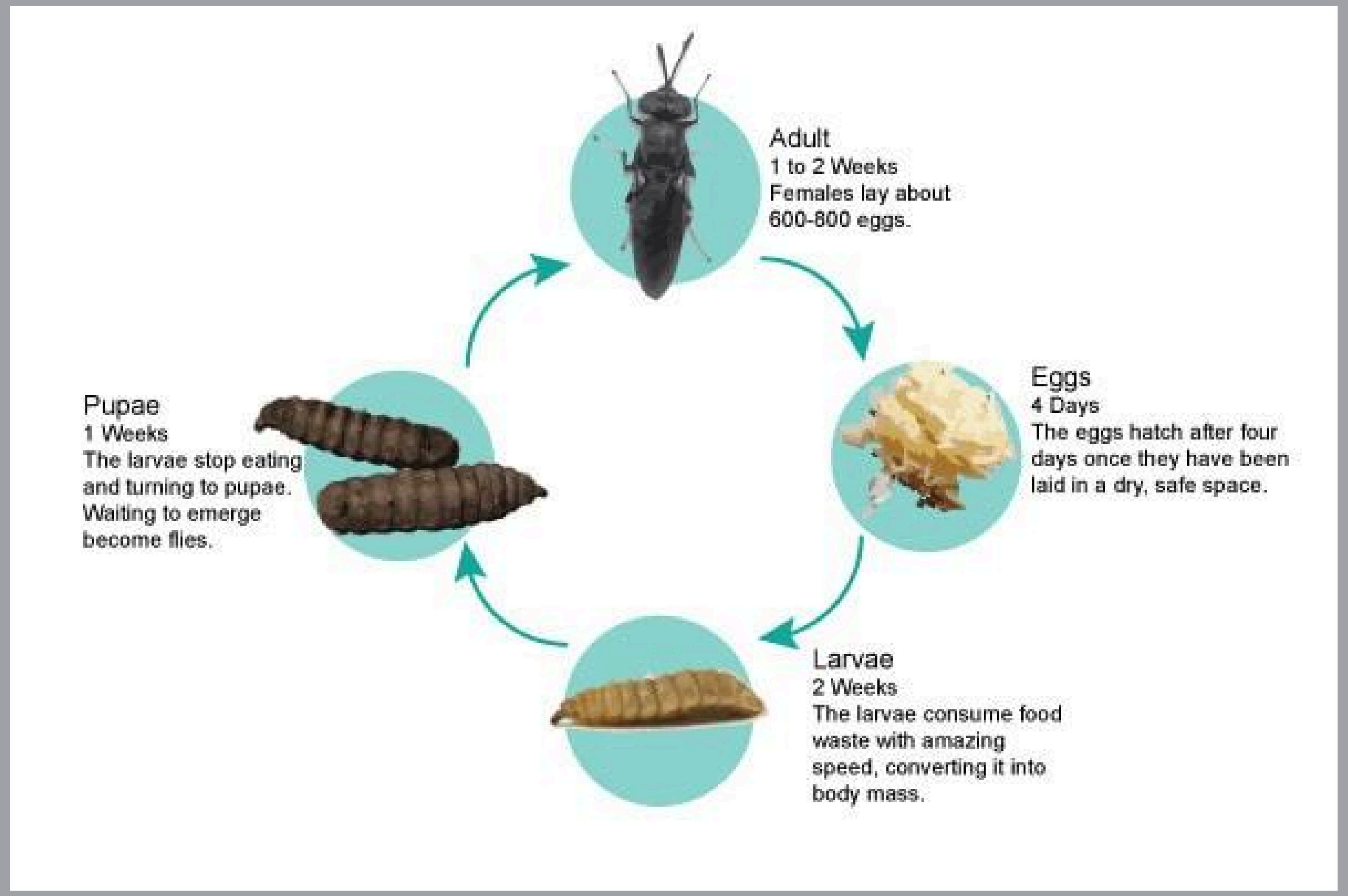
The life cycle of the black soldier fly (BSF) consists of distinct stages, each with specific requirements for optimal growth and development. Understanding these stages is crucial for designing an effective breeding system.

Egg Stage
Duration: 4–5 days.
Requirements: Eggs are laid in dry, protected areas near a moist substrate like food waste. T-27–30°C H-60–70%.

Larva Stage
Duration: 14–21 days
Requirements: Larvae thrive on organic waste, breaking it down into nutrient-rich frass. T-30–35°C H-50–70%. Adequate ventilation

Pupa Stage
Duration: 7–10 days.
Requirements: Larvae transition to pupae in a dry, dark environment. T-27–30°C H-(below 50%)

Adult Fly Stage
Duration: 5–8 days.
Requirements: Adult BSF do not feed and rely on fat reserves. T-27–30°C H- 60–70%, (12–16 hours/day) for mating.



Existing Solutions: Highlight existing products, their features, and limitations.

Common Challenges

1. Inconsistent environmental control, affecting larvae productivity.
2. Lack of user-friendly designs for small and medium-scale operators.
3. Difficulty in scaling down for home use or small-scale applications.
4. Limited focus on resource efficiency, such as optimizing water and energy use.

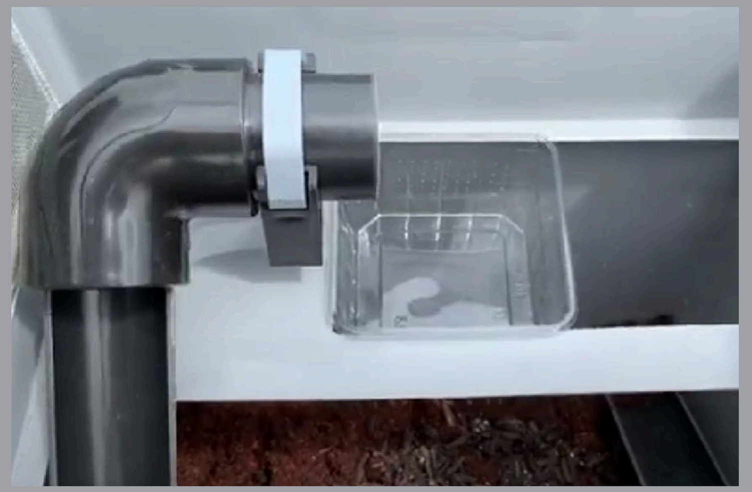
Address these gaps by:

- Providing a compact, modular design suitable for small and medium-scale users.
- Ensuring robust automation with precise temperature and humidity control using ESP32.
- Offering a cost-effective solution with easy maintenance and low energy consumption.
- Integrating mobile app connectivity for real-time monitoring and remote operation.















Key Challenges Identified: Address issues like temperature control, space efficiency, or automation gaps.

Waste Management

- Challenge: Efficiently handling and processing large amounts of wet food waste while avoiding odor, pests, or contamination.

Larvae Harvesting

- Challenge: Self-harvesting systems in existing designs often fail to efficiently collect all mature larvae or get clogged with waste.

Energy Efficiency

- Challenge: Automated systems often consume significant energy due to constant temperature and humidity regulation.

User Accessibility and Maintenance

- Challenge: Complex designs and lack of user-friendly interfaces make it hard for non-experts to operate and maintain systems.

Temperature Control

- Challenge: BSF larvae require precise temperature ranges (30–35°C) for optimal growth,

Humidity Control

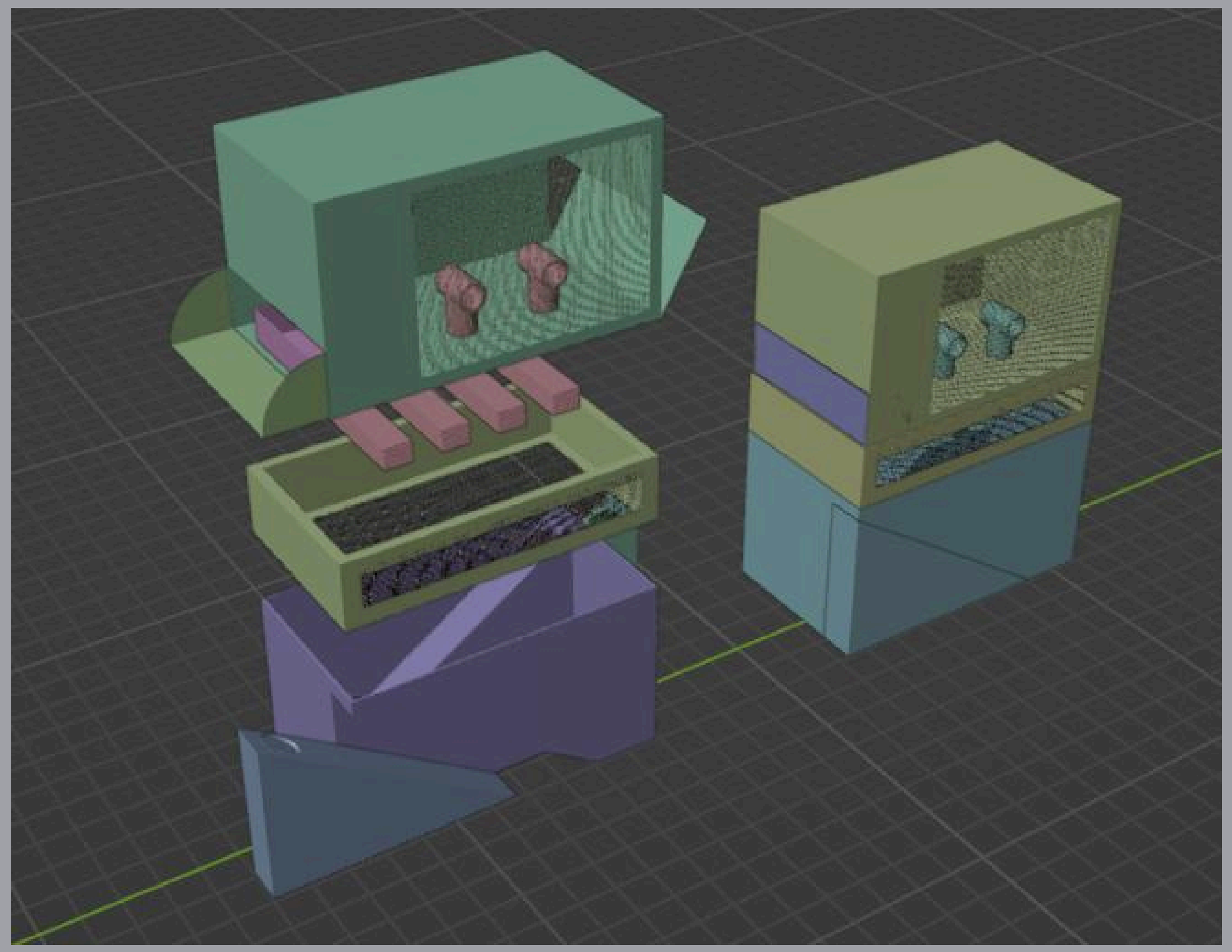
- Challenge: Different stages of the BSF lifecycle require varying humidity levels (e.g., 60–70%)

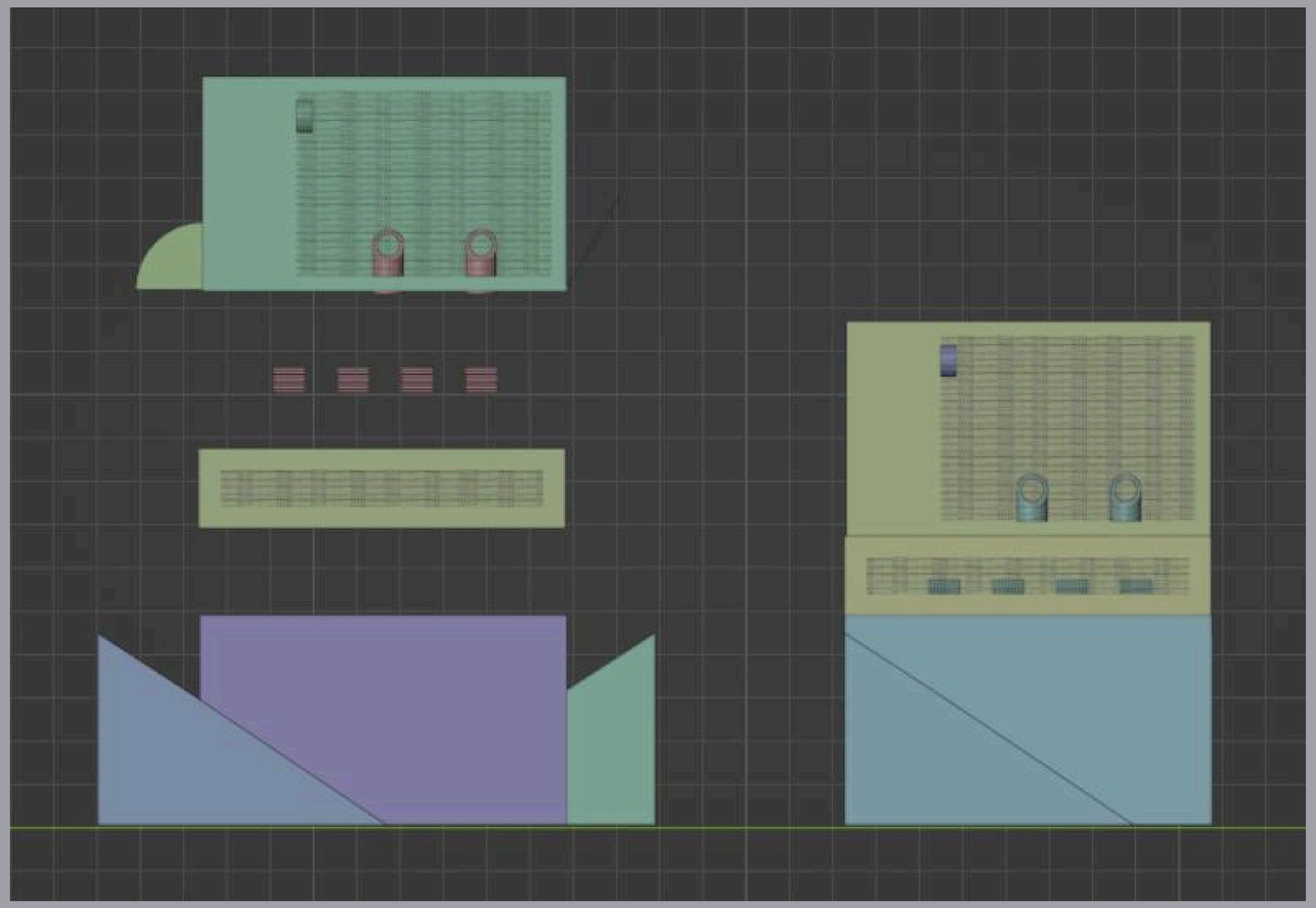
Space Efficiency

- Challenge: Existing systems often occupy significant space, making them unsuitable for small-scale operations.

Automation Gaps

- Challenge: Many current systems rely heavily on manual monitoring and intervention for temperature, humidity, and feeding.



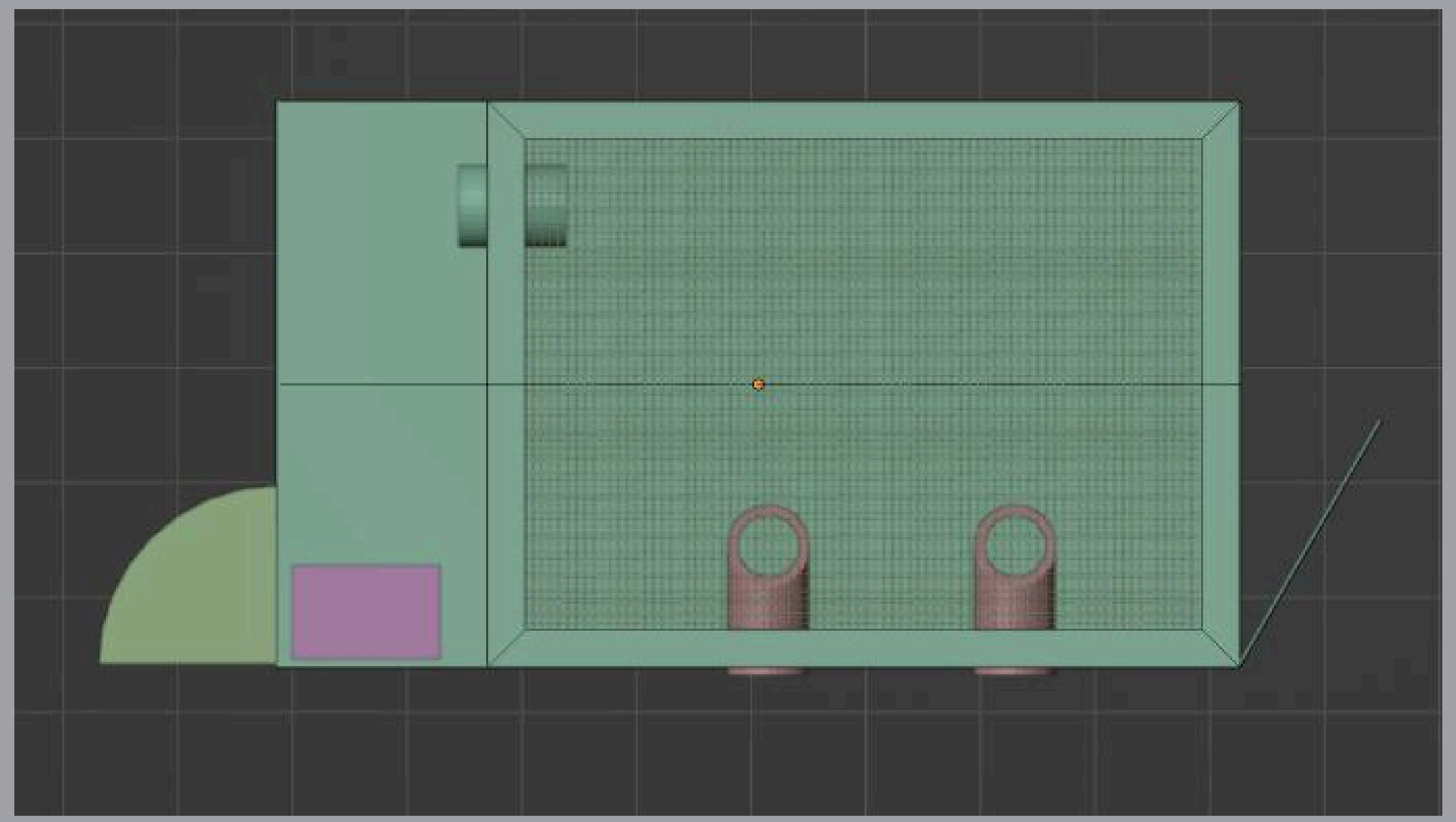


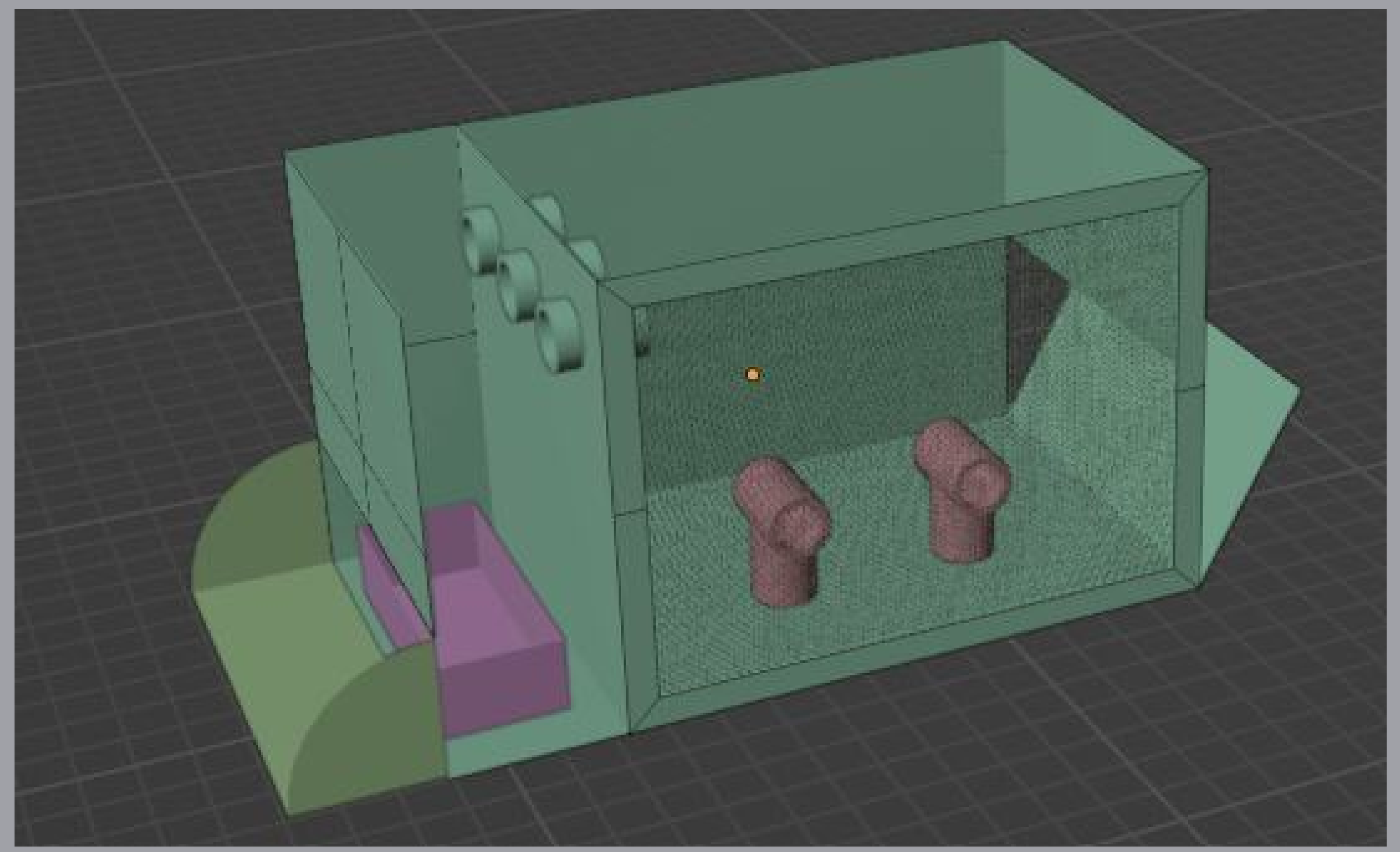
System Design:
Overview of the 3-section vertical design.
Top: Mating and pupa hatching.

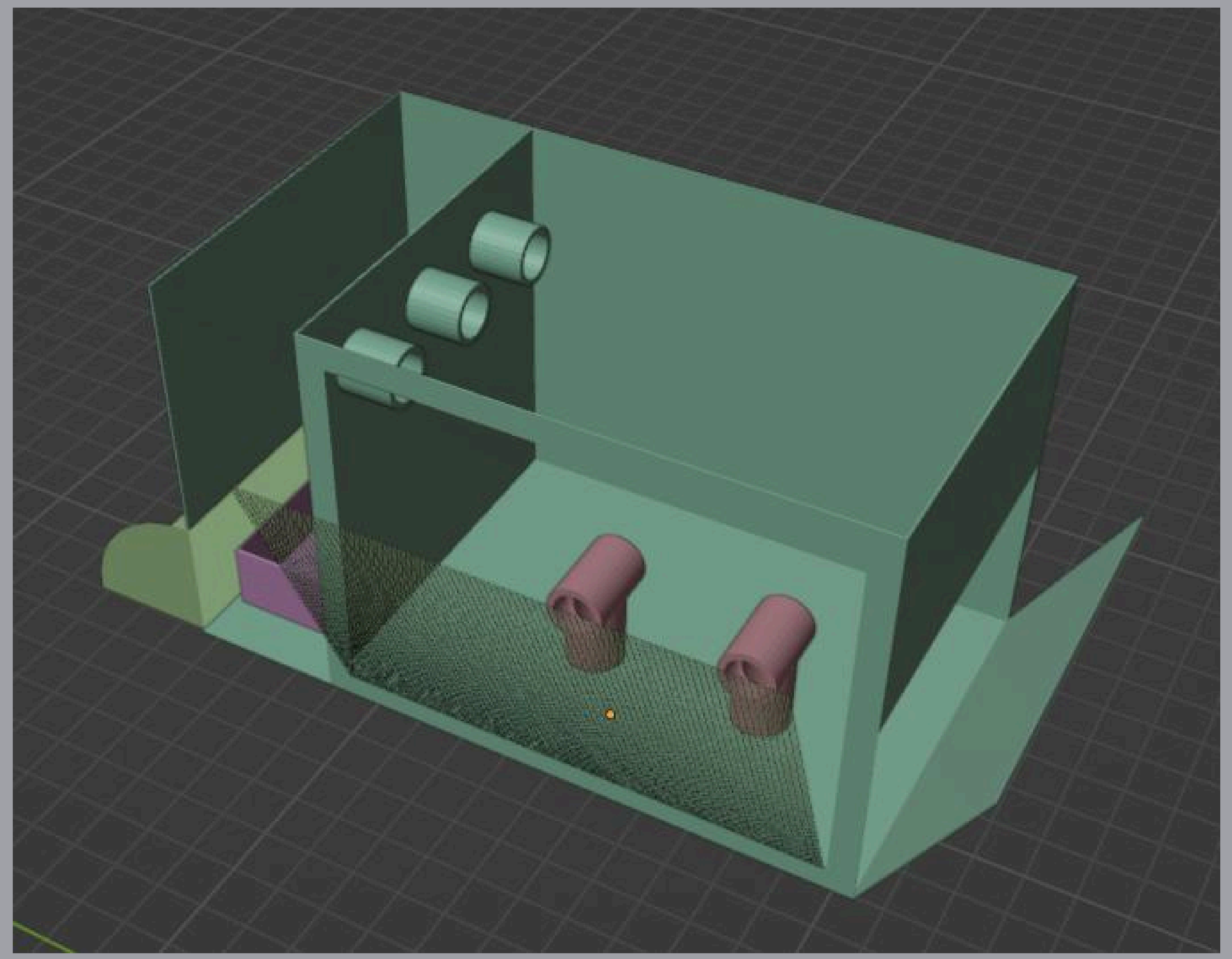
Purpose:
This section is dedicated to facilitating the mating of adult flies and the hatching of pupae into mature flies. It ensures the continuation of the BSF lifecycle and provides an environment conducive to reproduction.

Key Features:
Light Source: BSF adults require 12–16 hours of light per day to stimulate mating. A controlled LED lighting system replicates natural daylight.
Ventilation: Proper airflow prevents the buildup of heat and moisture, creating an ideal environment for fly activity.
Pupa Trays: Designated trays hold pupae in a stable and dry environment to allow them to hatch into adult flies.
Temperature and Humidity 27–30°C and humidity levels of 60–70%, which are ideal for both mating and hatching.

Challenges Addressed:
Ensures a high mating success rate by providing optimal light and environmental conditions.
Promotes efficient pupa hatching by maintaining stable temperatures and minimizing stress.





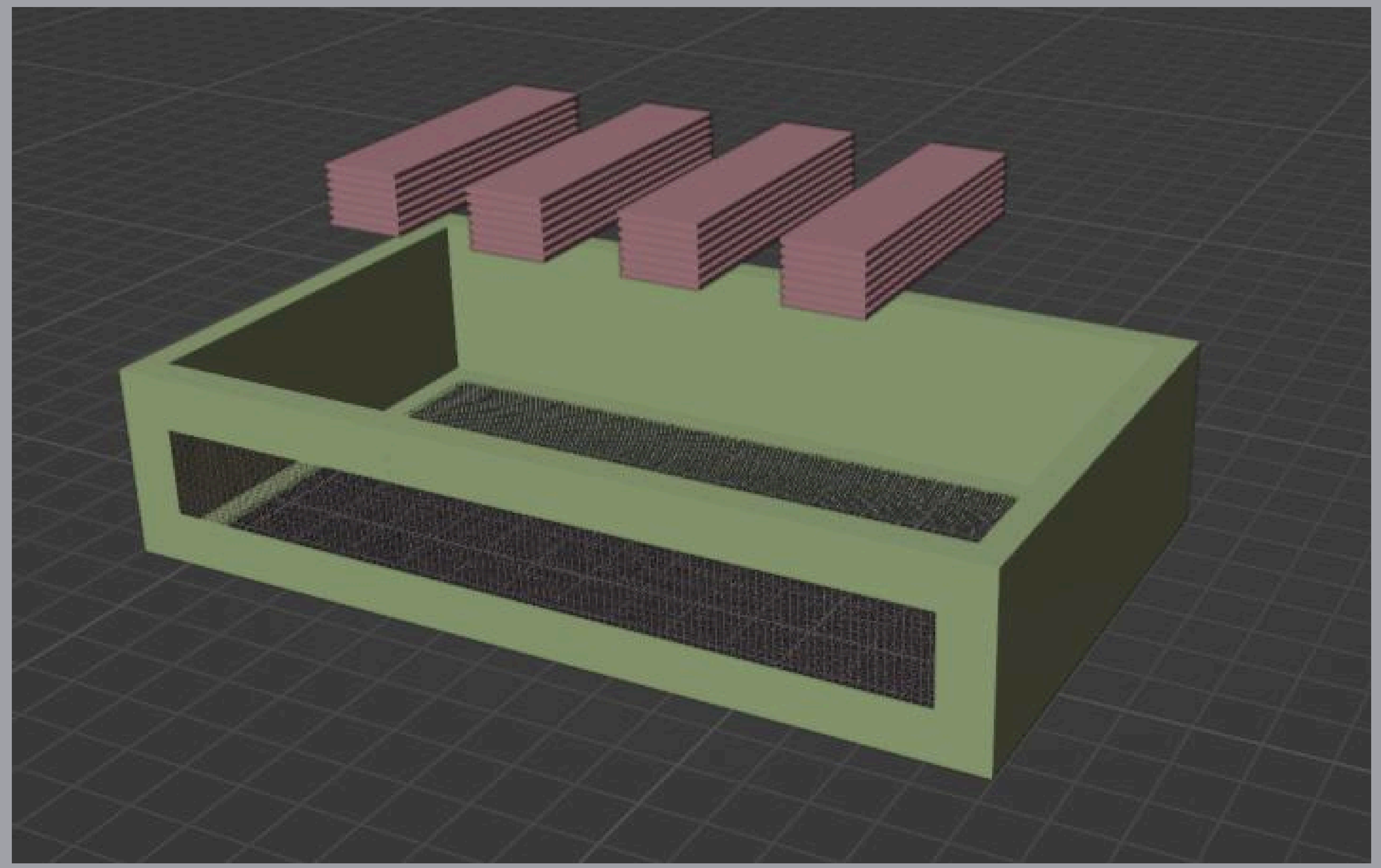


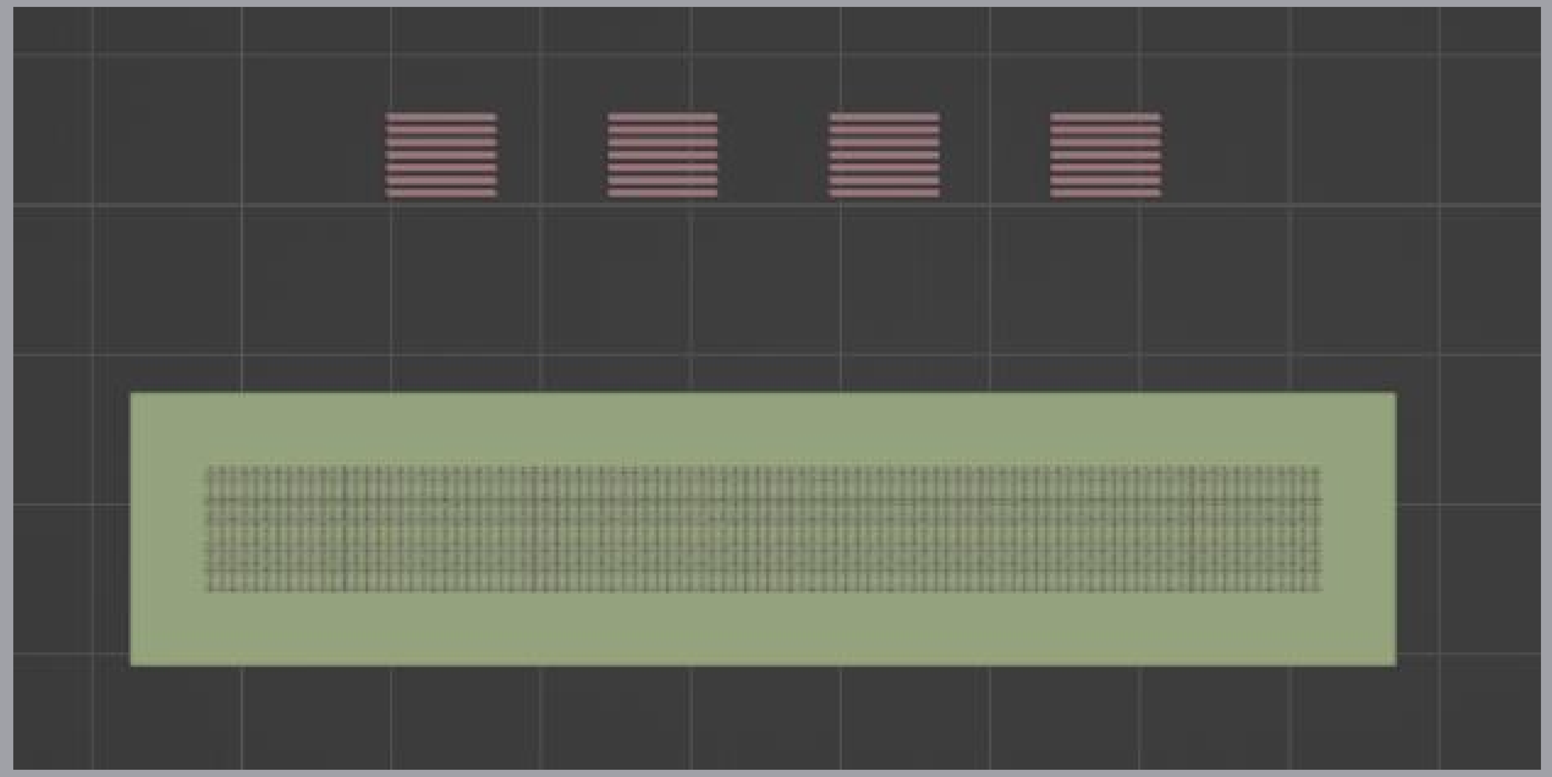
Middle: Egg-laying.

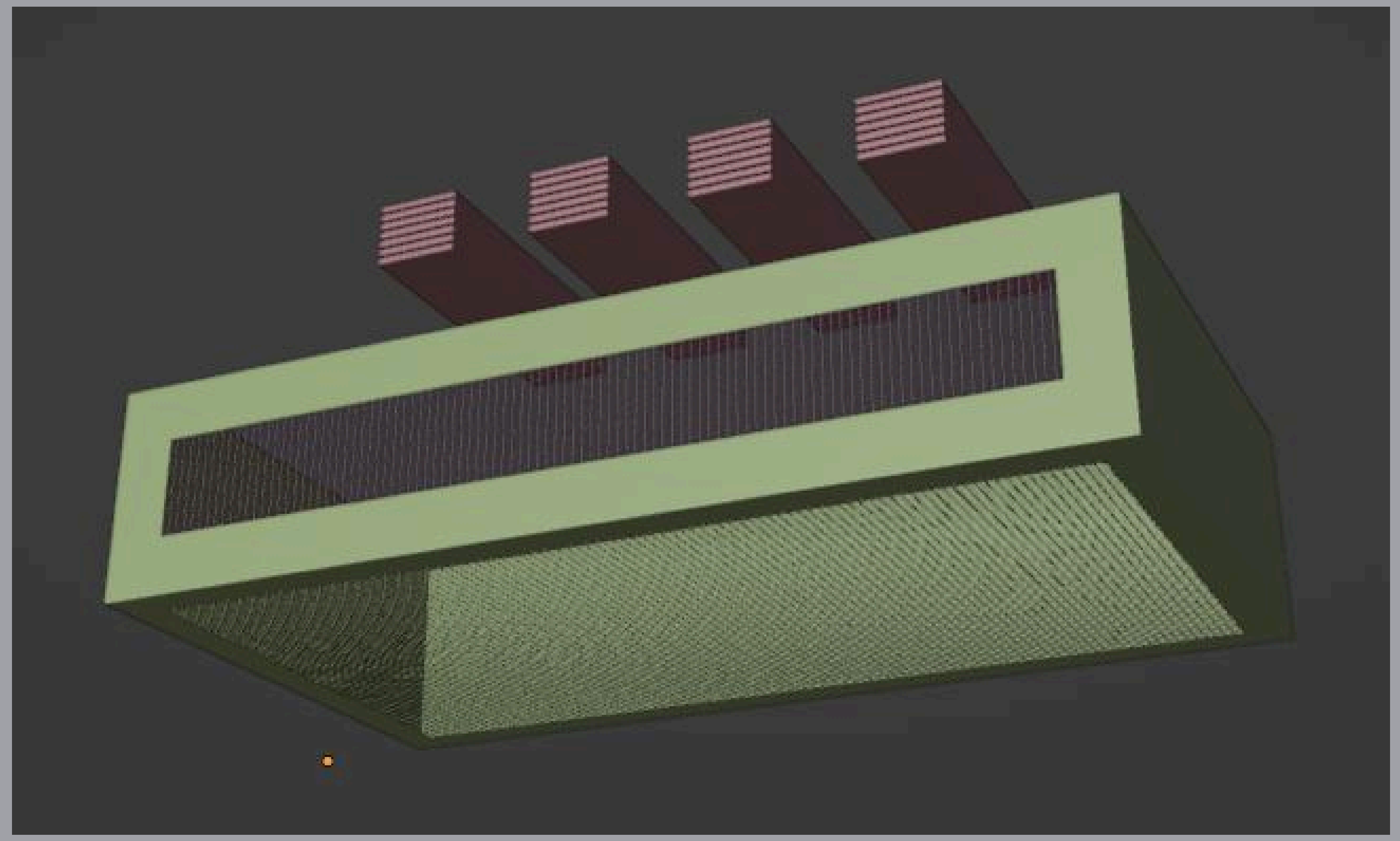
Purpose:
The middle section is designed specifically for adult female black soldier flies to lay their eggs. This area replicates the natural conditions required for egg-laying, ensuring high egg viability and efficient transition to the larval stage.

Key Features
Egg-laying females are attracted to dry, porous materials placed above moist food waste.
Moisture and Attractant Source:
A container with moist food waste or organic matter is placed strategically to attract females to lay eggs nearby.
The substrate's scent encourages egg deposition, mimicking natural conditions.
Environmental Controls:
Temperature: 27–30°C to
Humidity: Set at 60–70%
Light and Ventilation:
Low-to-moderate lighting (to mimic shaded areas preferred by BSF females).
Proper airflow prevents mold formation and ensures a healthy environment for egg development.

Challenges Addressed
Prevents eggs from drying out or being overexposed to moisture, which can impact their hatch rate.
Optimizes female egg-laying behavior by replicating natural environmental cues.





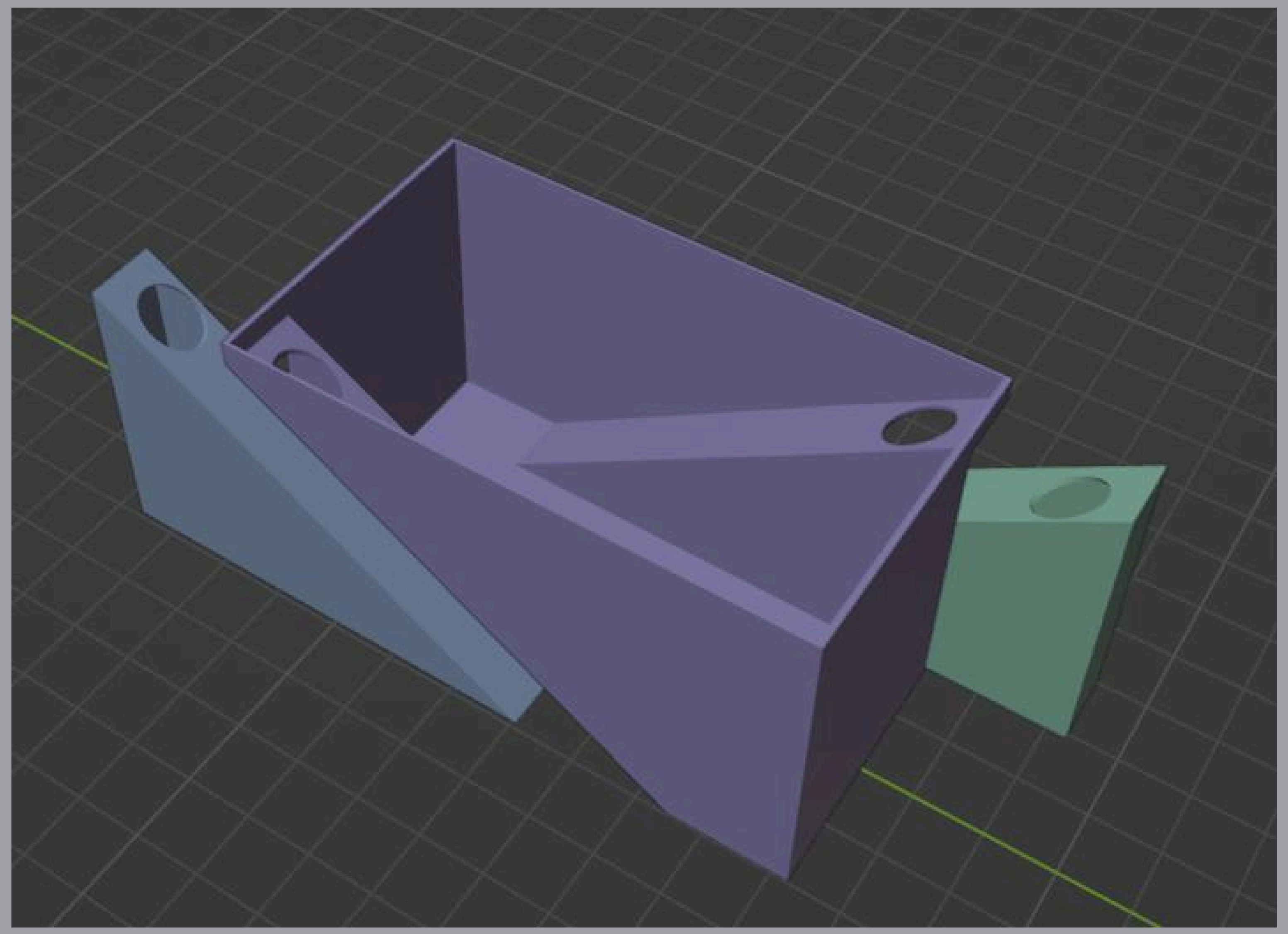


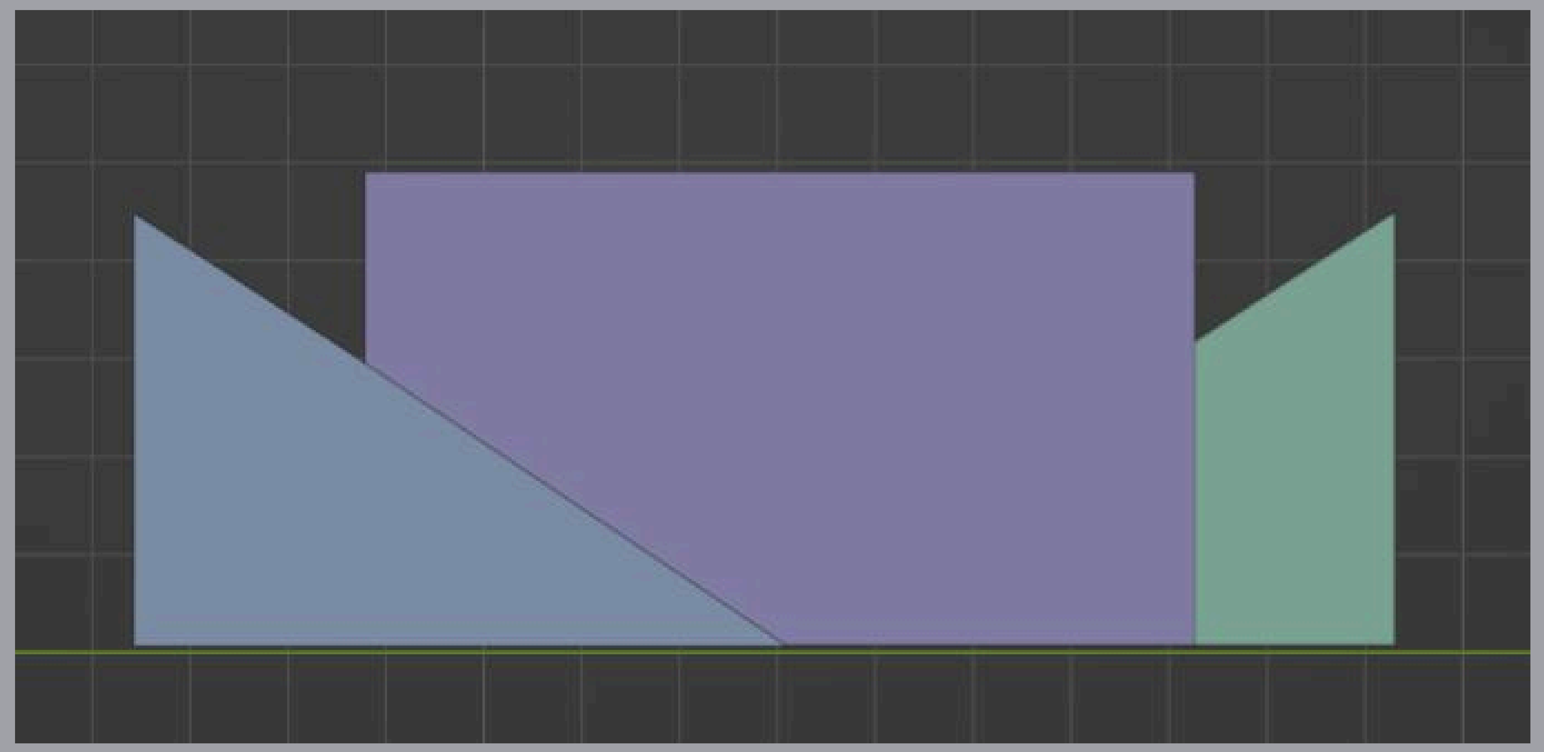
Bottom: Food waste and larvae harvesting.

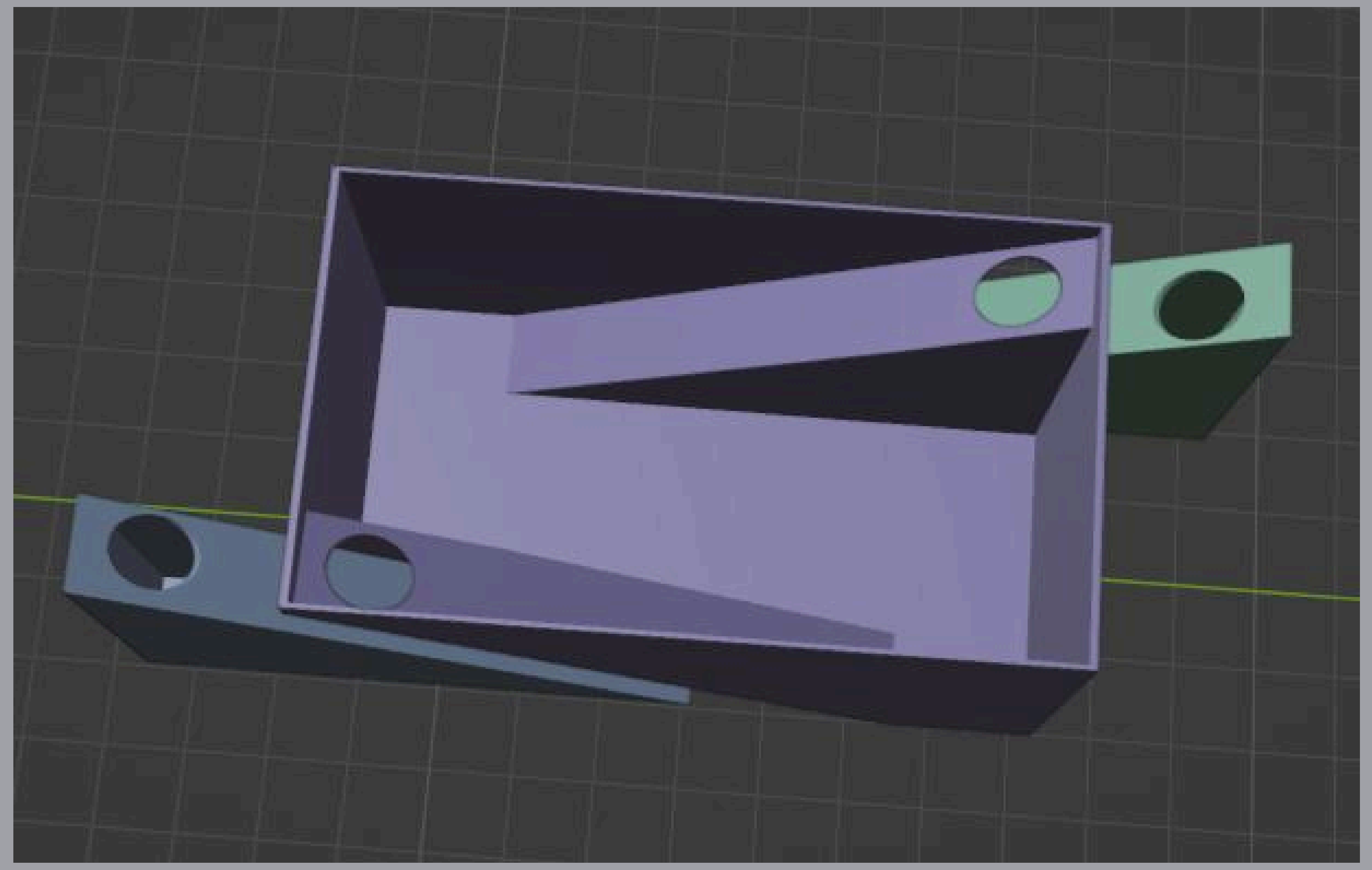
Purpose:
The bottom section is the core of the system, designed for feeding BSF larvae with organic waste and facilitating efficient self-harvesting of mature larvae. This area plays a dual role in processing food waste and collecting larvae for further use, such as animal feed or composting.

Key Features
Food Waste Bin:
Design: A spacious, well-ventilated bin stores organic waste to feed the larvae. The bin is constructed with a sloped bottom to direct excess moisture to a drainage outlet, preventing anaerobic conditions and foul odors.

Larvae Feeding Area:
Function: Provides ample space for larvae to feed and grow, maximizing waste processing efficiency.
Ventilation: Ensures proper airflow to prevent overheating and maintain aerobic conditions.
Self-Harvesting Mechanism:
Ramps or Channels: Inclined ramps allow mature larvae to self-harvest by instinctively climbing out in search of a dry environment to pupate. A separate container collects the larvae as they exit the bin.
Environmental Controls:
Temperature: 30–35°C
Humidity: 50–70%
Drainage System:
Excess moisture from decomposing waste is directed to a drainage outlet. This prevents waterlogging and keeps the environment suitable for larvae activity.

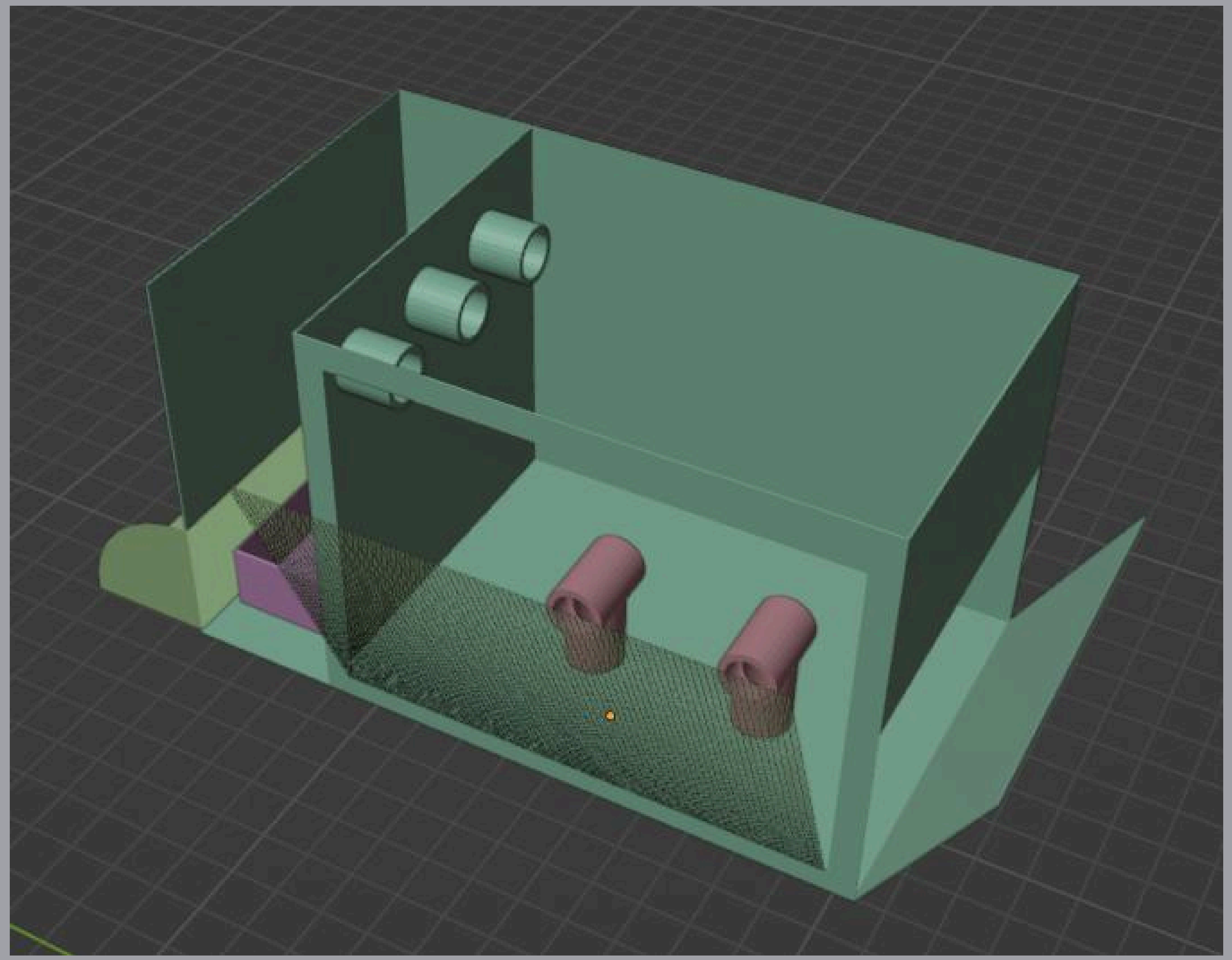


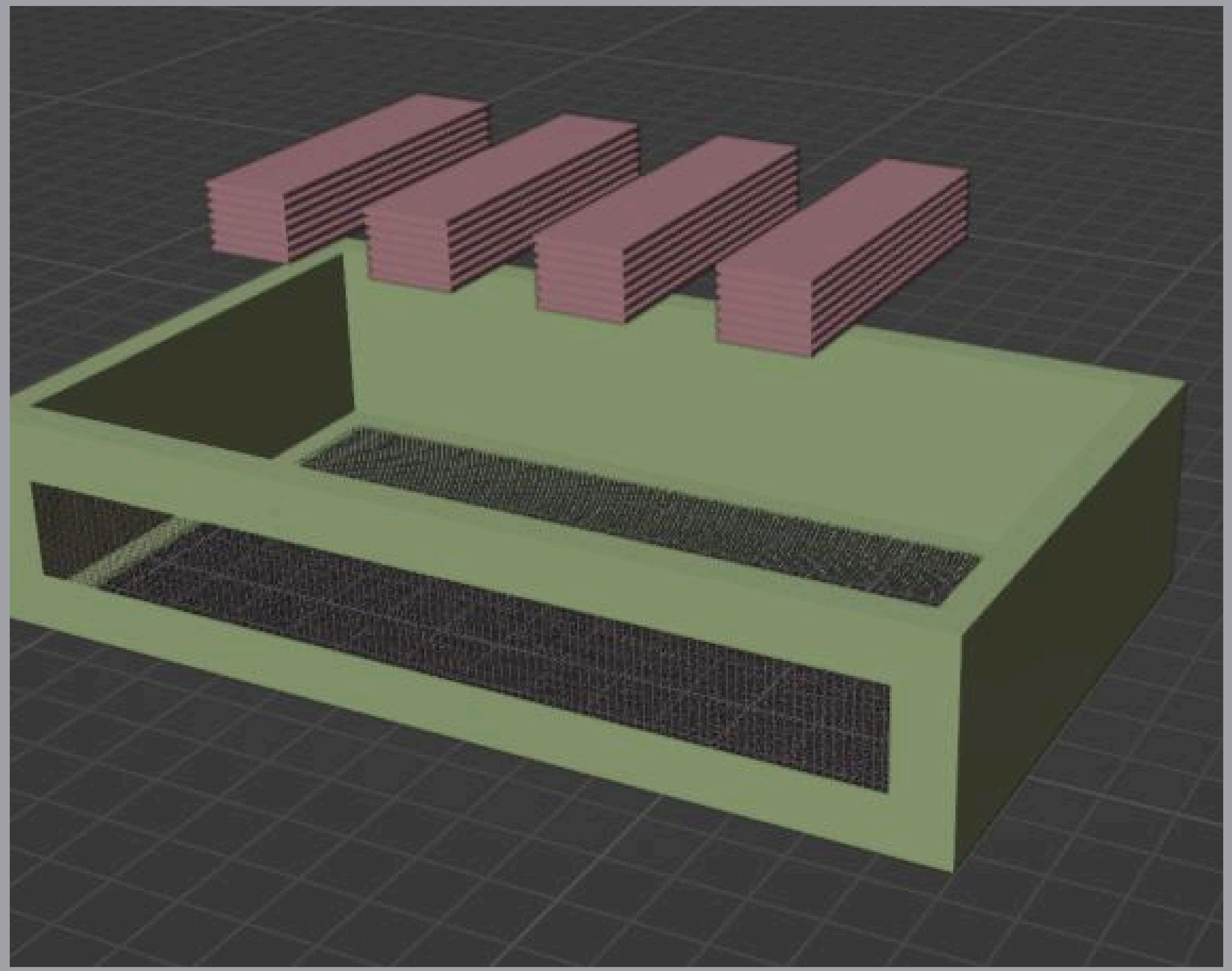




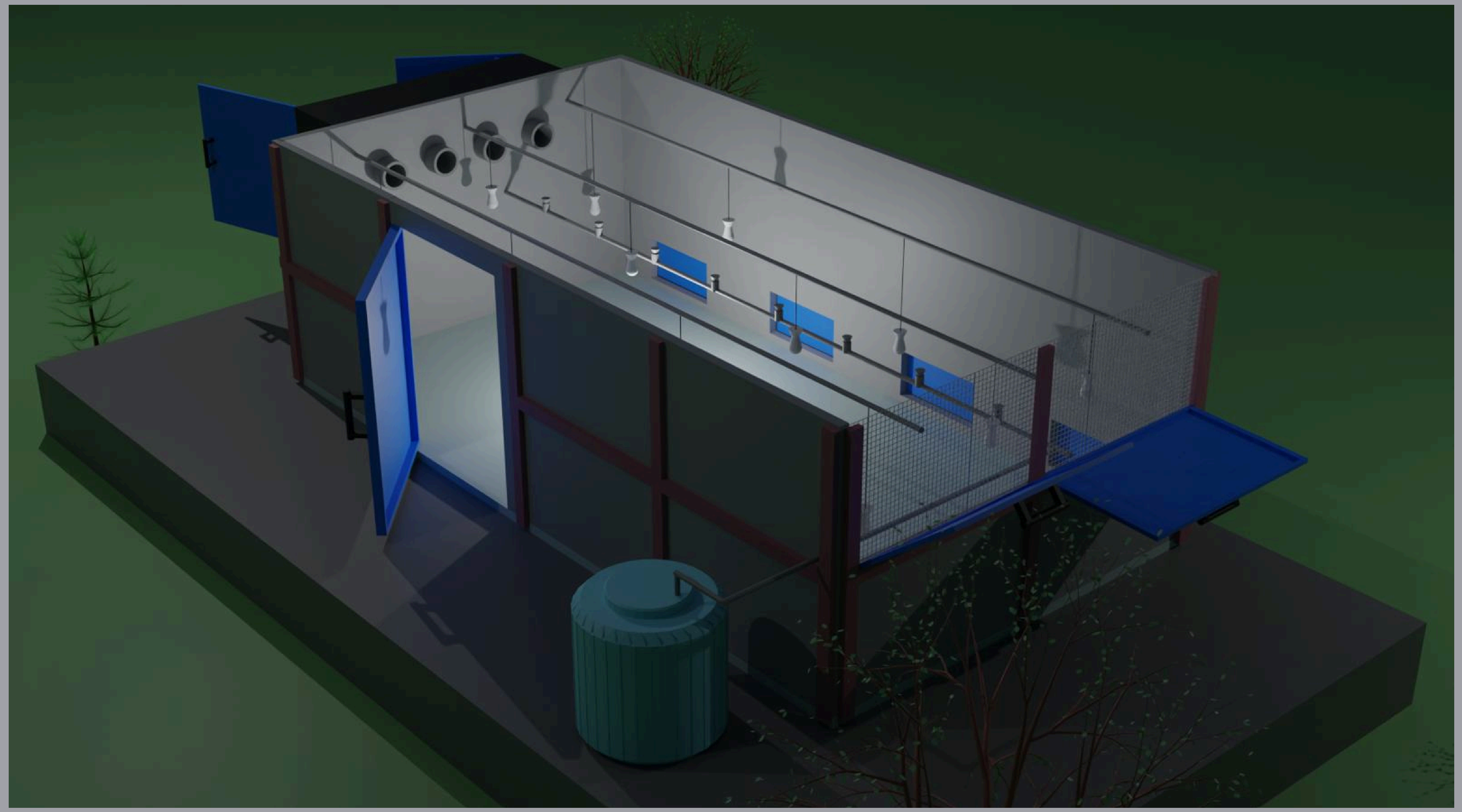
Feature	Previous Design	Current Design
Size and Space	Medium-sized room; challenging to maintain consistent temperature.	Compact vertical cupboard design; easier to control temperature and humidity.
Temperature Management	Difficult to regulate due to the larger space.	Efficient regulation in the smaller, enclosed space.
Functionality	Focused solely on producing larvae.	Integrated system for both larvae production and feeding ground in one unit.
Automation	Limited or no automation; manual monitoring required.	Automated system using sensors, ESP32, and mobile app integration for real-time monitoring.
Efficiency	Labor-intensive with separate areas for different processes.	Streamlined process with all stages in one unit, reducing labor.
Portability	Fixed, large structure; not portable.	Compact and portable for easier deployment in various locations.
Maintenance	Difficult to clean and maintain due to the larger size.	Easier to clean and maintain due to smaller, compartmentalized design.

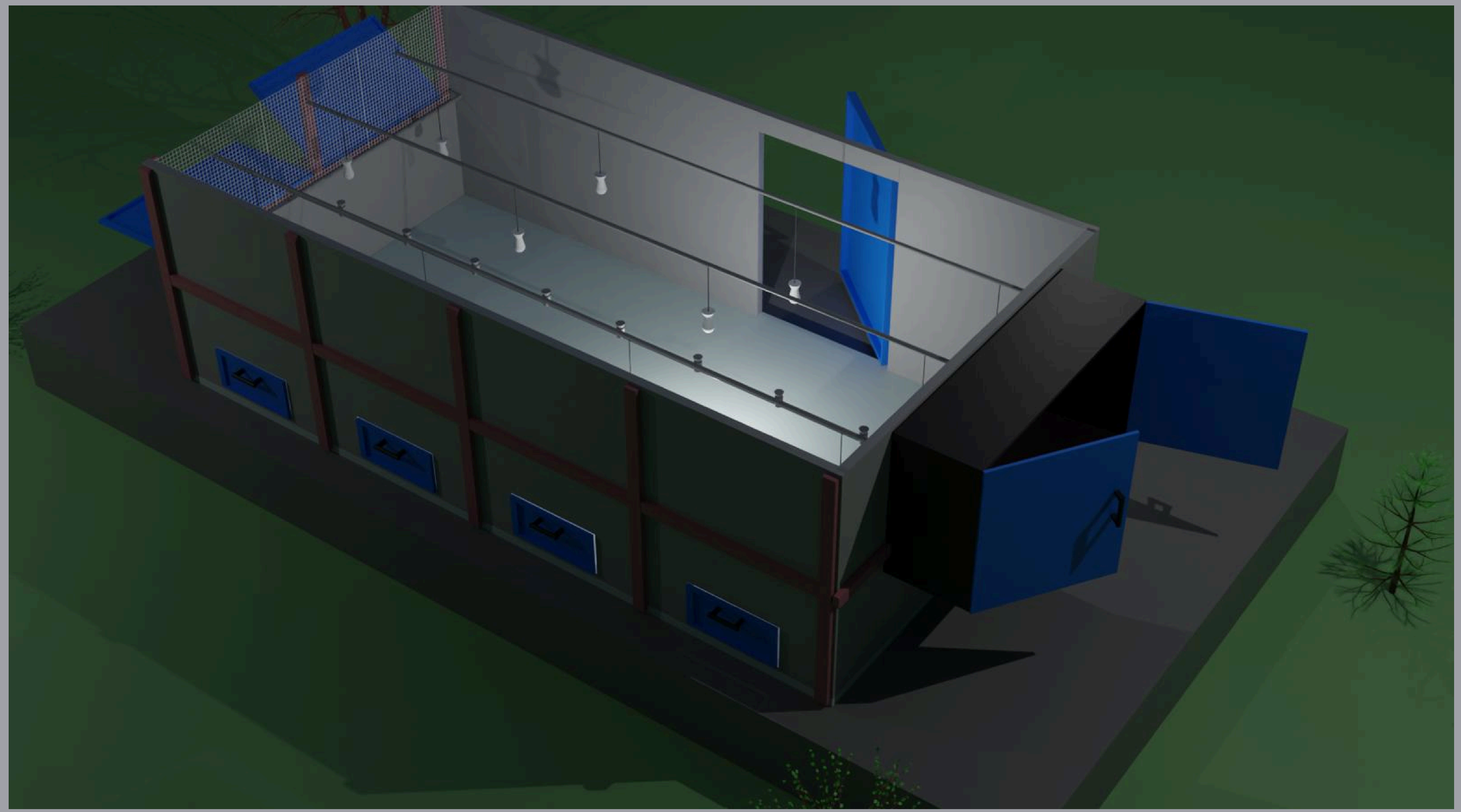
Current Design

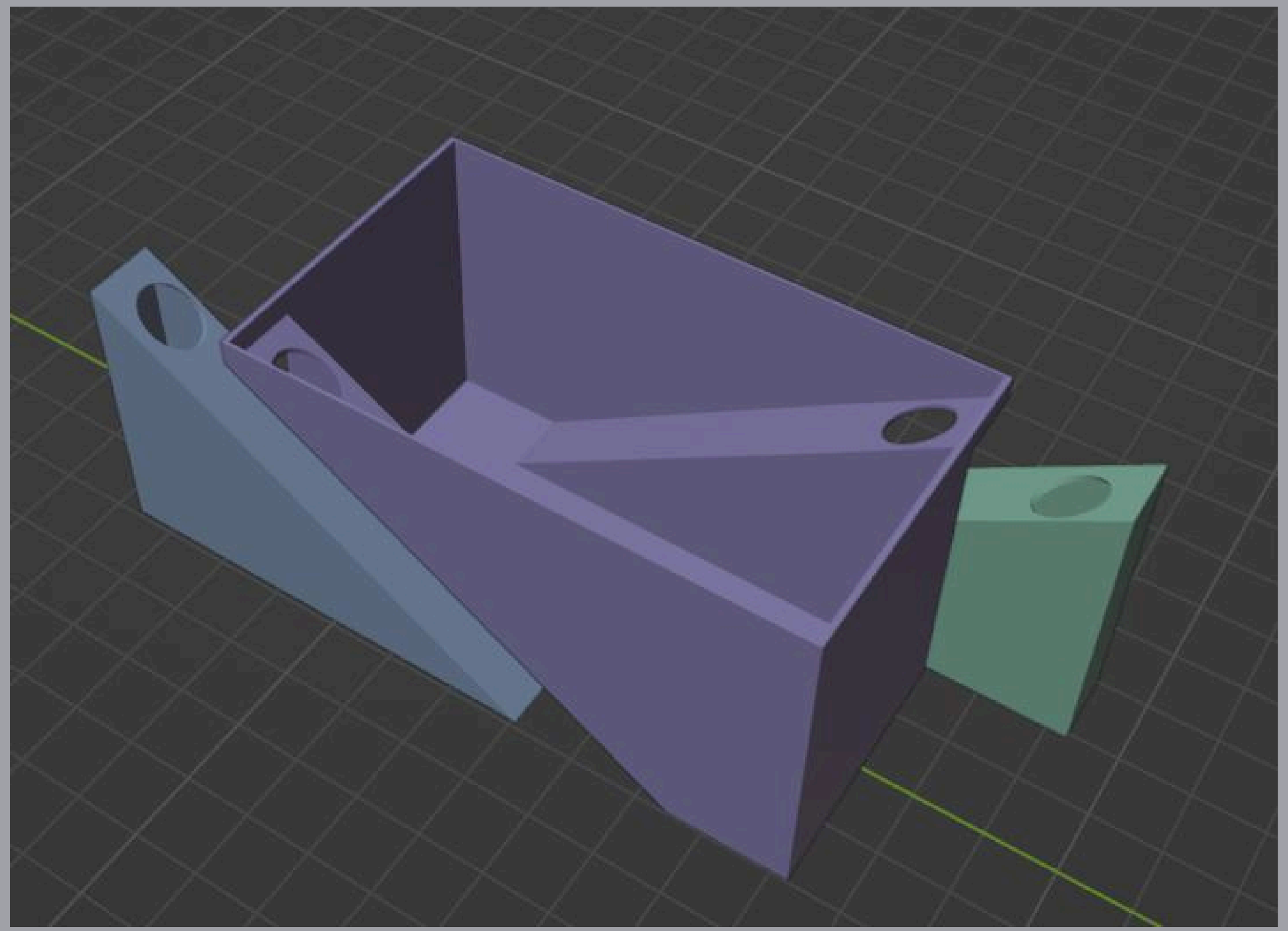
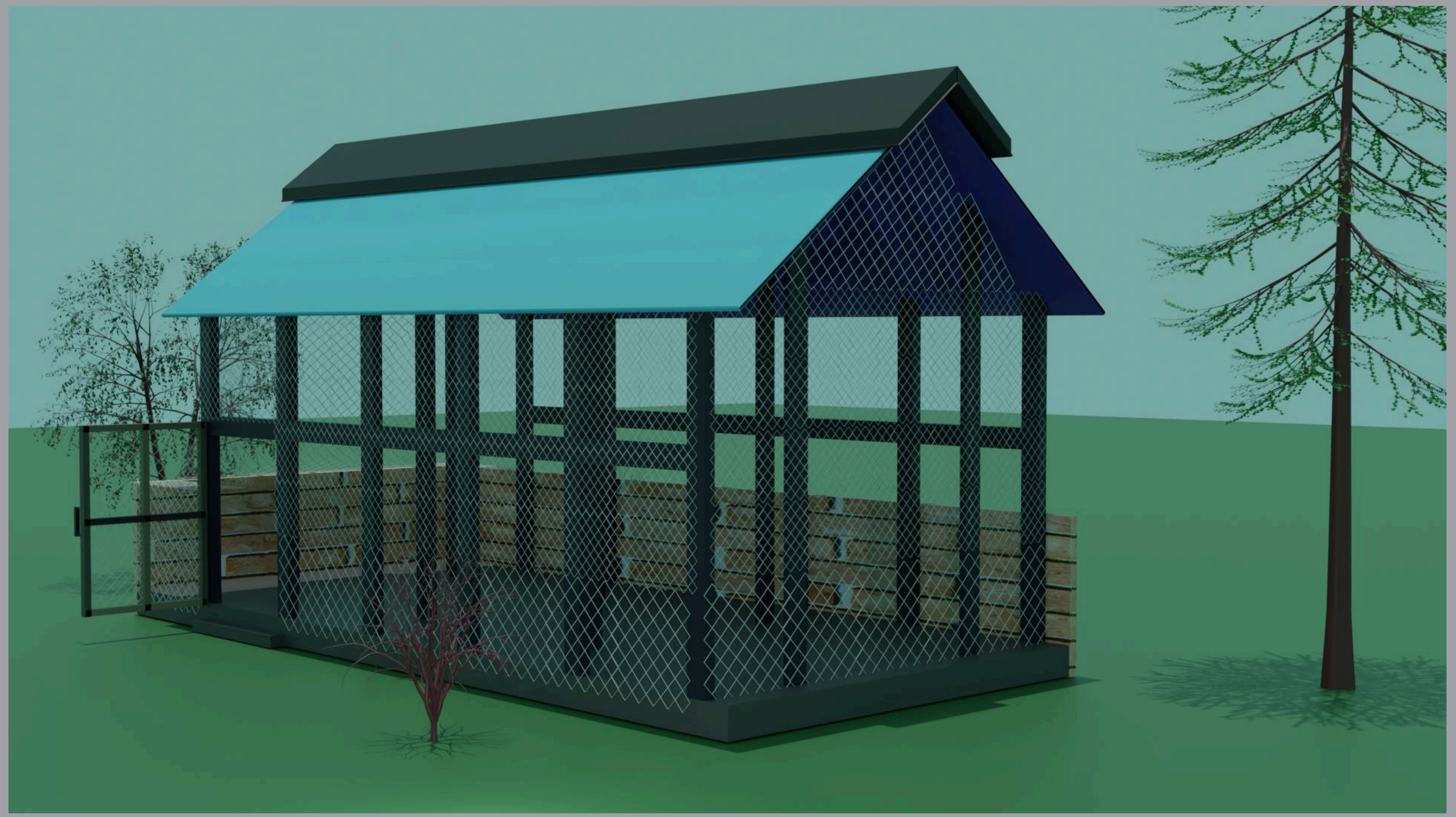
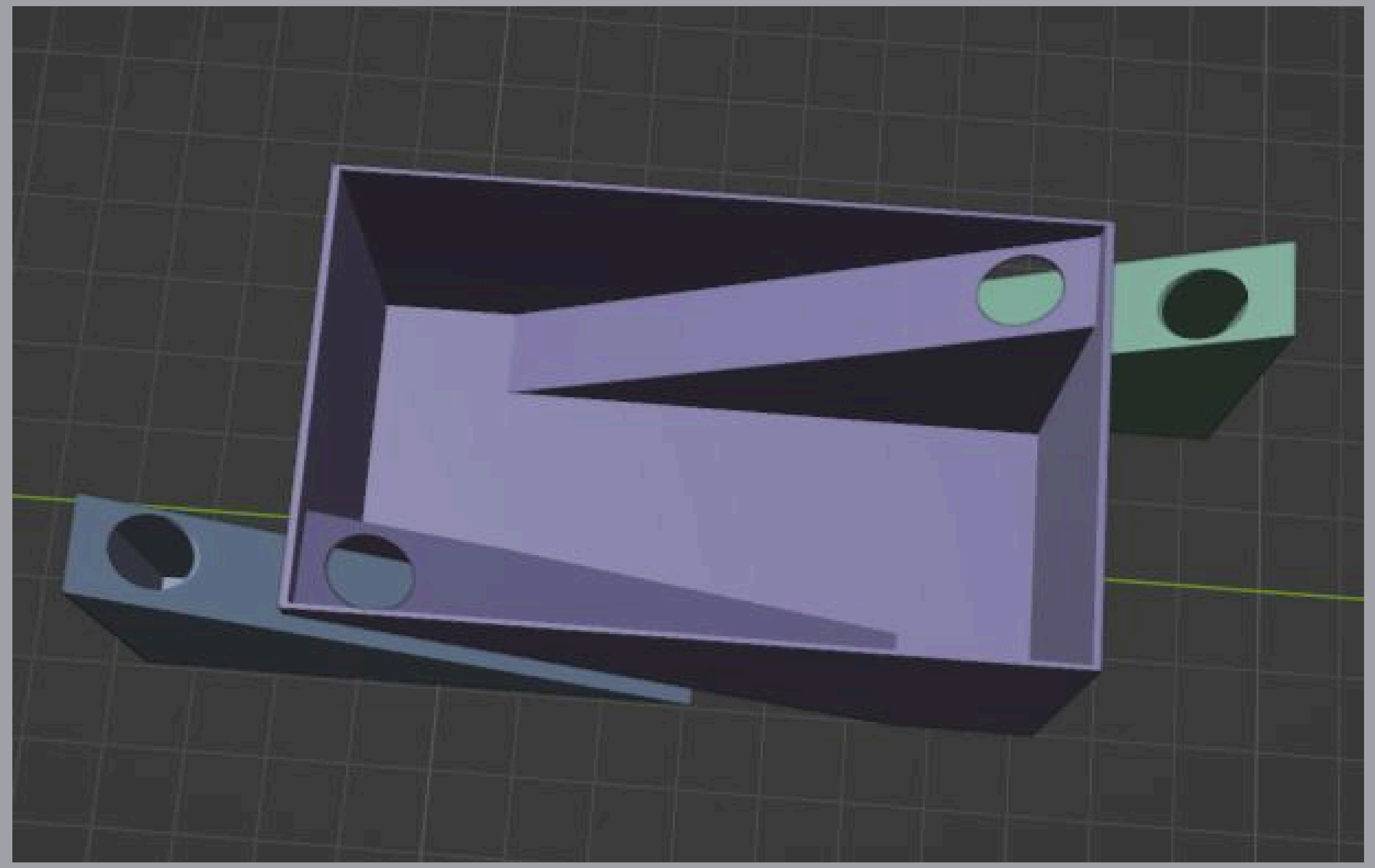
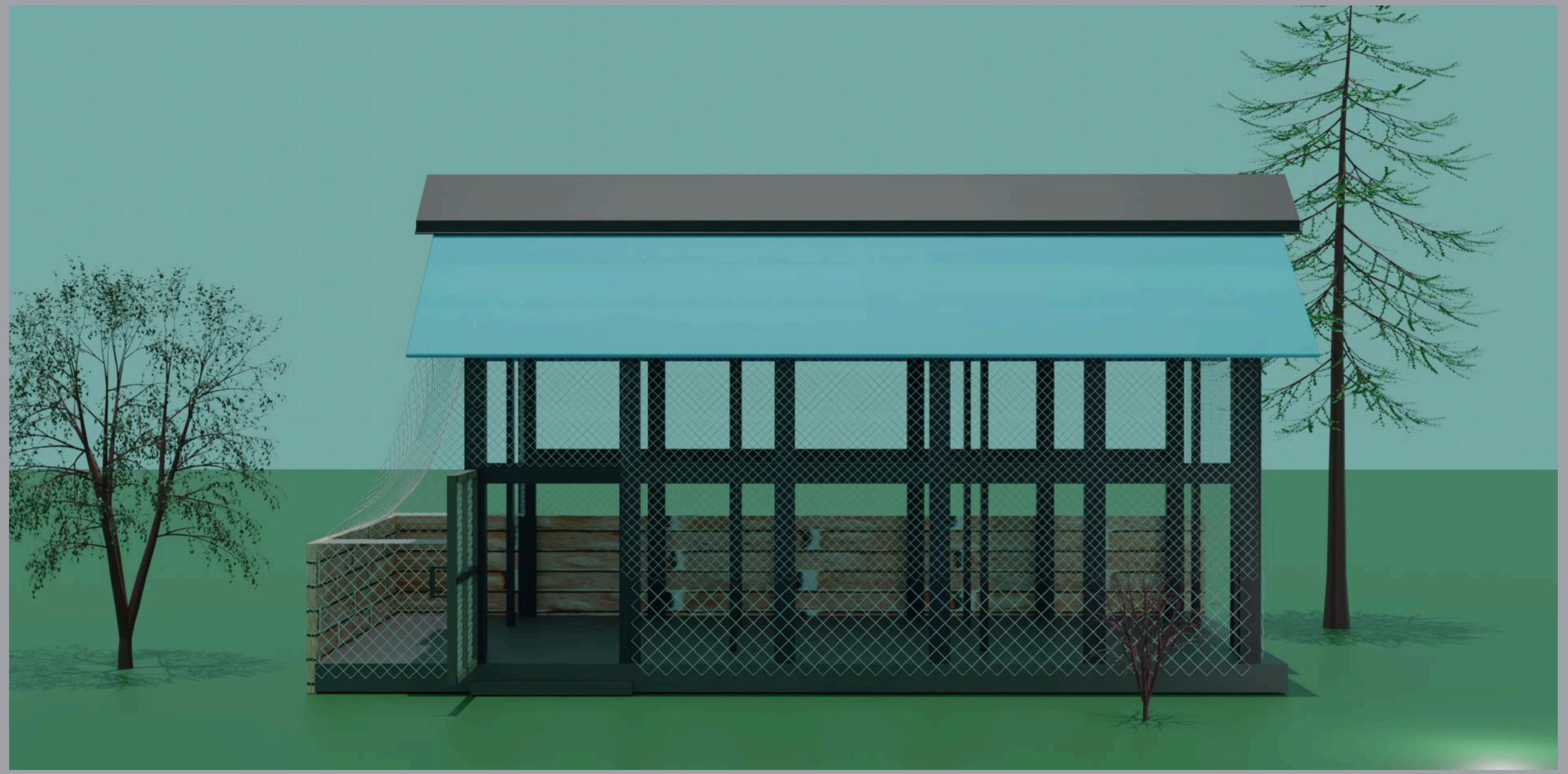




Previous Design

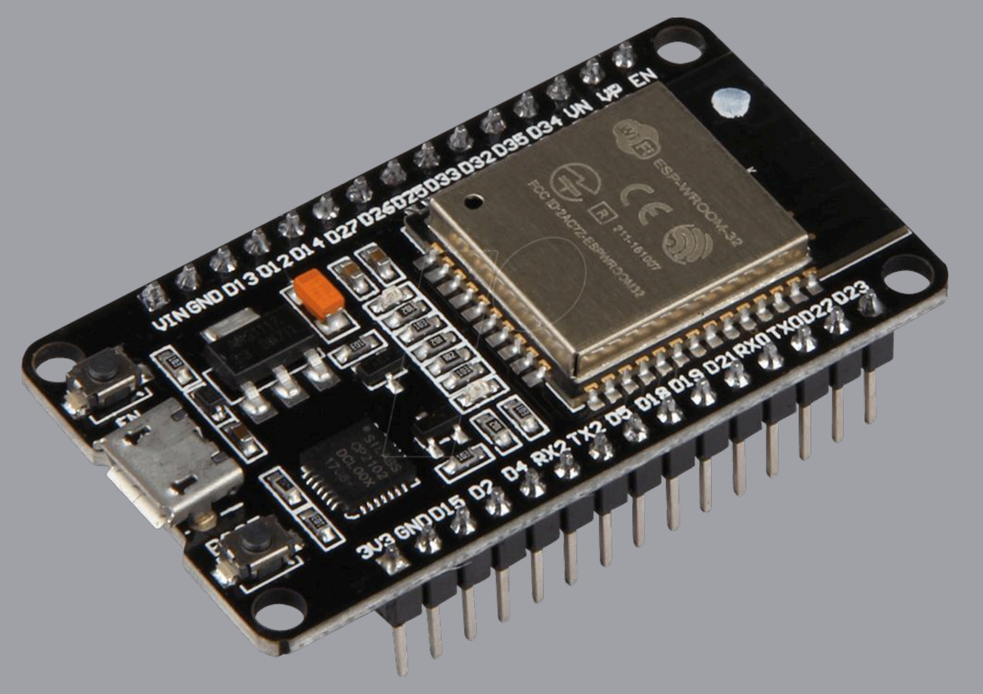


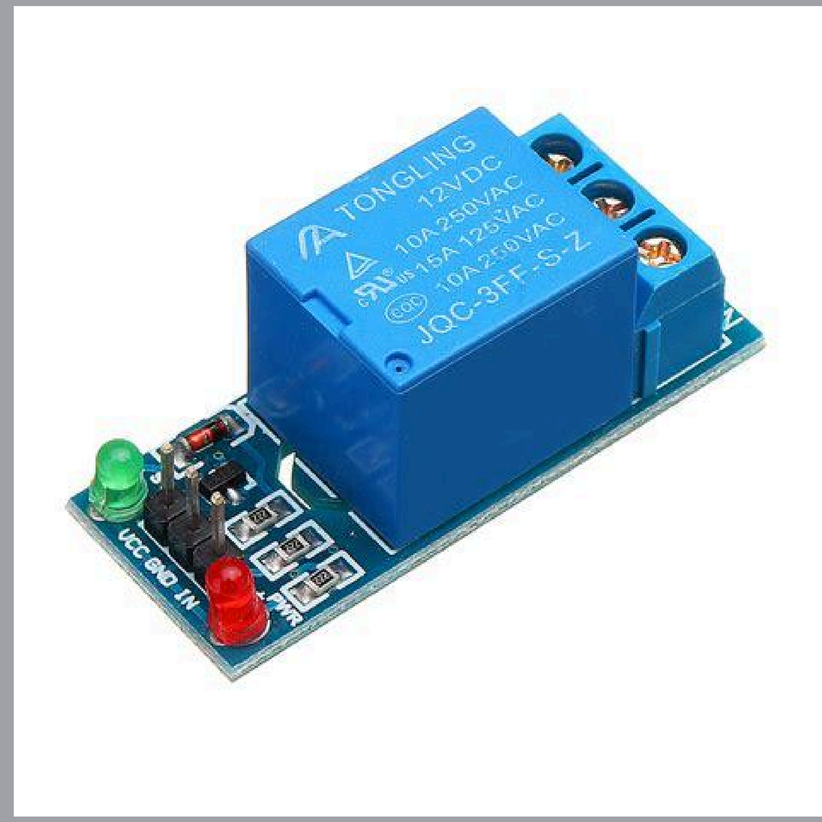


Current Design	Previous Design
	
	

Automation Concept: Use of ESP32, sensors, and actuators for control.

1. **Sensors:**
    - Temperature Sensors (DHT22, DS18B20)
      Monitor the temperature in each section.
    - Humidity Sensors (DHT22)
      Maintain optimal conditions for egg viability and larvae development.
    - Light Sensors (LDR)
      Detect light intensity to adjust artificial lighting for mating and other lifecycle stages.
2. **Actuators:**
    - Heaters and Cooling Elements:
      (ceramic heaters) or Peltier modules for cooling.
    - Humidifiers and Dehumidifiers:
    - Fans:
    - LED Lights:
      Provide controlled lighting to simulate daylight conditions for mating.
3. **Control Logic with ESP32:**
    - The ESP32 acts as the central hub, processing data from sensors and controlling actuators based on pre-set thresholds.
    - It ensures real-time adjustments, reducing the need for manual intervention.
    - Wi-Fi connectivity allows seamless integration with the mobile app for remote operation.
4. **Alerts and Notifications:**
    - The system can send alerts (via the app) if parameters deviate significantly from the set values, ensuring timely corrective actions.





- **Mobile App Integration: Planned features like real-time monitoring and control.**

Real-Time Monitoring:
- Display live temperature, humidity, and light intensity for each section.
- Show the system's operational status (e.g., actuator activity).

Parameter Adjustments:
- Allow users to set desired temperature and humidity levels for each section.
- Provide options to control light schedules and ventilation.

Waste and Larvae Status:
- Notify users when the waste bin requires replenishment or when larvae harvesting is complete.
- Provide data on the quantity of waste processed and larvae produced.

Alerts and Notifications:
- Send alerts for anomalies, such as temperature or humidity falling outside the acceptable range.
- Notify users of maintenance needs (e.g., cleaning or refilling water in the humidifier).

Data Analytics:
- Display historical data trends to help users optimize their BSF production process.

Remote Control:
- Enable users to adjust settings or turn specific components on/off remotely via Wi-Fi.

User-Friendly Interface:
- Include intuitive controls, visual graphs, and easy navigation to make the app accessible even to non-technical users.