P2 Project Report

Design of Portable Ethylene Removal Device for Fruits and Vegetables

Guided By

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Submitted by

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IIT Bombay

Approval Form

This is to certify that the Industrial Design Project entitled "Design of Portable Ethylene Removal Device for Fruits and Vegetables" by Priyadarshi Satyam is approved for partial fulfillment for the Master of Design degree in Industrial Design.

Prof. B. K. Chakravarthy
[Project Guide]

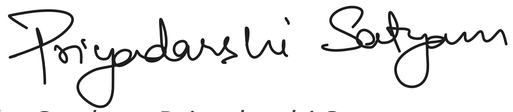
Signature of the
Chair Person

Signature of the
Internal Examiner

Signature of the
External Examiner

Declaration Form

I, declare that this written report represents my ideas in my own words, and where others' ideas or words have been included I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not falsified, misinterpreted or fabricated any idea, data, facts or source in my submission. I understand that any violation of the above will be caused for disciplinary action by the Institute and can also evoke penal action from the source, from which proper permission has not been taken or improperly been cited.

Signature: 

Name of the Student: Priyadarshi Satyam

Roll No: 22M2227

Acknowledgement

I would like to express my heartfelt gratitude to my guide, Prof. B. K Chakravarthy *, for his essential assistance throughout the project. Special thanks to the professors of Industrial Design Department for their critics and guidance . I am also grateful to all of the instructors, staff, and students at the Industrial Design Centre (IDC) for their assistance, advice, and suggestions. I would like to thank S4S Technology, Aurangabad and Sahyadri Farms, Nashik for providing field exposure and guidance. Finally I'd like to express my gratitude to my family and friends for their unwavering support.*

Abstract

Tomato price hikes and post-harvest losses are persistent challenges for small-scale farmers. This project proposes an innovative solution—a cost-effective, portable ethylene removal device designed specifically for farmers with 1-2 acres of land. By mitigating ethylene-induced ripening during transportation and storage, the device aims to extend the shelf life of tomatoes, reducing spoilage and enhancing income. This ethylene removal solution stands as a beacon of affordability and practicality, tailored to the unique needs of small-scale farmers who contribute significantly to the agricultural landscape. The outcomes of this project not only address economic concerns but also align with sustainability goals, empowering farmers and fostering resilience in the face of market fluctuations and perishability challenges.

Content

1. Introduction

Tomato price volatility poses a formidable challenge for farmers, leading to financial uncertainties and post-harvest losses. Small-scale farmers, essential contributors to the agricultural sector, grapple with the need for stable income. The "Grand Tomato Challenge" underscores the urgency to address this predicament, fostering innovation to stabilize prices, fortify farmers' livelihoods, and establish a resilient foundation for sustainable agriculture. This project delves into understanding the intricacies of tomato price fluctuations, unraveling the hurdles faced by farmers, and endeavors to contribute to the overarching goal of creating a more stable and equitable tomato value chain.

1.1 Tomato Farming in India

Tomatoes, originating from Western South America, arrived in India via Portuguese traders in the 16th century. As the world's second-largest producer, India yields 189 million metric tonnes yearly, with significant contributions from Madhya Pradesh (14.63%) and Andhra Pradesh (10.92%).

Madhya Pradesh
14.63%

Andhra Pradesh
10.92%

This versatile fruit has become a staple in Indian cuisine, showcasing its importance in both agricultural production and dietary habits across the country.

1.2 Current Issue

India's tomato industry grapples with multifaceted challenges, notably substantial wastage, price instability, and seasonal overproduction, leading to repercussions for both farmers and consumers.

a) Wastage

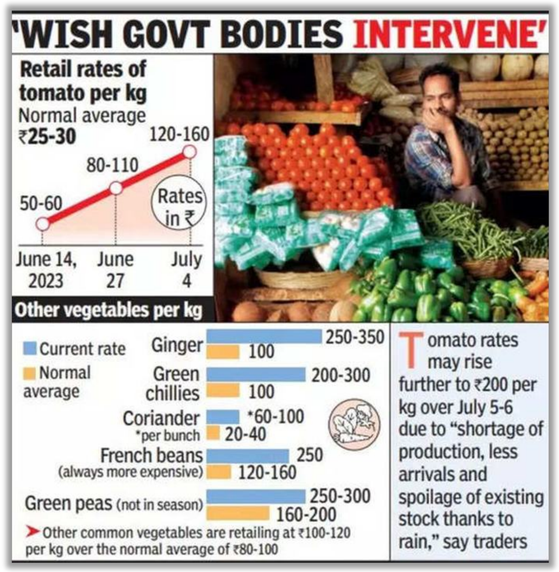
The absence of efficient storage and transportation infrastructure often results in significant post-harvest losses. Tomatoes, being perishable, are prone to spoilage due to inadequate facilities, causing financial setbacks for farmers.

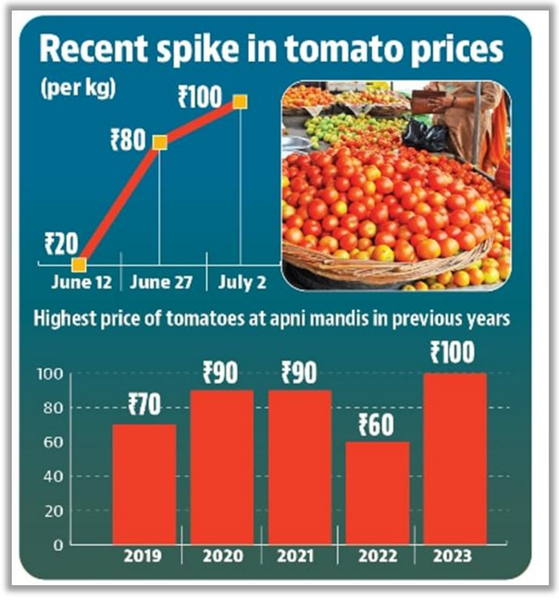
b) Price Instability

Fluctuating tomato prices are a recurrent concern, impacting the income of farmers. The volatility is attributed to factors such as weather conditions, transportation issues, and market dynamics, creating an unpredictable economic environment for those involved in tomato cultivation.

c) Seasonal Overproduction

The concentrated harvest seasons, particularly from December to March, lead to an excess supply of tomatoes in the market. The surge in supply during these periods, coupled with logistical challenges, often results in a glut, causing prices to plummet. This fluctuation can lead to substantial financial losses for farmers who struggle to find a balance between supply and demand.





1.3 Why did tomato price shoot up?

a) Lack of Plantation Forecast

Absence of accurate planting forecasts contributes to unplanned and uneven production, affecting market equilibrium.

b) Weather Disruptions

Adverse weather conditions, such as unseasonal rains or extreme temperatures, disrupt the natural growth and harvesting cycles, impacting supply.

c) Storage Loss

Inadequate storage facilities lead to post-harvest losses, as tomatoes are perishable and susceptible to spoilage without proper preservation methods.

d) Transportation Loss

Insufficient transportation infrastructure results in delays and losses during transit, affecting the overall supply chain efficiency.

e) Supply-Demand Interruption

Imbalances in supply and demand, often exacerbated by unforeseen events, contribute to sudden spikes in tomato prices, creating financial challenges for both farmers and consumers.

1.4 Consequences

As tomato prices soared, the repercussions were felt throughout the agricultural landscape. Consequences of the last tomato harvest included:

b) Surplus Left Untaken

The excess supply resulting from a price shoot-up left a surplus of tomatoes unclaimed in the market, contributing to widespread wastage.

c) Tomatoes Rotted in Fields

Unprofitable market prices compelled farmers to abandon harvested tomatoes in the fields, where they rotted due to the lack of economic viability for transportation and sale.

d) Farmers Discouraged from Growing Tomatoes

The financial losses incurred by farmers during the last harvest, coupled with unprofitable market conditions, discouraged many from cultivating tomatoes in subsequent seasons, impacting overall agricultural practices and livelihoods.

2. Tomato Grand Challenge

Vertical 3 of Tomato Grand Challenge

The third vertical of the Tomato Grand Challenge focuses on implementing innovative post-harvest treatments, advanced packaging solutions, and cutting-edge technologies for long-term storage. The primary goal is to minimize post-harvest losses incurred during transportation and storage, ultimately mitigating the necessity for panic selling triggered by the perishable nature of tomatoes. This approach addresses the critical issue of spoilage and financial losses faced by farmers while enhancing the overall efficiency and sustainability of the tomato value chain.

Challenges	Scope of Improvement
• Shelf-life of tomatoes	• Solutions to improve shelf-life while preserving quality such as appearance, color and firmness
• Safe and economical packaging solutions	• Sustainable packaging material
• Long-term storage solutions	• Low cost, low energy requiring, and environmentally sustainable storage solutions
• Losses during transportation	• Special material for containers/ packaging to reduce loss during transportation, loading, and unloading

3. Tomato Lifecycle in Value Chain

Understanding the tomato life cycle in the value chain is crucial for optimizing cultivation, minimizing post-harvest losses, ensuring quality during transportation, and meeting consumer demands for fresh, nutritious produce.

Sowing Seed

The tomato life cycle begins with sowing seeds, either directly in the field or in seedbeds, where they germinate into young seedlings.

Planting Sapling

Seedlings are transplanted into the field once they reach a suitable size, and the plants start to grow, developing leaves and branches.

Plant Maturing

As the tomato plants mature, they produce flowers, which later turn into green, unripe tomatoes.

Bearing Tomato

The green tomatoes gradually ripen and change color, bearing mature, ready-to-harvest fruits.

Harvesting & Storage

The ripe tomatoes are harvested, sorted, and graded. Depending on their destination, they might undergo further processing or be stored for later use.

Transportation

Tomatoes are transported to various destinations, including local markets, processing facilities, or export destinations. Proper packaging is crucial to prevent damage during transit.

Retail Stores

In retail stores, tomatoes are displayed for consumers. Factors like appearance, ripeness, and pricing influence consumer choices.

Kitchen and Household

Consumers purchase tomatoes and incorporate them into their culinary activities. Tomatoes are used in salads, sauces, soups, and various other dishes.

3.1 Tomato Shelf Life and Quality

Tomato shelf life and quality are paramount for ensuring consumer satisfaction, minimizing food waste, and supporting the economic viability of farmers, making them critical factors in the agricultural value chain.

a) Temperature

Tomatoes are sensitive to temperature fluctuations; storage at optimal temperatures preserves firmness, color, and flavor while deterring premature ripening or decay.

b) Humidity

High humidity fosters mold growth and decay, emphasizing the need for controlled humidity during storage to prevent surface moisture and fungal development.

c) Ethylene Produced

Ethylene accelerates tomato ripening. Efficient ethylene removal is crucial to extend shelf life, controlling ripening and preventing premature softening and decay

d) Transportation Damage

Rough handling during transportation can bruise or damage tomatoes, compromising their structural integrity and accelerating decay

3.2 Ways to Increase Shelf Life of Tomato

Increasing the shelf life of tomatoes is crucial for reducing food waste, ensuring year-round availability, enhancing market access for farmers, and meeting consumer demands for fresh and nutritious produce.

a) Solar Drying / Sun Drying

Utilizing natural solar energy to dehydrate tomatoes, enhancing shelf life through reduced moisture content.

b) Controlled Atmosphere Storage

Regulating oxygen, carbon dioxide, and humidity levels to slow down ripening and extend shelf life in storage facilities.

c) Modified Atmosphere Packaging

Altering the composition of the air surrounding tomatoes in packaging to control respiration and slow down deterioration

d) Humidity and Temperature Control Techniques

Implementing controlled environments with optimized humidity and temperature to deter microbial growth and slow down ripening

a) Post Harvest Treatment

Applying natural preservatives to reduce microbial activity and decay, enhancing the longevity of tomatoes post-harvest

b) Ethylene Absorption and Management

Employing methods to absorb ethylene, a ripening agent produced by tomatoes, to slow down the ripening process and extend shelf life

c) Innovative Packaging Approaches

Introducing novel packaging methods, materials, or technologies that provide enhanced protection, preventing physical damage and preserving tomato quality

3.3 Processed Tomato Products

Processed tomato products, such as ketchup, sauces, soups, and canned tomatoes, offer diverse culinary options, convenience, and extended shelf life, contributing to the versatility and popularity of tomatoes.

Canned

Dehydrated

Puree

Pulp

Ketchup

Juice

4. Field Visit 1: S4S Technology, Aurangabad

As part of our primary research, we conducted a field visit to S4S Technology in Aurangabad, founded by IIT Bombay alumnus Ashwin Pawade. S4S employs solar dehydrators, converting farm losses into valuable food ingredients. This initiative establishes a customer-centric, sustainable, and equitable agri-value chain.

Insights

a) Seasonal Limitations

Solar dehydrators face constraints during certain seasons, impacting the year-round feasibility of tomato drying.

b) Humidity Dependency

Effective solar drying relies on low humidity; high humidity poses challenges, leading to potential fungal growth on tomatoes.

c) Free Moisture Removal

Pre-drying moisture removal involves electricity usage, presenting a sustainability challenge in the overall process.

d) Market Access

Farmers encounter difficulties in accessing markets, emphasizing the importance of a structured product chain for effective sales

e) Sustainability and Business Integration

The integration of sustainable practices and a robust business model is essential for the success of tomato drying initiatives, ensuring both environmental and economic sustainability

4. Field Visit 1: S4S Technology, Aurangabad

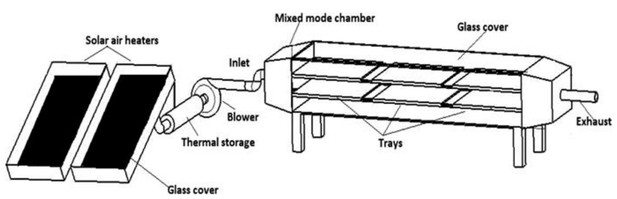
5. Exploring Facilities at IIT Bombay

6. Types of Solar Dehydrators

Open Drying

Integrated Solar Dring

Distributed Solar Drying



Mixed Mode Drying

Tunnel Drying

7. Field Visit 2: Sahyadri Farms, Nashik

Second field visit was at Sahyadri Farms in Nashik, India's leading fruits and vegetables platform. Distinguished for its inclusive partnership with farmers, Sahyadri excels in primary processing, frozen, aseptic, and processed products. Notably, the platform prioritizes sustainable waste management, reflecting its commitment to holistic and environmentally conscious agricultural practices

What they do?

Integrated Fruits and Vegetables Platform

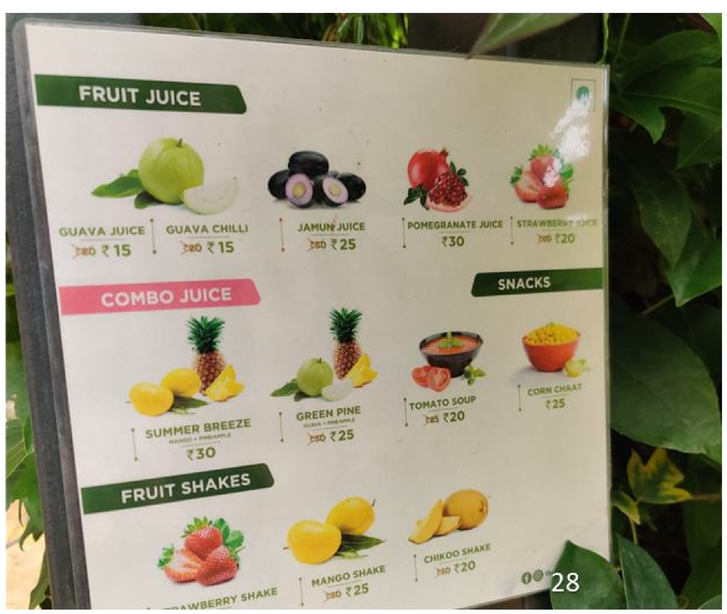
Empowering Small Farmers

Diverse Crop Range

Expansion & Contract Manufacture

7. Field Visit 2: Sahyadri Farms, Nashik

7. Field Visit 2: Sahyadri Farms, Nashik



7.1 Conversations with Farmers

Insights from conversations with farmers at Sahyadri Farms revealed:

a) Difficulties Faced by Farmers in Tomato Farming

Farmers highlighted challenges in tomato farming, including unpredictable weather conditions, pest infestations, and market price fluctuations

b) Transportation and Storage Challenges

Farmers expressed concerns about transportation logistics and storage facilities, citing issues such as inadequate infrastructure and post-harvest losses during transit.

c) Solar Dehydration Tools & Techniques

The discussion delved into the utilization of solar dehydration methods, exploring tools and techniques employed by Sahyadri Farms to preserve tomatoes and minimize waste

d) Shelf Life of Tomatoes

Farmers shared perspectives on the shelf life of tomatoes, emphasizing the importance of effective preservation methods to prolong freshness and enhance market access.

e) Sustainability and Business Integration

Sustainability and the integration of effective business models emerged as critical points, with farmers expressing the need for practices that balance environmental concerns with economic viability in tomato farming.

7.2 Sahaydri Farms Insights

Lack of Data for Predicting Plantation Needs

Challenges in Post-Harvest Solar Drying

Need for Ethylene Removal System During Transport

7.3 Lack of Data for Predicting Plantation Needs

Data for predicting plantation needs is crucial for informed decision-making, mitigating tomato price fluctuations, optimizing cultivation seasons, and aligning planting quantities with market demand for sustainable and profitable farming.

1. Farmers face challenges due to a lack of data.
2. Tomato price fluctuations result from demand and supply imbalances.
3. Information gaps exist regarding optimal seasons and quantities for cultivation.
4. Absence of data sources hinders informed planting decisions for farmers.

7.4 Challenges in Post-harvest Solar Drying

key difficulties faced in the solar drying process after harvesting tomatoes

1. Ineffectiveness of solar drying year-round.
2. Tomato spoilage in rainy or high-humidity conditions due to fungus attack.
3. Requirement for a solution to manage humidity in solar drying processes.

7.5 Need for Etylene Removal System During Transport

Reducing ethylene from fruits is essential because ethylene is a natural plant hormone that triggers and accelerates the ripening process. Controlling ethylene levels helps extend the shelf life of fruits, preventing premature ripening, decay, and spoilage during storage and transportation.

- Ethylene Production:
  - Tomatoes emit ethylene, inducing premature ripening.
- Categorization for Export:
  - Tomatoes classified by ripeness for long-distance export.
- Damage During Ripening:
  - A substantial portion of tomatoes faces damage during ripening.
- Need for Shelf Life Extension:
  - Crucial need for a solution to enhance tomato shelf life during transportation and storage.

Tomatoes waiting in trucks to get inside the processing plant

8. Cause & Context

Cause

This project aims to elevate small-scale farmers' income by safeguarding their produce against spoilage.

Context

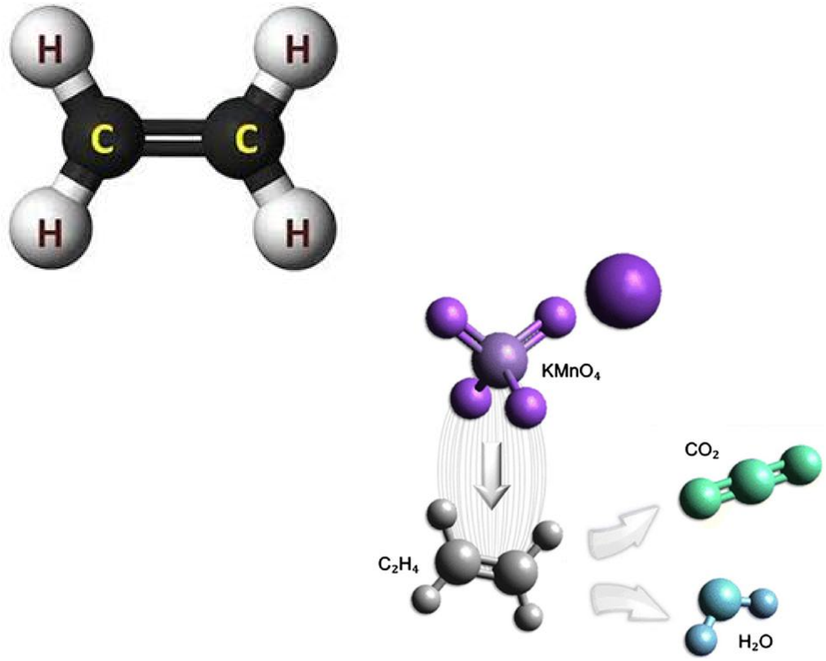
Focused on those supplying aggregators, it addresses the unique challenges faced by these farmers. The central objective is to devise affordable and sustainable solutions that effectively extend the shelf life of tomatoes, ultimately fostering economic growth and stability in the agricultural sector.

9. Design Brief

This project entails the creation of a cost-effective and portable solution designed specifically for small-scale farmers. The objective is to develop a tool capable of efficiently removing ethylene, a ripening agent produced by tomatoes, during transportation and storage. By curbing premature ripening, this solution aims to minimize spoilage, thereby contributing to increased income for farmers. The emphasis on affordability and portability ensures accessibility for small-scale farmers, addressing a critical need in the agricultural value chain and fostering sustainable practices in tomato cultivation.

10. Ethylene Gas

Ethylene gas, a natural plant hormone, exerts a profound impact on the ripening process. Even in minute quantities, ranging from a few parts per billion (ppb) to a few parts per million (ppm), ethylene can significantly accelerate the ripening rate for plants. Paradoxically, its presence at these levels can have detrimental effects on plant health. The gas is known to diminish plant vigor, shorten the lifespan of various plant parts, and compromise the overall quality of the plant stock. Therefore, controlling ethylene levels is crucial to ensure optimal plant development, longevity, and quality in agricultural and horticultural contexts.



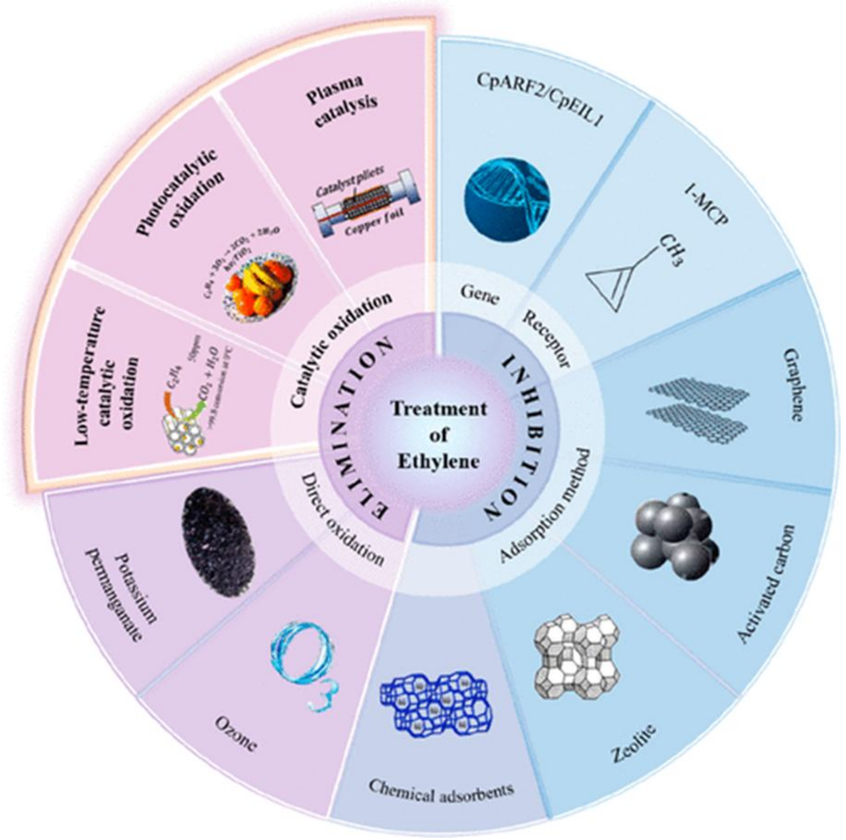
10.1 Ethylene Removal

The process of ethylene removal is inherently natural and does not alter the intrinsic properties of fruits. It involves the mechanisms of adsorption and chemisorption, which effectively capture and neutralize ethylene gas. By controlling ethylene levels through these methods, the aim is to preserve the natural characteristics of fruits and vegetables. This ensures that the ripening process is slowed down or regulated without introducing any external substances that might compromise the inherent qualities of the produce. The emphasis on adsorption and chemisorption techniques highlights a non-intrusive approach, allowing fruits and vegetables to retain their natural freshness, flavor, and nutritional content during storage and transportation.

10.2 Ethylene removal process

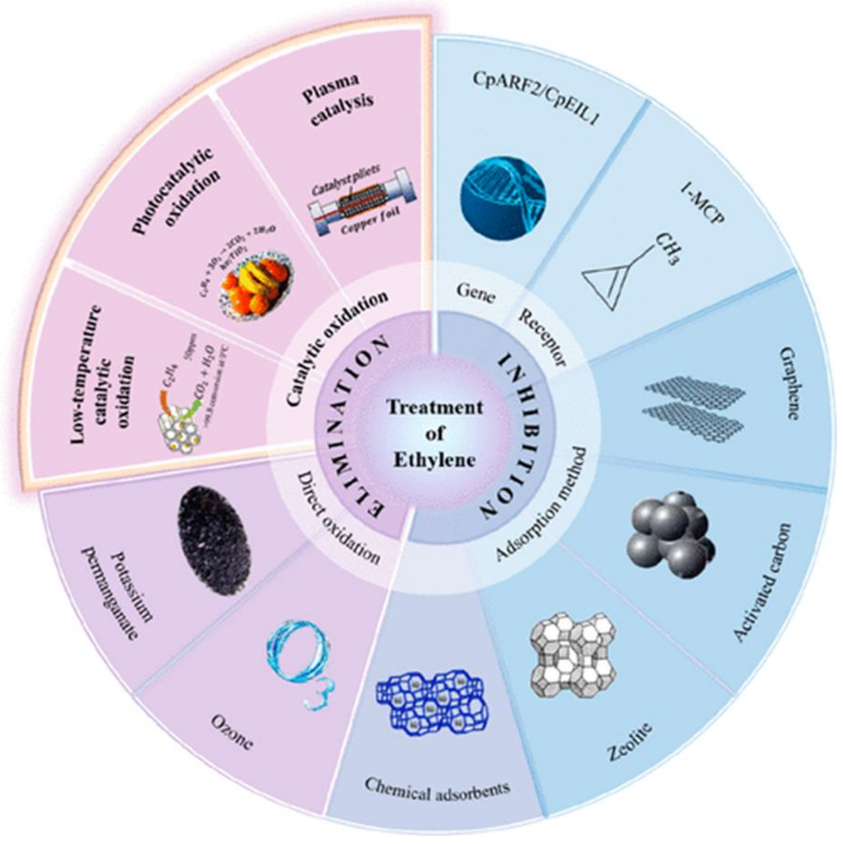
There are various methods for ethylene removal, each employing distinct processes. Here are different types:

1. Adsorption:
    - Adsorption involves trapping ethylene molecules onto a solid surface, such as activated carbon or other porous materials. This physical process effectively captures ethylene, preventing it from influencing surrounding produce.
2. Chemisorption:
    - Chemisorption is a chemical process where ethylene molecules react with a substance, forming stable chemical bonds. This alters the ethylene's chemical structure and renders it inactive, thus preventing its impact on ripening.
3. Catalytic Conversion:
    - In catalytic conversion, ethylene is exposed to a catalyst, initiating a chemical reaction that transforms ethylene into non-ripening byproducts. This method is efficient and helps maintain the quality of stored fruits.



10.2 Ethylene removal process

4. Oxidation:
    - Oxidation involves exposing ethylene to oxygen, leading to the formation of ethylene oxide. This compound is then removed, reducing the ethylene concentration and slowing down the ripening process.
5. Membrane Filtration:
    - Membrane filtration uses specialized membranes that selectively allow the passage of certain gases, effectively separating ethylene from the surrounding atmosphere and controlling its concentration.
6. Activated Charcoal Filters:
    - Activated charcoal filters utilize porous charcoal surfaces to adsorb ethylene molecules, preventing them from affecting nearby fruits and vegetables.



10.3 Ethylene removal products

1. Ethylene Scrubbers:
    - It removes excess ethylene in fruit and vegetable storage.
2. UV Filtration:
    - UVV light treatment to absorb Ethylene.
3. Use of Scavangers
    - Use of Japanese Oya clay, KMnO4-based scavengers, silica, zeolite, montmorillonite, cloister, and activated carbon.


Cassettes

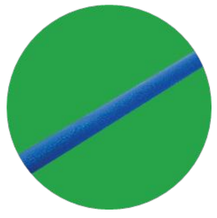

Bags


Paper

UV Filteration


UV Filteration

Curtains

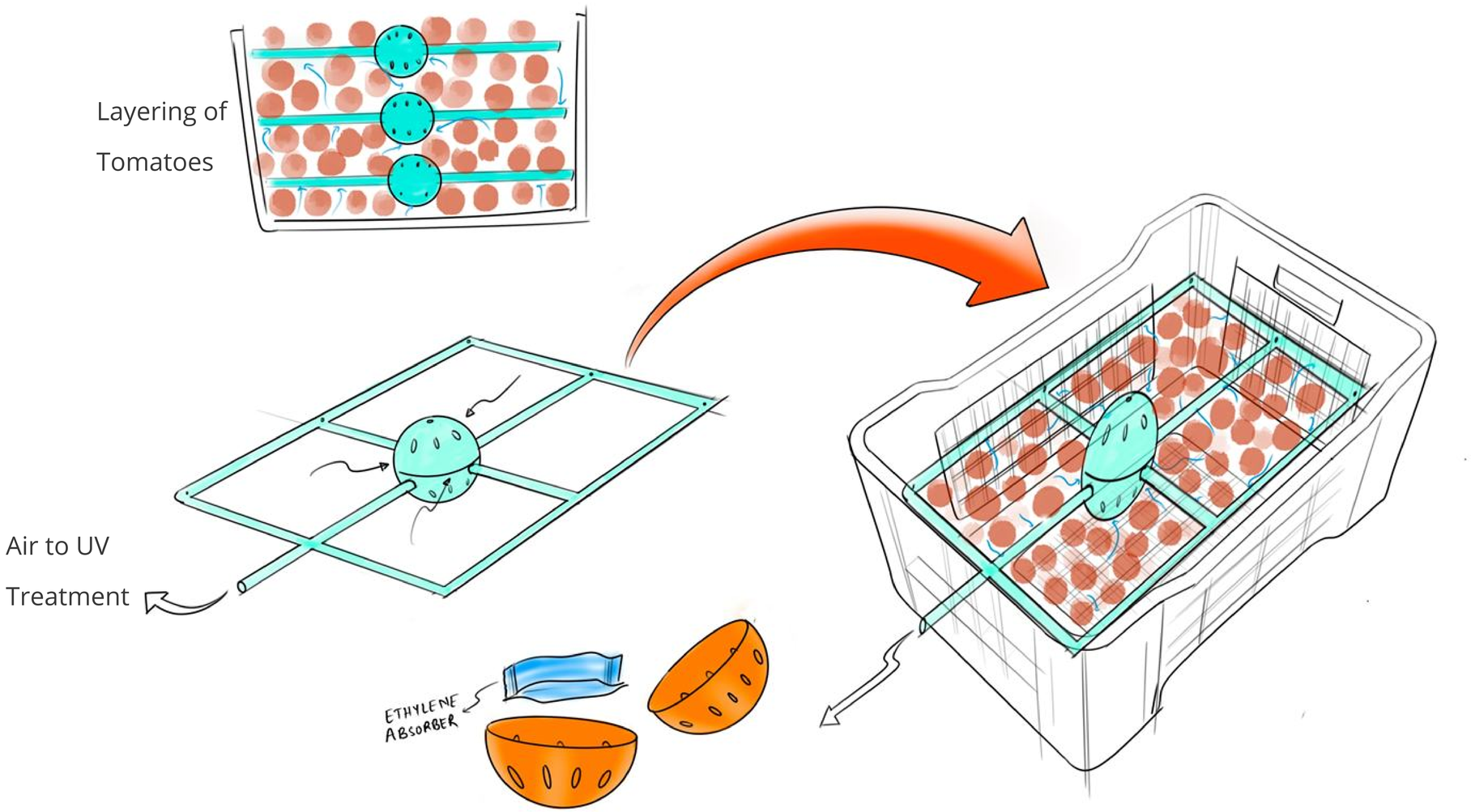

Tubes


Packaging


Scavengers

Scrubbers

11. Ideations



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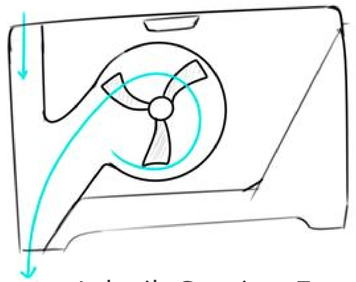
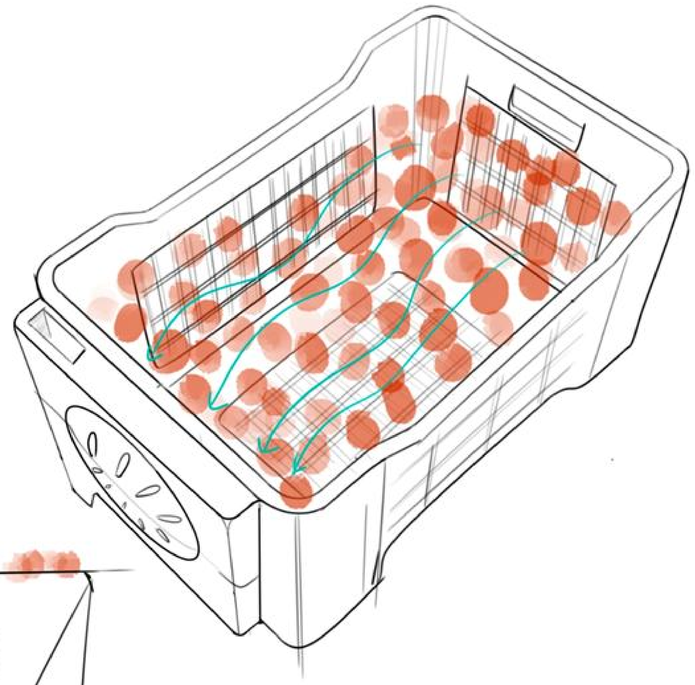
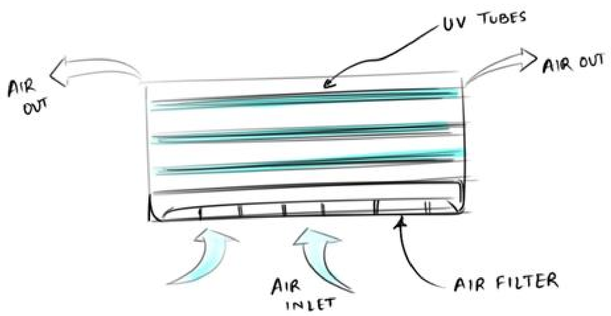


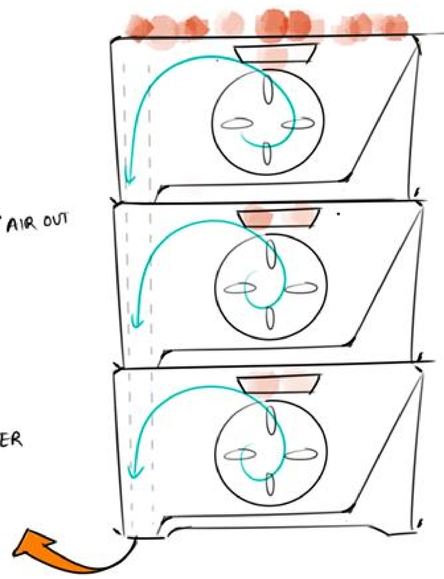
Inbuilt Suction Fan



Inbuilt Air Suction Unit

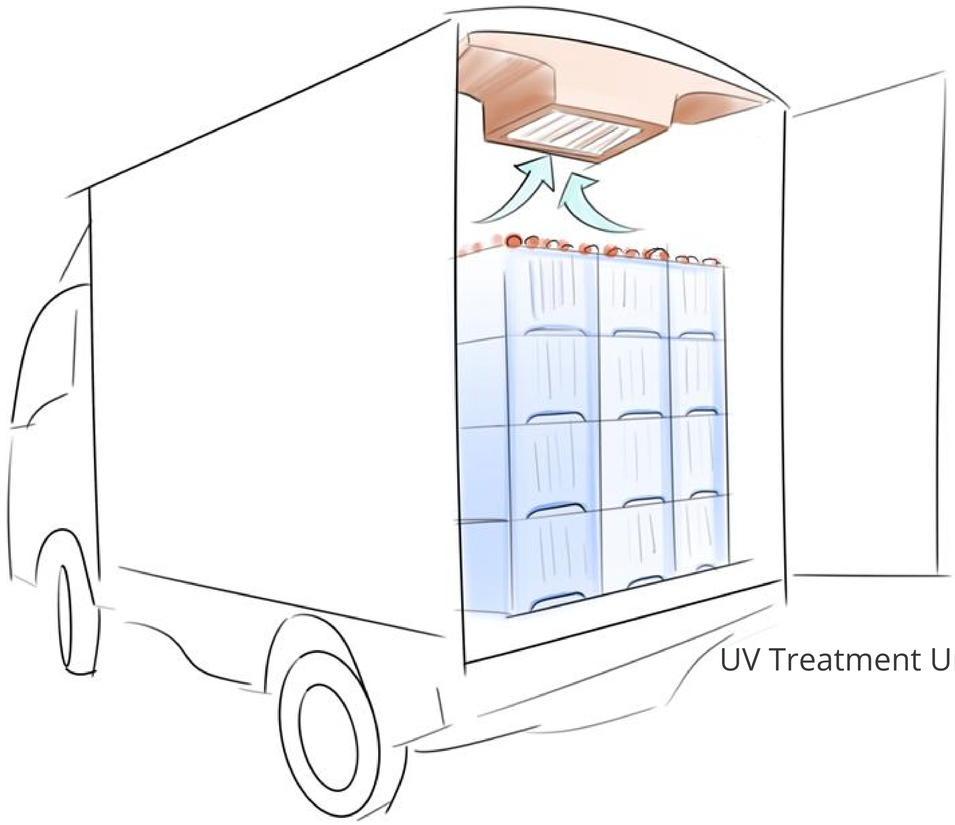


UV Treatment Unit

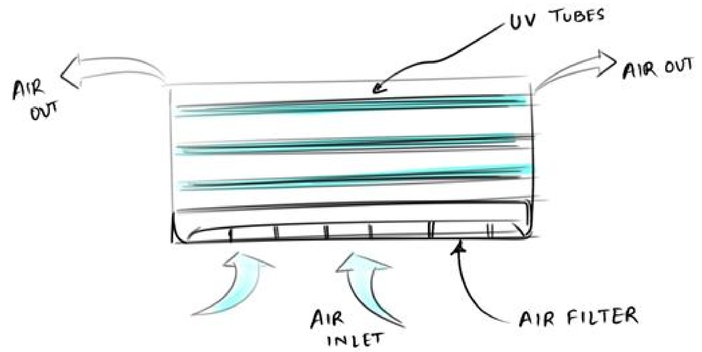


Stacking to create air channel

11. Ideations



UV Treatment Unit

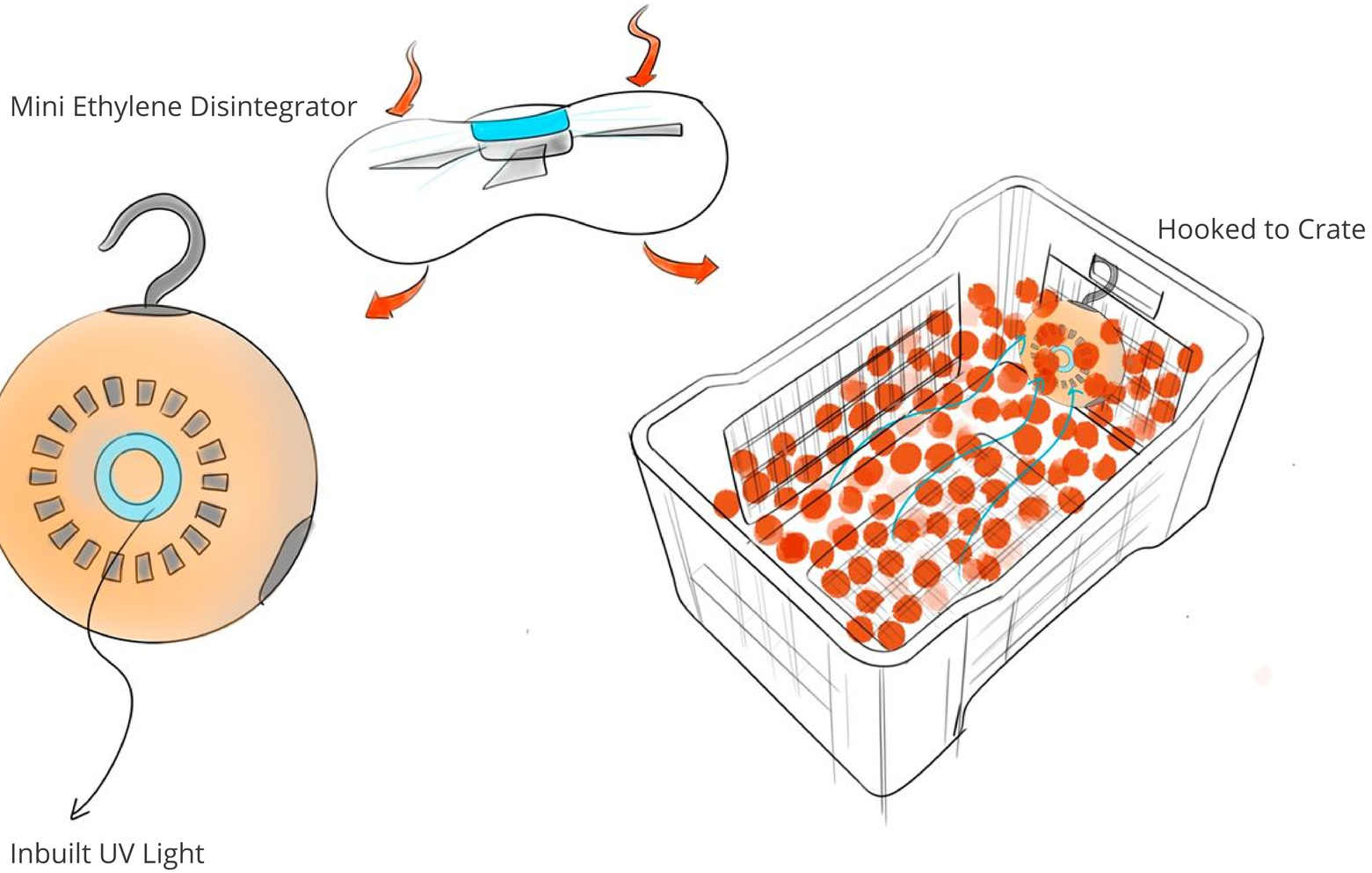


Inbuilt Suction Fan

Inbuilt Air Suction Unit

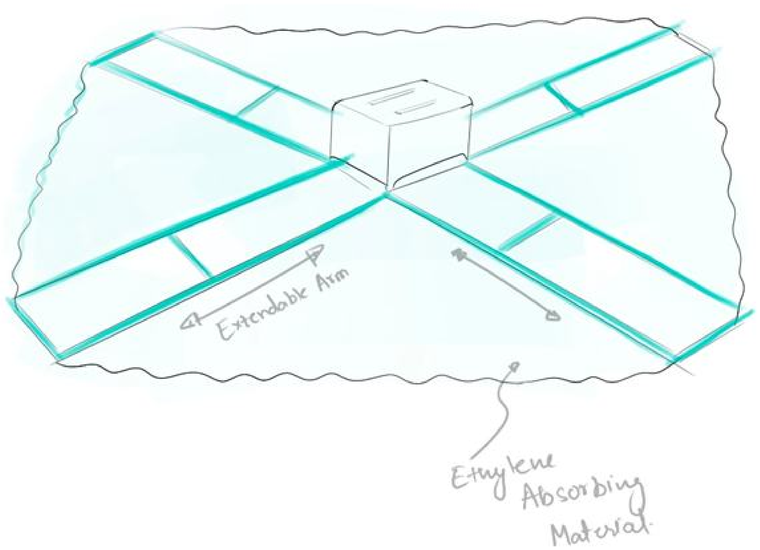
Stacking to create air channel

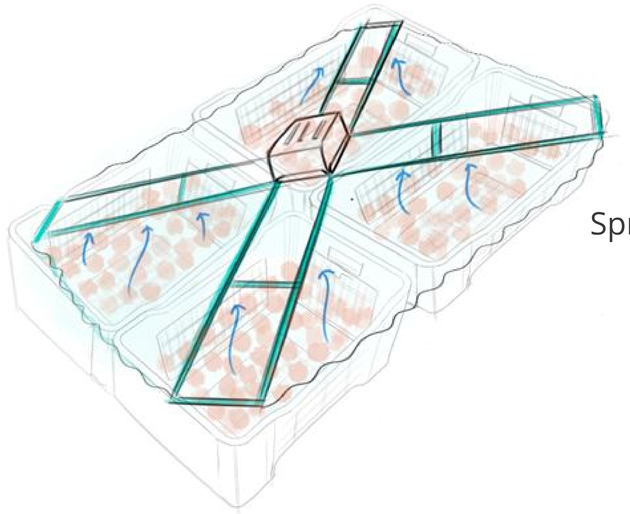
11. Ideations



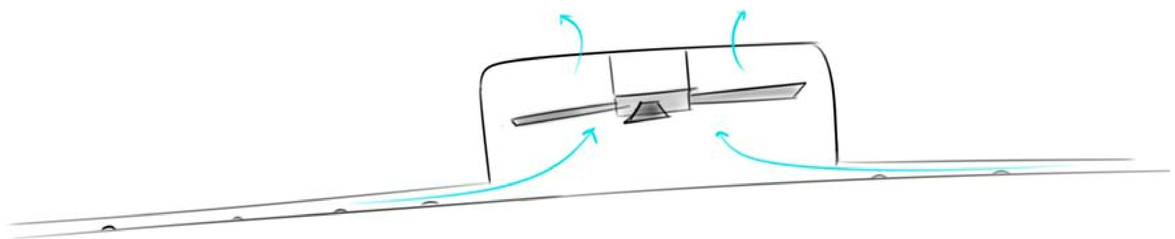
11. Ideations

Ethylene Absorbing Canopy



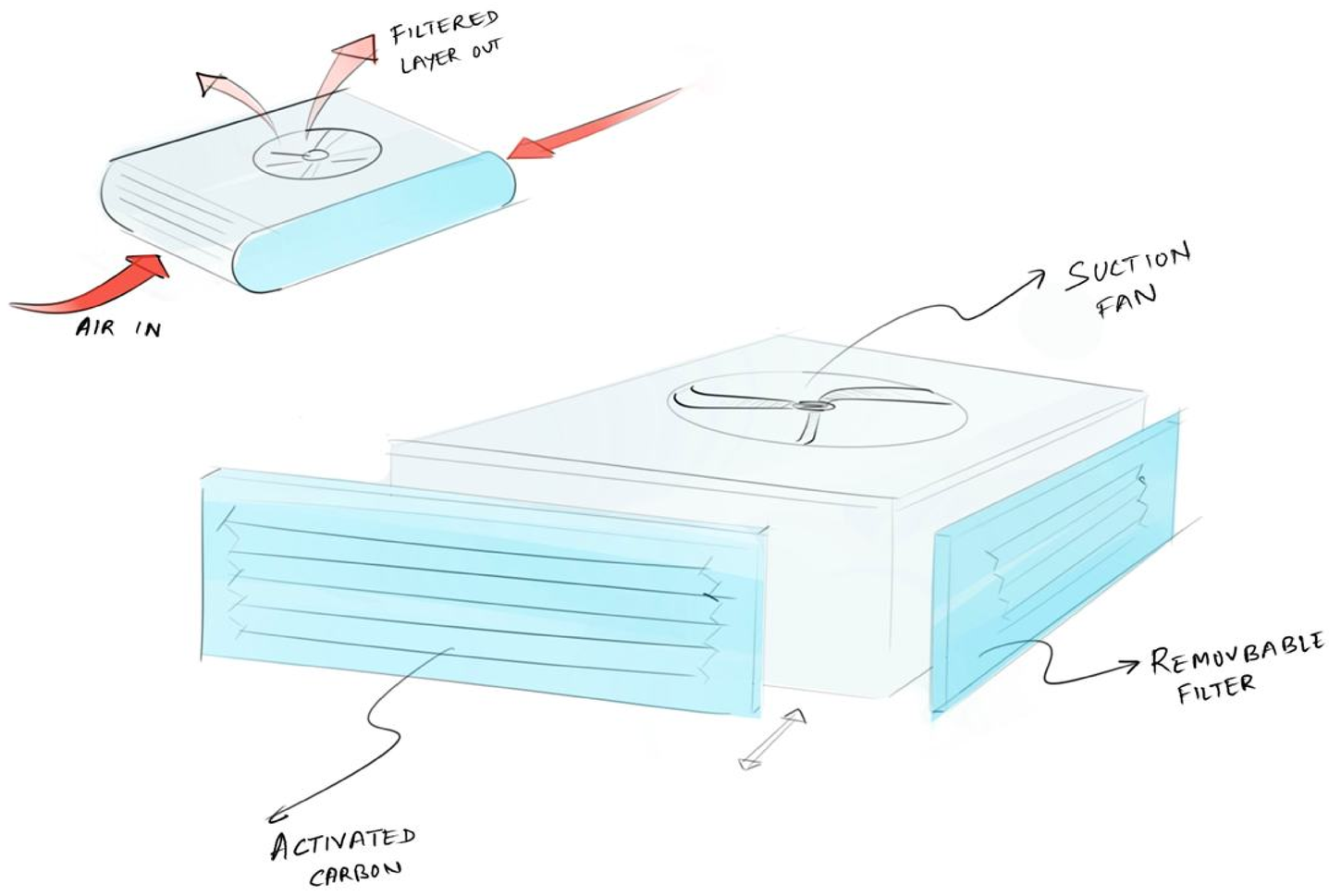


Spread over Crate



Canopy with tubular air channel

11. Ideations



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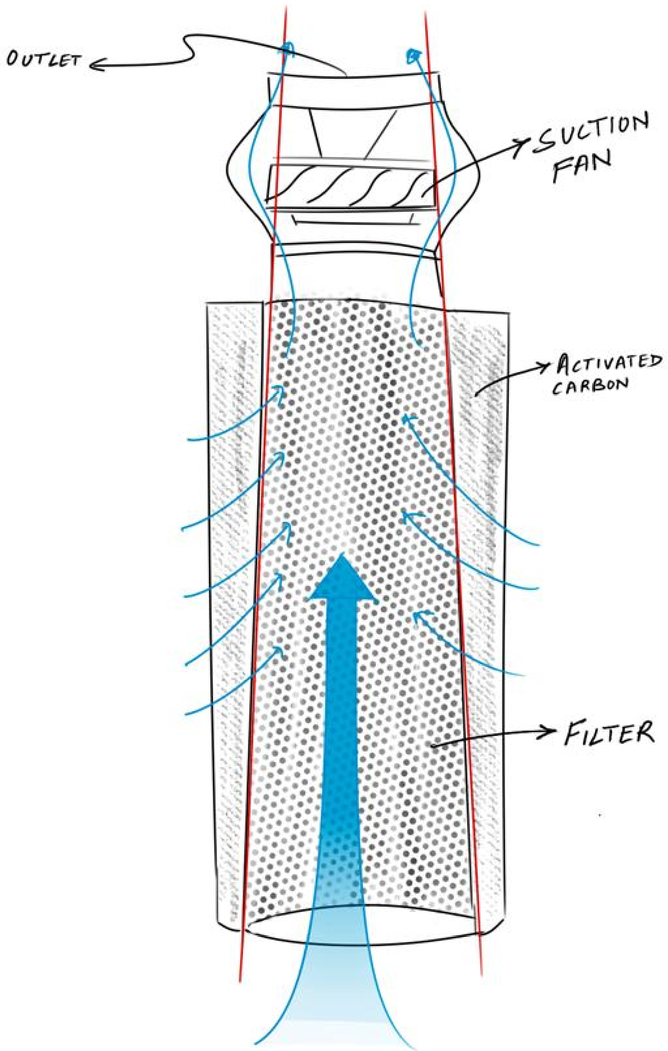

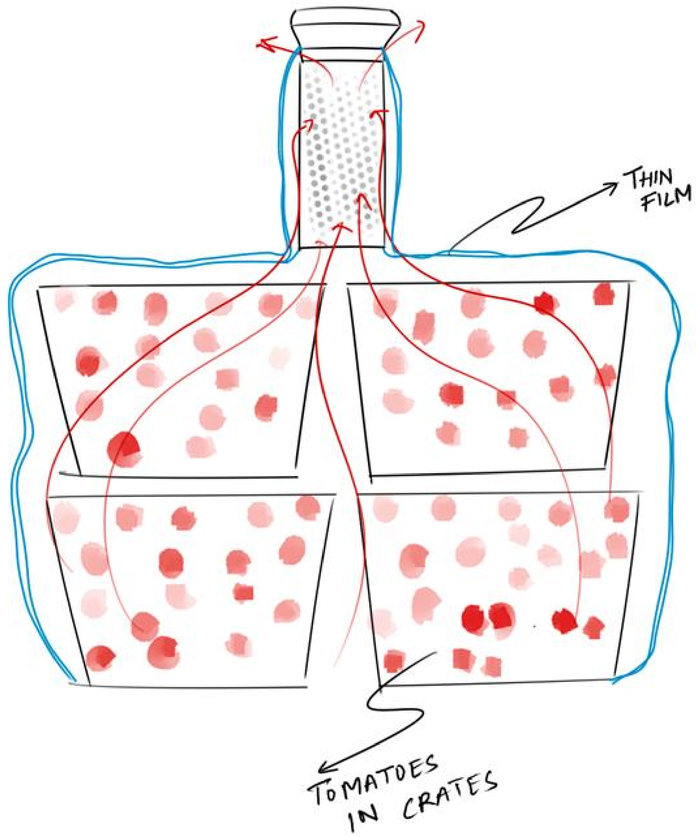

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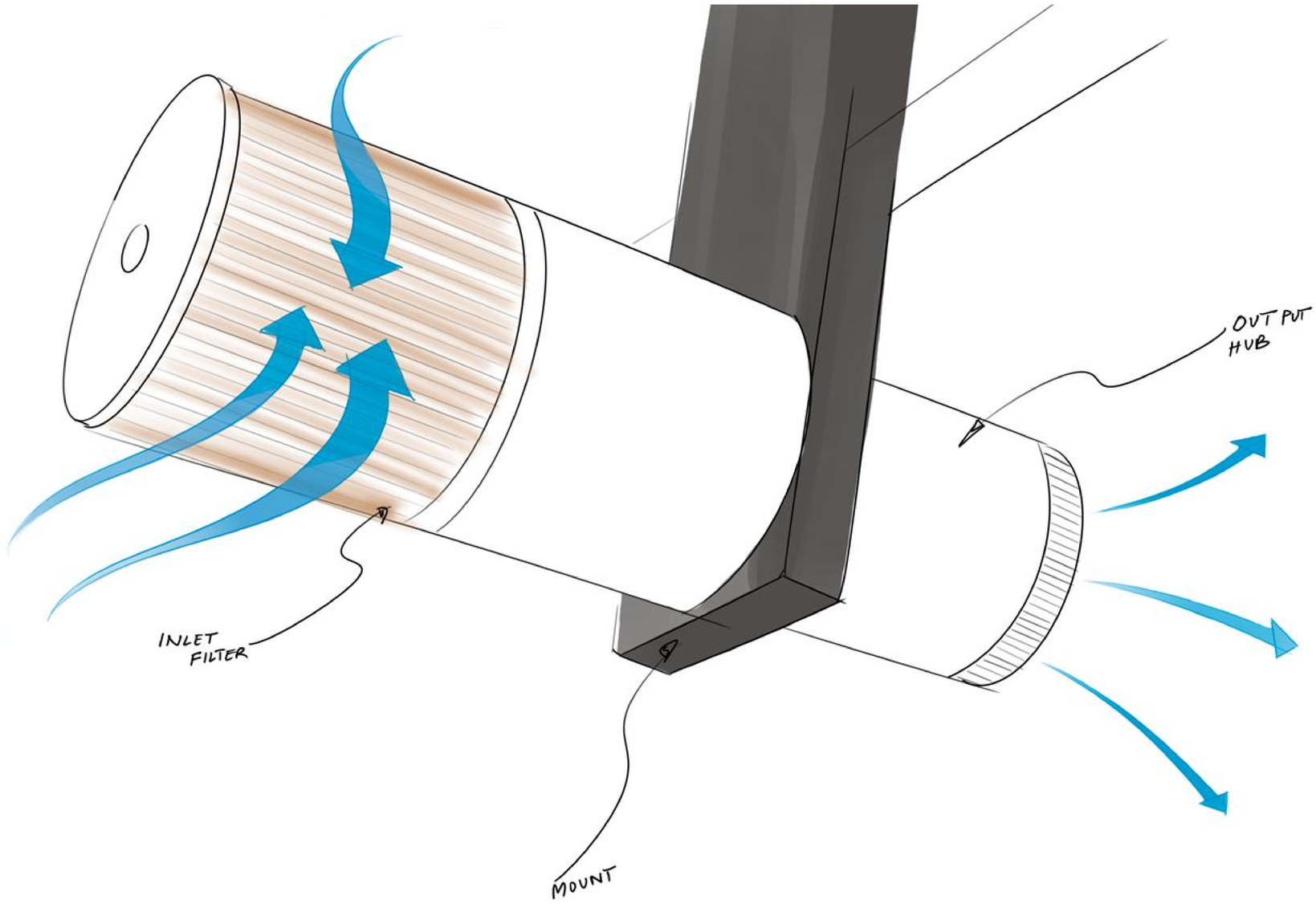
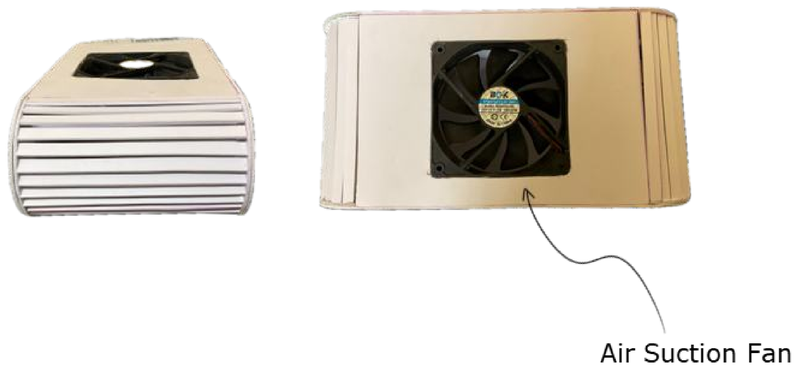


12. Mockups


Activated
Carbon Filter


Air Suction Fan

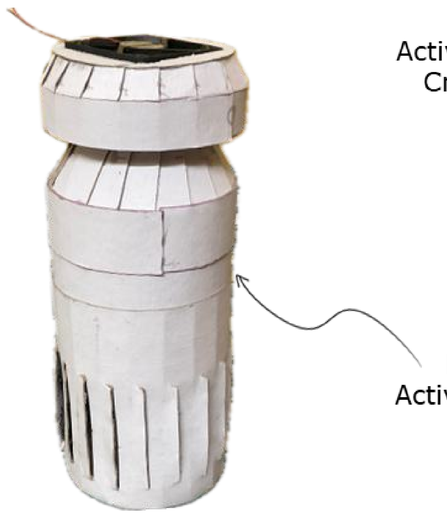

Removable
Activated Carbon
Filter

12. Mockups

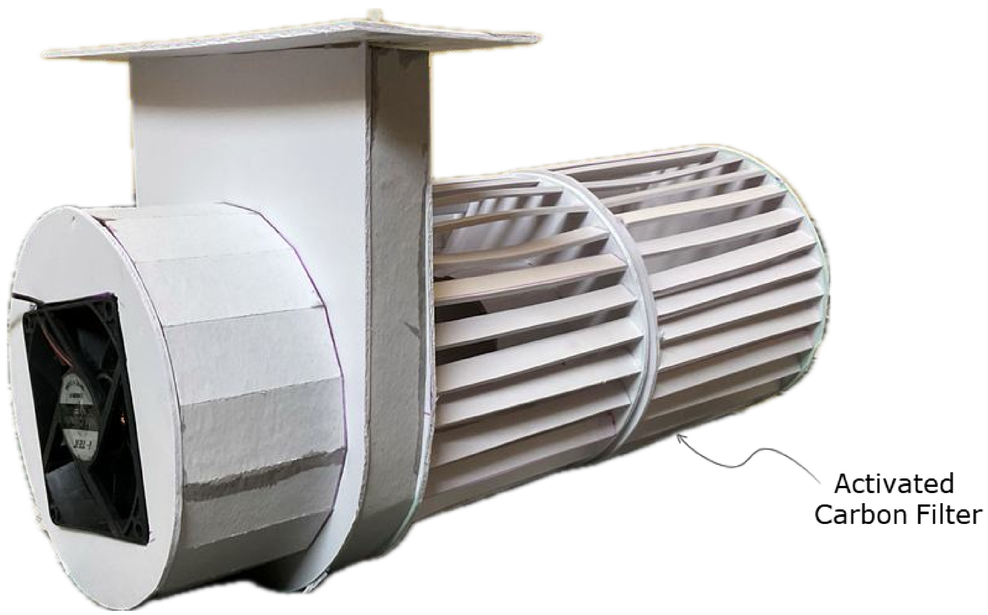

Activated
Carbon Filter


Activated Carbon
Cross Section


Modular Unit

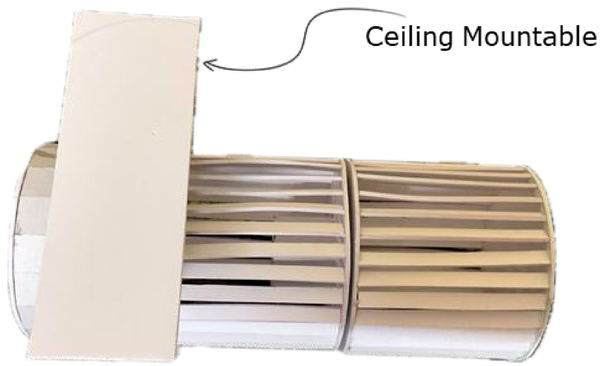

Refillable
Activated Carbon
Filter

12. Mockups


Activated
Carbon Filter

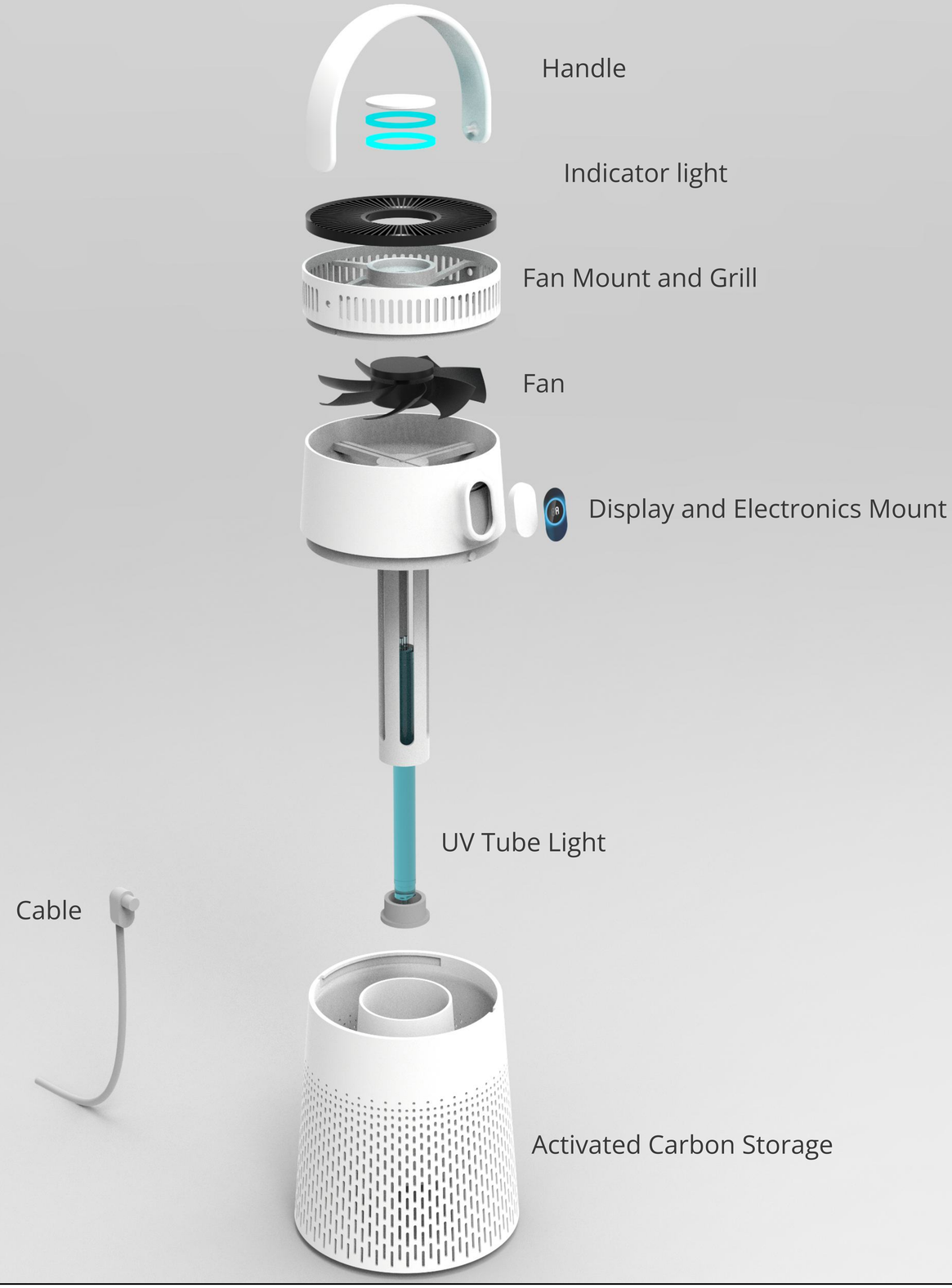

Suction Fan

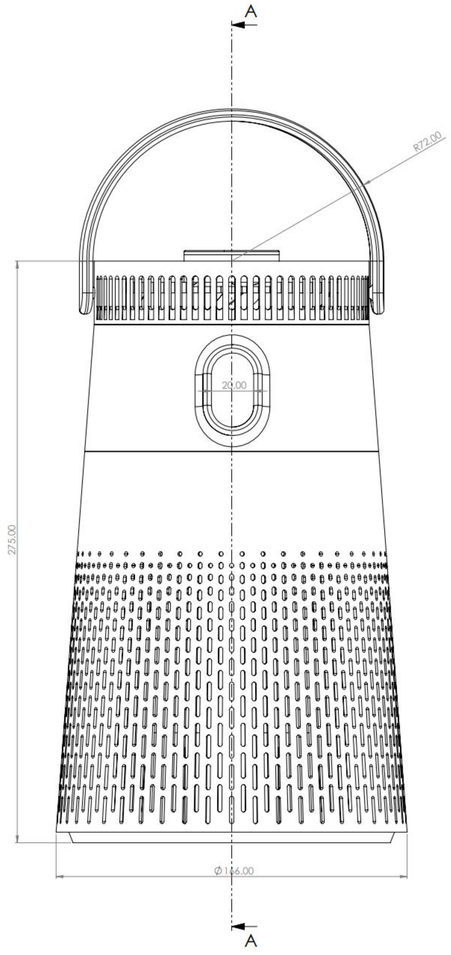

Modular
Filters

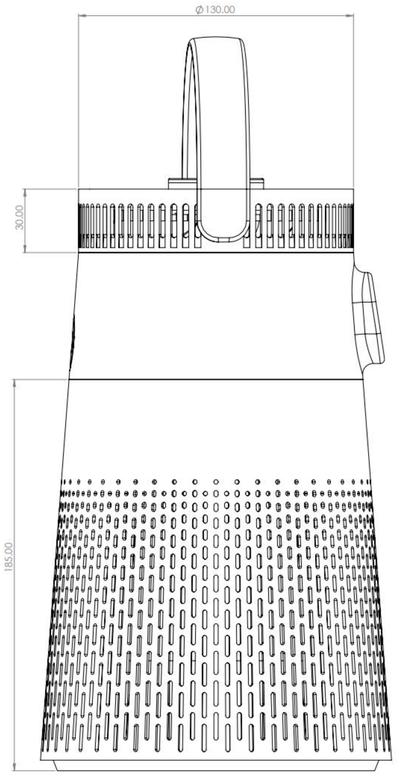

Ceiling Mountable

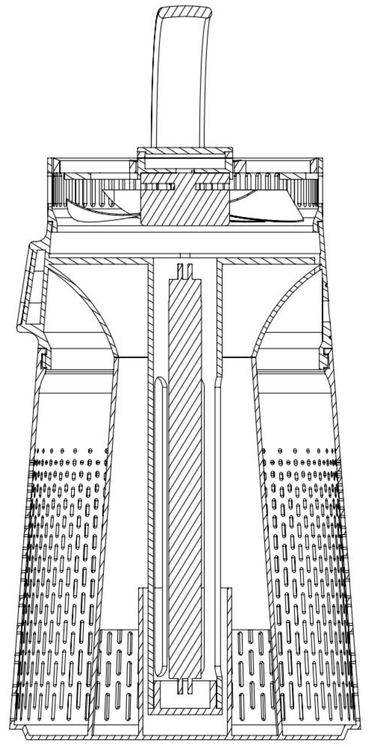
13. Form Ideation

14. Final Model

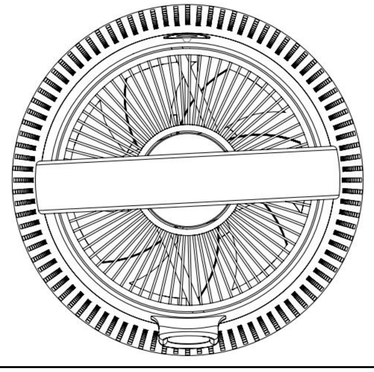

Handle
Indicator light
Fan Mount and Grill
Fan
Display and Electronics Mount
UV Tube Light
Cable
Activated Carbon Storage







SECTION A-A
SCALE 1 : 1



16. Prototype