GNG5140F

Design Project User and Product Manual

Sustainable Food Storage (A)

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Acronym	Definition
CUT	Customizable ubiquitous technology
UPM	User and Product Manual
BOM	Bill of materials

Table 1. Acronyms

1. Introduction

Regenerative agriculture and sustainable food storage systems play integral roles in addressing global challenges related to food security and environmental sustainability. This academic document focuses on the mission of a sustainable food storage system, emphasizing its commitment to fostering direct action in regenerative agriculture, preservation, and the essential infrastructure supporting local food systems. The overarching goal is to facilitate year-round access to a local, regenerative diet for all community members. Within this context, the document addresses critical challenges faced by the current root cellar system, particularly in the winter season. The first challenge involves excessive electricity consumption, especially on overcast days requiring heaters for temperature maintenance. To mitigate this, our design team proposes an innovative solution: the integration of an air conditioning unit with CoolBot technology to reduce constant ventilation and heating, thereby optimizing power consumption. The second challenge pertains to the absence of an automated humidity control system within the root cellar, posing risks to the quality and shelf life of stored produce. Our approved proposal recommends the installation of an automated humidity control system, capable of continuous monitoring and adjustment to ensure consistent and ideal storage conditions. This academic exploration seeks to contribute valuable insights and solutions to the intersection of regenerative agriculture and sustainable food storage, advancing our collective understanding of innovative approaches to address pressing challenges in the agricultural sector.

The goal of these improvements is to reduce operational costs, enhance energy efficiency, and maintain optimal storage conditions for the produce stored in the root cellar throughout the year. By addressing both heating efficiency and humidity control, this initiative aims to significantly improve the root cellar's performance and resource utilization.

This User and Product Manual (UPM) serves as a comprehensive guide, facilitating the understanding and utilization of the innovative Customizable Ubiquitous Technology (CUT), solution designed to revolutionize energy-efficient root cellars. Within this document, we aim to elucidate the essential context, assumptions, and organizational structure that form the foundation of our work.

Context and Assumptions: Our endeavor is rooted in addressing the challenges faced by our client's existing solar-dependent root cellar, primarily operational during winter. Assumptions include a focus on energy consumption efficiency, low-cost alternatives, and an automated control system. The manual assumes a diverse audience, encompassing both end-users and technical stakeholders involved in the prototype's development and implementation.

1. Climate Focus: Low solar energy availability during winter, necessitating alternative energy sources for sustained operation.

2. CoolBot Integration: The integration of CoolBot technology with an air conditioner is assumed to provide an effective means of temperature control, offering a more energy-efficient alternative to constant heating.

3. CoolBot Cost-Benefit Analysis: The assumption is that the initial investment in CoolBot technology will be justified by the long-term cost savings resulting from reduced energy consumption. A detailed cost-benefit analysis is assumed to support the decision to adopt CoolBot for temperature regulation.

4. Humidity Control System: The incorporation of a humidity control system is assumed to be vital for preserving the quality of stored produce. Design assumes the successful implementation of physical and analytical prototypes to regulate humidity levels within the root cellar, mitigating potential issues associated with excess moisture.

5. Heat Pump Efficiency: The assumption is that the integration of a small, efficient heat pump will contribute significantly to temperature control during winter, especially when the external temperature drops below 5 or 10 degrees. The design considers these heat pumps as a viable alternative to constant heating.

6. SCADA System Reliability: The SCADA system is assumed to be a reliable means of remote monitoring and control. While occasional offline issues are acknowledged, the assumption is that enhancements to the system will address and minimize downtime, ensuring continuous, automated operation.

7. Biogas Plant Viability: The feasibility of a biogas plant is assumed to be contingent upon successful anaerobic digestion despite winter conditions. The assumption acknowledges potential challenges such as fungi and cold temperatures, and it is emphasized that this aspect may be considered an alternative rather than a primary solution.

8. Budgetary Considerations: Assumptions are made regarding the budgetary constraints of the project. The proposed design solutions aim to be cost-effective, with an assumed implementation probability of 80% if the overall cost remains within the range of $2,000-$3,000. Beyond this range, additional funding sources may be sought.

9. Automated Ventilation Optimization: The assumption is that the existing automated ventilation system can be optimized to overcome intermittent issues. This involves upgrading motorized dampers to enhance reliability, ensuring consistent air circulation for temperature and humidity control.

10. Low-Power Sensors and Actuators: It is assumed that the integration of low-power sensors and actuators will facilitate a more energy-efficient automation system. These components are expected to enhance the responsiveness of the system while minimizing overall energy consumption during routine operation.

11. Localized Energy Generation: It is assumed that exploring localized energy generation options, such as micro-wind turbines or small-scale hydroelectric systems, can supplement solar power during periods of insufficient sunlight. The design envisions a diversified energy portfolio to maximize efficiency.

12. Remote Monitoring Stability: The assumption is that stability issues with remote monitoring, as reported by the SCADA system, can be addressed through software and hardware enhancements. A more robust monitoring infrastructure is assumed to ensure uninterrupted remote access and control.

13. Low-Cost Material Selection: It is assumed that the use of cost-effective insulation materials and construction methods, such as recycled or locally sourced materials, can

contribute to a low-cost yet efficient thermal envelope. The design prioritizes affordability without compromising effectiveness.

14. DIY Implementation Feasibility: The assumption is that the proposed design solutions are accessible for a do-it-yourself (DIY) implementation by local farmers. The design prioritizes simplicity and ease of assembly, ensuring that farmers can actively contribute to the construction and modification process.

15. Integration of Machine Learning Algorithms: It is assumed that the integration of machine learning algorithms for predictive control can further optimize energy consumption. These algorithms are expected to learn from historical data and adjust the system parameters dynamically for increased efficiency.

16. Flexible Design for Scalability: It is assumed that the design solutions presented allow for scalability, accommodating future expansions or modifications. This flexibility is envisioned to support the evolving needs of the root cellar system and local food ecosystem.

1.1. Document Structure Overview

The document unfolds systematically, commencing with an insightful introduction, followed by a detailed exploration of the existing system, its limitations, and the identified areas for improvement. The subsequent sections delve into proposed design solutions, categorized under energy efficiency, heating, humidity control, system upgrades, and cost-effective considerations. Each section provides a thorough analysis, integrating physical and analytical prototypes, simulations ensuring a holistic understanding of the proposed enhancements.

1.2. Purpose and Scope

This document serves as a comprehensive guide for various stakeholders involved in the transformative modifications to the existing solar-operated root cellar system in Canada. It aims to equip local farmers, potential investors, and end-users with a thorough understanding of Customizable Ubiquitous Technology (CUT). The document not only identifies challenges within

the current system but also proposes viable solutions, ranging from physical prototypes to analytical algorithms, to enhance efficiency and sustainability. Specifically tailored to the unique challenges of Canadian agriculture ecosystem during harsh winters, the proposed modifications prioritize cost-effectiveness, energy efficiency, and automation. By fostering collaboration among farmers, university students, and local communities, the document promotes inclusive stakeholder participation, regenerative agriculture practices, and year-round access to locally sourced, sustainable food. Emphasizing affordability without compromising sustainability, the proposed modifications are designed to be adaptable to diverse Canadian climates and regional agricultural practices, reflecting a commitment to building a resilient, self-sufficient, and regenerative local food ecosystem.

1.3. Intended Audience

This manual caters to a diverse audience, including university students engaged in the design project, technical experts involved in system implementation, potential investors considering financial support, farmers, and end-users responsible for day-to-day operations. By tailoring information to different audience segments, this document aims to foster collaboration and knowledge-sharing among stakeholders.

1.4. Security and Privacy Considerations

In adherence to ethical standards, this document emphasizes the importance of security and privacy in the use of the User and Product Manual. It underscores the need for responsible information handling and secure protocols, ensuring the integrity and confidentiality of data associated with the Customizable Ubiquitous Technology (CUT).

As we embark on this journey of sustainable innovation, this User and Product Manual stands as a guiding beacon, steering stakeholders toward a future where regenerative agriculture and local food ecosystems thrive year-round.

2. Overview

2.1. The Problem & Importance:

Humidity control is crucial for sustainable food storage, preventing issues like mold and ensuring optimal freshness. Traditional methods often fall short, leading to food wastage and compromised quality.

2.2. Fundamental User Needs:

Users need a reliable, cost-effective, and user-friendly humidity control system that integrates seamlessly with existing applications. The system should maintain optimal humidity levels, be energy-efficient, and contribute to economic, social, and environmental sustainability.

2.3. Product Differentiation:

Our prototype stands out through its accurate humidity control, cost efficiency, and user-friendly interface. It integrates advanced sensors, smart algorithms, and sustainable design, setting it apart from conventional solutions.

2.4. Key Features
- Accurate humidity control
- Cost-effective design
- User-friendly interface
- Seamless integration with existing applications
- Energy-efficient operations
- Socially and environmentally sustainable

2.5. System Architecture

The system employs a modular architecture with a Raspberry Pi microcontroller, DHT22 sensors, and actuators. User interaction is facilitated through a graphical user interface (GUI) accessible

via web-based platforms. The system operates in various environments, adapting to different production scales.

2.6. Conventions

1. Instructions Format:
   - All instructions and actions will be presented in a step-by-step format for easy comprehension.

2. Action Indicators:
   - Whenever your input or action is required, the text will begin with the word 'Action' to clearly prompt you.

   Example:

Action: Connect the humidity sensor to the designated port on the Raspberry Pi.

3. Warnings and Important Notices:
   - Critical information and warnings will be highlighted to ensure your attention is drawn to important details.

   Example:

Warning: Disconnect the power supply before attempting any hardware adjustments.

4. Command Line Syntax:
   - If there are specific commands to be entered, they will be presented in a distinct format.

   Example:

Open the terminal and enter the following command: $ sudo nano /etc/humidity-control/config

5. Visual Cues:

  - Visual elements such as diagrams, charts, and icons will be utilized to enhance understanding.

Example:

> Refer to Figure 1 for the system architecture.

6. Interactive Elements:

  - Interactive steps or processes will be indicated, guiding you through the manual seamlessly.

Example:

> Click on the 'Settings' tab and select 'Humidity Control' to access configuration options.

7. Notes for Emphasis:

  - Important notes or additional information will be presented with the label 'Note' for emphasis.

Example:

> Note: Regular software updates are crucial for optimal system performance.

8. Reference Points:

  - References to sections, figures, or external resources will be clearly marked for easy cross-referencing.

Example:

> Refer to Section 4.2 for information on scaling functionality.

By adopting these conventions, we aim to make your experience with the user manual as intuitive and straightforward as possible. If you have any questions or need further clarification, feel free to reach out. Happy exploring!

2.7. Cautions & Warnings

1. Electrical Safety:

  - Caution: The system involves electrical components. Do not attempt to disassemble or modify any electrical parts unless you are a qualified technician.

  - Warning: Unplug the system from the power source before performing any maintenance or cleaning.

2. Integration with Other Devices:

  - Caution: When integrating the system with other devices, follow the provided guidelines and ensure compatibility to avoid malfunctions.

  - Warning: Improper integration may lead to system errors. Obtain guidance from our support team if uncertain.

3. Real-World Testing:

  - Caution: While simulations provide insights, real-world testing is essential. Do not solely rely on simulated results; conduct practical tests for accurate performance evaluation.

  - Warning: Inadequate real-world testing may result in unexpected behavior. Use caution during the initial implementation phase.

4. User Interface:

  - Caution: Familiarize yourself with the user interface before operation. Incorrect settings may affect the system's performance.

  - Warning: Avoid making drastic changes without understanding the consequences. Refer to the user manual for guidance.

5. Maintenance and Repairs:

- Caution: Regular maintenance is crucial for optimal performance. Follow the provided maintenance schedule and procedures.

- Warning: Unauthorized repairs may void the warranty. Contact our authorized service centers for any repairs or adjustments.

6. Environmental Considerations:

- Caution: Place the system in well-ventilated areas and away from direct sunlight to prevent overheating.

- Warning: Exposure to extreme environmental conditions may impact the system's functionality. Follow the specified operating conditions.

7. User Training:

- Caution: Users should undergo training to understand the system's features and functionalities.

- Warning: Inadequate training may lead to misuse. Provide comprehensive training sessions for all users.

8. User Feedback:

- Caution: Share constructive feedback for continuous improvement. Report any abnormalities promptly.

- Warning: Ignoring feedback may hinder system enhancements. Your input is valuable for ongoing improvements.

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3. Getting started

This user manual will guide you through the steps to set up and use the humidity control system for optimal food storage. Whether you're a farmer, food enthusiast, or simply looking to enhance your food storage capabilities, this system is designed with simplicity and effectiveness in mind.

Step 1: Unboxing

Upon receiving your package, ensure that all components are present. Refer to the provided checklist to confirm the contents.

Step 2: Hardware Assembly

Follow these steps to assemble the hardware components:

1. Connect the Humidity Sensor (DHT22) to the Raspberry Pi.

2. Attach the Raspberry Pi to the main control unit.

3. Connect the main control unit to the humidifier/dehumidifier.

 Step 3: Software Installation

1. Insert the provided SD card with the system software into the Raspberry Pi.

2. Power up the system by connecting it to a reliable power source.

Step 4: Initial Configuration

1. Access the user-friendly interface on your computer or mobile device.

2. Follow the on-screen instructions to configure system preferences.

Step 5: Real-world Testing

1. Perform real-world testing by introducing the system to your food storage environment.

Step 6: Monitoring and Control

1. Utilize the remote monitoring feature to observe and control humidity levels.

3.1. Immediate Functionality

If you need to deploy the prototype immediately, ensure the following:

1. Power Connection: Confirm that the system is connected to a stable power source.

2. Initial Setup: Check that the hardware components are correctly assembled and the software has been initialized.

3. User Interface: Access the user interface to monitor and control the system.

For any further assistance, refer to the troubleshooting section or contact our support team.

3.2. Set-up Considerations

Setting up our humidity control system is a straightforward process, designed with simplicity in mind. As you embark on the journey to ensure optimal humidity levels for your storage space, here's a step-by-step guide that even non-technical users can follow effortlessly.

Equipment and Components:

1. Humidity Control Unit: Our central unit, equipped with intuitive controls and indicators, serves as the brain of the system. It's where you can easily configure and monitor humidity settings.

2. Humidity Sensors: These devices ensure accurate readings of the current humidity levels in your storage area. They are strategically placed for comprehensive coverage.

3. Actuators (Dehumidifier/Humidifier): These devices respond to the data from the sensors, maintaining the desired humidity levels by adjusting moisture levels.

4. User Interface: Accessible via your computer or smartphone, the user interface provides a friendly platform to interact with the system. It's where you can set preferences, monitor real-time data, and receive system notifications.

Communication:

The components communicate seamlessly through a secure wireless connection. No intricate wiring or technical expertise is needed. Once the devices are powered on, they establish a reliable network for efficient data exchange.

Configuration:

1. Initial Setup: Begin by placing the humidity control unit in a central location within your storage area. Ensure the humidity sensors are evenly distributed.

2. Power On: Connect the devices to a power source. The humidity control unit, sensors, and actuators are designed to operate efficiently with minimal power consumption.

3. Connect to User Interface: Use your computer or smartphone to connect to the user interface. Simply follow the user-friendly on-screen instructions for initial configuration.

4. Set Desired Humidity Levels: Through the user interface, specify your preferred humidity levels. The system is designed to maintain these levels automatically.

Type of Input and Output Devices:

- Input Devices: Your computer or smartphone serves as the primary input device. Through the user interface, you input your desired humidity settings and receive real-time data from the sensors.
- Output Devices: Indicators on the humidity control unit and notifications on the user interface are the main output mechanisms. They provide real-time feedback on the system's operation and any necessary alerts.

3.3. User Access Considerations

1. General Users:

  - These are individuals responsible for day-to-day operation and monitoring of the humidity control system.

  - No significant restrictions on accessibility, as they will primarily interact with the user-friendly interface and receive real-time information on humidity levels.

  - Ensure users are familiar with basic operation through provided documentation or training resources.

2. Administrators:

  - Administrators have elevated privileges for system configuration and management.

  - Access to advanced settings, such as configuring control algorithms and user management.

  - Limited to individuals with the necessary technical knowledge and authorization.

3. Maintenance Personnel:

   - Individuals tasked with maintaining and repairing the system.

   - Access to internal components may be required, so guidelines for safe access and proper procedures should be followed.

   - Technical expertise and adherence to safety protocols are essential.

4. Developers/Integrators:

   - Those involved in system integration, especially with the existing application.

   - Access to APIs and compatibility documentation.

   - Limited to individuals with programming skills and knowledge of the existing application architecture.

5. End Users with Remote Access:

   - Users who access the system remotely through cloud-based solutions.

   - Accessibility contingent on secure authentication and authorization procedures.

   - Remote control and monitoring accessible through user-friendly interfaces.

6. Community Representatives:

   - Individuals representing the local community where the system is implemented.

   - Limited access for monitoring and receiving system performance updates.

   - Engagement in community decisions related to the humidity control system.

7. Training Participants:

   - Individuals participating in training sessions for system operation and maintenance.

   - Access to training materials and resources.

   - Limited to the duration of training sessions.

8. Environmental Impact Assessors:

   - Professionals assessing the system's environmental impact.

   - Access to data analysis and performance monitoring features.

   - Limited to authorized personnel involved in environmental assessments.

9. External Auditors/Certification Agencies:

 - Entities responsible for certifying the system's adherence to environmental standards.

 - Access to relevant documentation, data, and system configurations for verification.

 - Limited to authorized external auditing personnel.

10. Regulatory Authorities:

 - Government bodies or agencies overseeing compliance with regulations.

 - Access to relevant data for compliance checks and verification.

 - Limited to authorized personnel for regulatory purposes.

3.4. Accessing the System

Welcome to our innovative humidity control system! Accessing and turning on the system is a breeze. Follow these simple steps:

1. Power Up the System:

 - Ensure that the system is properly connected to a power source.

 - Turn on the power switch located on the main control panel.

2. User ID and Log-in:

 - If you are a new user, contact our support team to obtain your unique User ID.

 - Once you have your User ID, visit our online portal at [insert portal link].

 - Enter your User ID along with the initial password provided by our team.

3. Changing Your Password:

 - Upon your first log-in, you'll be prompted to change your password for security reasons.

 - Follow the on-screen instructions to set a new, secure password of your choice.

4. Resetting Your Password:

 - In case you forget your password, click on the "Forgot Password" link on the login page.

- Provide the necessary information, and a password reset link will be sent to your registered email.

- Follow the link to reset your password and regain access to the system.

Remember, our system is designed with your convenience in mind. If you encounter any issues or have questions, don't hesitate to reach out to our support team at [insert support contact].

3.5. System Organization & Navigation

The home page serves as the central hub of our humidity control system, providing users with an intuitive and informative interface. Here's an overview of the main components and navigation paths:

1. Humidity Overview:

   - Navigate to this section to get an instant snapshot of the current humidity levels in the controlled environment.

   - Graphical representation and numerical values are displayed for quick reference.

2. System Status:

   - Check the overall status of the humidity control system.

   - Indicators for active components, such as humidifiers or dehumidifiers, are prominently displayed.

3. Settings:

   - Access the settings menu to customize the system according to specific requirements.

   - Subsections include:

     - Humidity Setpoint: Adjust the desired humidity level.

     - Mode Selection: Choose between different operation modes (e.g., normal, eco-friendly).

     - Device Integration: Link and configure additional components like humidifiers or sensors.

4. Real-time Monitoring:

   - Dive into real-time data visualization, including historical trends and fluctuations.

   - Analyze system performance and identify patterns for informed decision-making.

3.6. Navigation Paths to Main Functions

1. Navigate to Humidity Overview:

  - From the home page, select the "Humidity Overview" section.

  - Graphs and numerical data provide detailed insights into current humidity conditions.

2. Check System Status:

  - On the home page, locate the "System Status" indicator.

  - A quick glance reveals the operational status of key components.

3. Adjust System Settings:

  - Access the "Settings" menu from the home page.

  - Subsections provide options for modifying humidity setpoints, selecting modes, and integrating additional devices.

4. Explore Real-time Monitoring:

  - From the home page, navigate to the "Real-time Monitoring" section.

  - Visualize and analyze historical data for comprehensive system performance evaluation.

By organizing the system in this manner, users can easily navigate through key functions, ensuring a seamless and user-friendly experience.

3.7. Exiting the System

To properly exit or turn off the system, follow these steps:

1. Access the Main Menu:

  - If you are currently in a specific mode or screen, navigate back to the main menu of the system.

2. Select "Power Options":

  - Once in the main menu, locate and select the "Power Options" or a similar section that manages the system's power settings.

3. Choose "Shutdown" or "Exit":

   - Within the "Power Options," choose the appropriate action, such as "Shutdown" or "Exit," to initiate the process of turning off the system.

4. Confirm the Shutdown:

   - The system may prompt you to confirm the shutdown action to avoid accidental power-offs. Confirm your intention to proceed.

5. Wait for Shutdown Process:

   - Allow the system a moment to complete the shutdown process. You may see on-screen notifications indicating the progress.

6. Power Off the Hardware:

   - Once the system indicates that it is safe to do so, power off any associated hardware components, such as the humidity control device and any connected sensors.

7. Disconnect Power Source (if applicable):

   - If the system is powered by an external source, such as a power outlet, disconnect the power source to ensure a complete shutdown.

By following these steps, you ensure a proper and safe exit from the system, preserving its components and maintaining an efficient operation.

4. Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the Humidity Control System.

4.1. Humidity Control System Functions

The Humidity Control System provides users with advanced features to automate and maintain optimal humidity levels in environments like cold root cellars. This section outlines key functions and features, guiding users through the calibration of the humidity sensor and the integration with the humidifier and dehumidifier. Rich graphical representations, including screenshots, facilitate a user-friendly experience.

4.2. Humidity Sensor Calibration

The Humidity Sensor Calibration function allows for precise calibration using a 21-point calibration process involving Sodium Chloride and a Silicon Moisture Absorber.

- **Access:** Power on the system and ensure the proper connection of the DHT22 sensor.
- **Expected Input:** Prepare a controlled humidity environment using a combination of Sodium Chloride and Silicon Moisture Absorber. Insert the DHT22 sensor into this environment.
- **System-Produced Output:** Real-time humidity data and calibration status.
- **Expected Results:** Obtain accurate and calibrated humidity readings.

Figure 4.1.1. - Humidity Sensor Calibration

Alternative Text: A screenshot showing the system interface with the 21-point calibration process. The DHT22 sensor is highlighted, displaying real-time humidity readings during calibration.

Special Instructions:

- Set up a controlled environment with known humidity using Sodium Chloride and Silicon Moisture Absorber.
- Follow a 21-point calibration process, adjusting the sensor readings at each point.

Caveats and Exceptions:

- If "Failed to read from DHT sensor!" message appears, check sensor connection or replace if necessary.
- Ensure the calibration environment remains stable throughout the process.

4.3. Integration with Humidifier/Dehumidifier

This function involves the system's ability to interact with the humidifier and dehumidifier based on the analyzed data from the calibrated DHT22 sensor.

- **Access:** After calibration, the system automatically switches to Integration mode.
- **Expected Input:** Calibrated humidity data and user-set thresholds.
- **System-Produced Output:** Activation status of the humidifier and dehumidifier, user notifications.
- **Expected Results:** Effective maintenance of desired humidity levels.

5. Troubleshooting & Support

5.1. Error Messages or Behaviors

1. "Failed to Read from DHT Sensor!"

Cause:

- Poor connection or malfunction of the DHT22 sensor.

Corrective Actions:

- Check Sensor Connection:

  Ensure the DHT22 sensor is properly connected to the Raspberry Pi GPIO pins.

  Verify the wiring and connections for any loose or damaged components.

- Replace Sensor:

  If the issue persists, replace the DHT22 sensor with a new one.

2. Humidity Control System Not Activating Humidifier/Dehumidifier

Cause:

- Relay module issues or incorrect threshold settings.

Corrective Actions:

- Inspect Relay Connections:

  Check the wiring and connections of the relay modules for loose or damaged components.

  Replace relay modules if necessary.

- Adjust Threshold Settings:

  Access the settings menu to ensure the user-set thresholds align with the desired humidity levels.

  Modify thresholds as needed for effective system operation.

5.2. Special Considerations

5.2.1 Operating in Extreme Temperatures

Consideration:

The system's performance might be affected in extremely low temperatures typical of root cellars.

Actions:

Insulate Components:

- Add insulation around the Raspberry Pi and relay modules to protect them from harsh temperatures.

Regular Inspections:

- Conduct regular inspections of the cellar environment and system components, addressing any issues promptly.

5.3. Maintenance

Inspect Components:

- Regularly check the physical components, including sensors and relay modules, for signs of wear or damage.

Verify Battery Status:

- Ensure the battery is functional and replace it if needed.

5.4. Support

For emergency assistance, contact our support team:

Support Desk:
- Name: Customer Support Team
- Email: support@cut.com

Reporting Problems

Instructions:

To report identified problems or seek further assistance:

Email Support:

- Send an email to the support team at support@cut.com with a detailed description of the issue.

Include Information:

- Provide system details, error messages, and any relevant information for a quicker resolution.

Security Incident Handling

Urgent Contact:

- If you suspect a security breach, contact manager immediately.
- Email: [security@[CUT].com](mailto:security@[CUT].com)

6. Product Documentation

A DHT22 Humidity Sensor is integrated with the Raspberry Pi Pico in this Raspberry Pi-based humidity control system to track and manage humidity levels. The Raspberry Pi Pico W GPIO pins are connected to the DHT22 sensor, which enables precise measurement of the surrounding humidity. Two Relay modules are used, one for the humidifier and one for the dehumidifier, each with a distinct function, to make humidity control easier. The central processing unit, the Raspberry Pi Pico, is in charge of organizing the sensor data and regulating the relays to produce the appropriate humidity levels. The DHT22 sensor is contacted by the system via a Arduino C++ script, which reads the humidity data on a regular basis. The script's preset thresholds are used to regulate the relay modules. The results are then sent to the HumiPi application we created, which displays the information to the client on their phone, providing a smooth user interface. For example, the humidifier's relay is triggered if the humidity reading drops below a predetermined threshold, and the dehumidifier's relay is triggered if the detected humidity exceeds a predetermined level. The circuit layout can be made organised using the Solderless Perfboard and Breadboard Jumper Wires to ease the assembling process. The power supply to the micro-controller is given up the usb socket present in the root cellar.

The main motive of the product is to provide a solution to the clients needs in the most economical way as possible. Raspberry Pico was chosen as it performs exponential well for the price point and the needs for the prototype. In addition, the DHT22 sensor was used instead of DHT11 because of the following points;

- Ultra-small size
- Extremely low power consumption, and with a signal transmission distance of more than 20 meters thus it's able to withstand the most demanding applications.
- Humidity sensor of 0 to 99.9 %RH with ±2% accuracy while the temperature sensor ranges from -40 to 80°C with ±0.5°C accuracy.

6.1. Bill of materials

No.	Item Name	Description	Qts	Unit Cost (CAD)	Extended Cost (CAD)
1	DHT22	Humidity and Temperature sensor	1	10.50	18.54
2	Raspb Pi PICO	Embedded System	1	12.95	20.73
3	Perfboard	1.574 X 2.362 in (size)	1	8.80	9.94
4	Breadboard Jumper Wires	10 cm wires	60	11	19
5	Relay Board	3-volt relay board	2	23.99	29.37
6	Enclosure box	Rasp unit holder	1	8.5	12.5
7	Enclosure Plate	Rasp unit closure	1	3.2	9.5
Total product cost (without taxes or shipping) (CAD)					$83.43
Total product cost (inc. taxes and shipping) (CAD)					$93.44

Table 2. Bill of materials used for the prototype

6.2. Equipment list

To build the CUT humidity control system we need the following equipment.

1. **Raspberry Pi Pico**: The Raspberry Pi Pico is a microcontroller board that will serve as the brain of our project. It's a silicon-based microcontroller board used to program them to receive input from and output to the input/output pins sends text to screens, activate lights, produce noises, and do a lot more with these programmable connections.

Figure 1. Raspberry Pi 3 board

2. **DHT22 Sensor**: The DHT22 is a humidity and temperature sensor that we will use to measure the humidity levels. It measures the surrounding air with a capacitive humidity sensor and a thermistor and outputs a digital signal on the data pin (no analog input pins are required). The sensor is calibrated and does not require any additional components, allowing you to accurately measure relative humidity and temperature. It is simple to operate, but data collection requires precise timing. It can only provide updated info every 2 seconds.
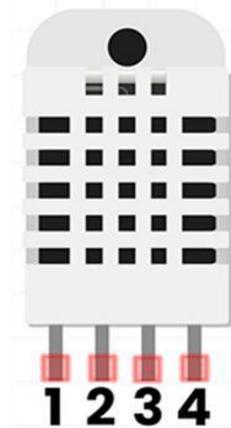
Figure 2. DHT22 Sensor (Humidity sensor)

3. **Relay Module**: A relay module is used to control the humidifier or dehumidifier. It acts as a switch that can be controlled by the Raspberry Pi Pico. A power relay module is an electromagnetically operated electrical switch. A separate low-power signal from a microcontroller activates the electromagnet. The electromagnet pulls to open or close an electrical circuit when activated. A simple

relay is made up of a wire coil wrapped around a soft iron core, or solenoid, an iron yoke that provides a low reluctance path for magnetic flux, a movable iron armature, and one or more contact sets. The movable armature is hinged to the yoke and connected to one or more groups of moving contacts. When the relay is de-energized, the armature, which is held in place by a spring, leaves a gap in the magnetic circuit.
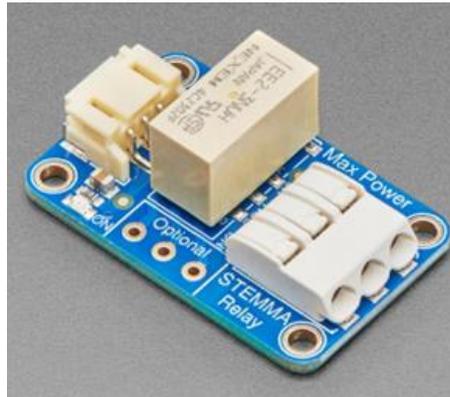

Figure 3. Adafruit STEMMA Non-Latching Mini Relay

4. **Jumper Wires**: These wires will be used to connect the Raspberry Pi Pico to the DHT22 sensor and the relay module. Typically used to interconnect the components of a breadboard, without soldering. Individual jump wires are connected by inserting their "end connectors" into slots provided on a breadboard, a circuit board's header connector, or a piece of test equipment.

Figure 4. Breadboard Jumper Wires

5. **Enclosure box**: A 3D-printed box for a Raspberry Pi Pico board, used as the enclosure with precise openings for ports, buttons, and connectors. Ensure a snug fit and incorporate a secure mechanism to hold the board in place. Choose a durable yet lightweight material like PLA or ABS for the 3D printing

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process, taking structural integrity into consideration. Include ventilation slots to prevent overheating if necessary and design the box with mounting holes for flexibility in installation. Before the final print, prototype the design to identify and address any fit or functionality issues.
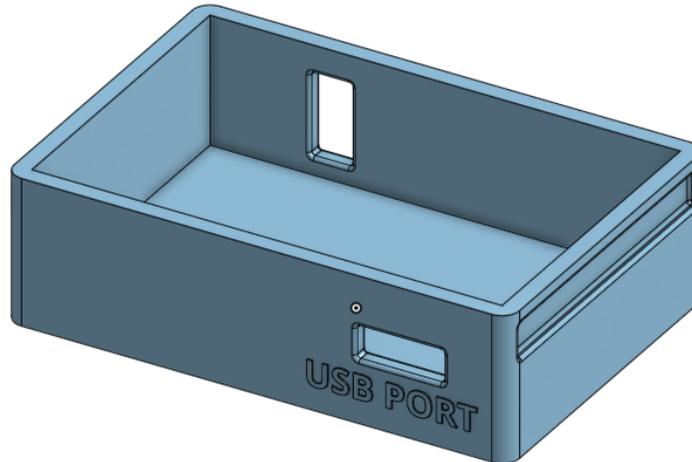

Figure 5. Top view of the enclosure box

6. **Enclosure cover plate**: A 3D-printed snap-fit cover plate for a Raspberry Pi Pico enclosure, with interlocking features like tabs or hooks to ensure a secure fit without additional fasteners. Choose a durable 3D printing material such as PLA or ABS, considering thickness and flexibility for strength and ease of installation adding textures or logos.
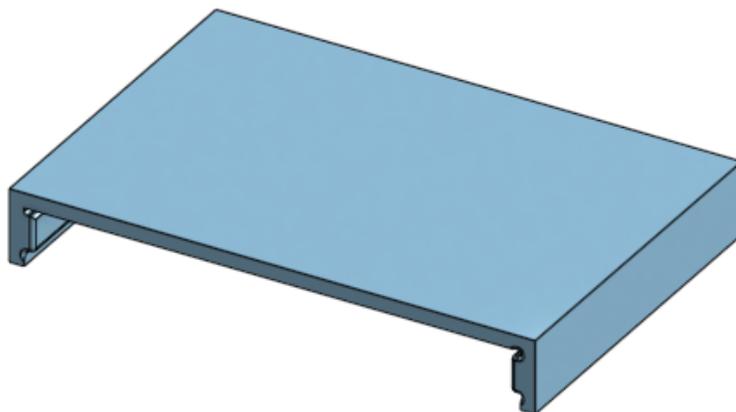
Figure 6. Top view of the cover plate

6.3. Instructions

Here's a simple overview of how you might connect these components:

Connect the DHT22 sensor to the Raspberry Pi Pico using jumper wires. Make sure to connect the power (VCC), ground (GND), and data (OUT) pins. Connect the relay module to the Raspberry Pi Pico. The relay module will have input pins for control (connected to the Pico), as well as output pins that can be connected to the device you want to control (humidifier or dehumidifier). Follow electrical circuit diagram provided below.

Connections:

DHT22 Sensor **Vcc+** to Raspberry Pi PICO **5V**

DHT22 Sensor **GND** to Raspberry Pi PICO **GND**

DHT22 Sensor **Signal** to Raspberry Pi PICO **PIN 14 (GPIO PIN 4)**

Relay module's (1&2) **Vcc+** to Raspberry Pi PICO **5V**

Relay module's (1- 2) **GND** to Raspberry Pi PICO **GND**

Relay module 1 signal to Raspberry Pi PICO **PIN 22 (GPIO PIN 22)**

Relay module 2 signal to Raspberry Pi PICO **PIN 16 (GPIO PIN 16)**
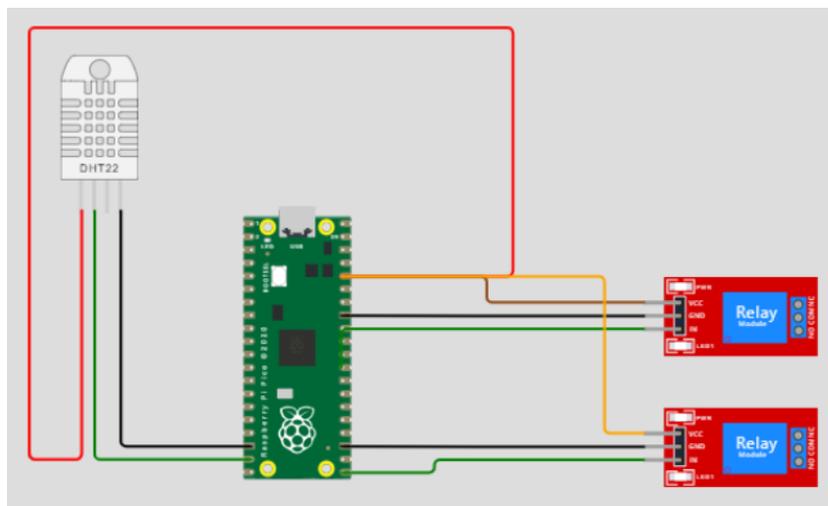
Figure 7. Electrical wiring- circuit diagram

Write a C++ script for the Raspberry Pi Pico to read data from the DHT22 sensor and control the relay module based on humidity levels. The script includes conditional statements to turn the relay on or off depending on the humidity threshold.

The program is written in Arduino C++ programming language and was tested on Wokwi online simulator. We downloaded and used important Adafruit libraries required for the simulation. The program used is given below in the appendix.

Here, the flow chart describes the steps of the program used for our prototype.
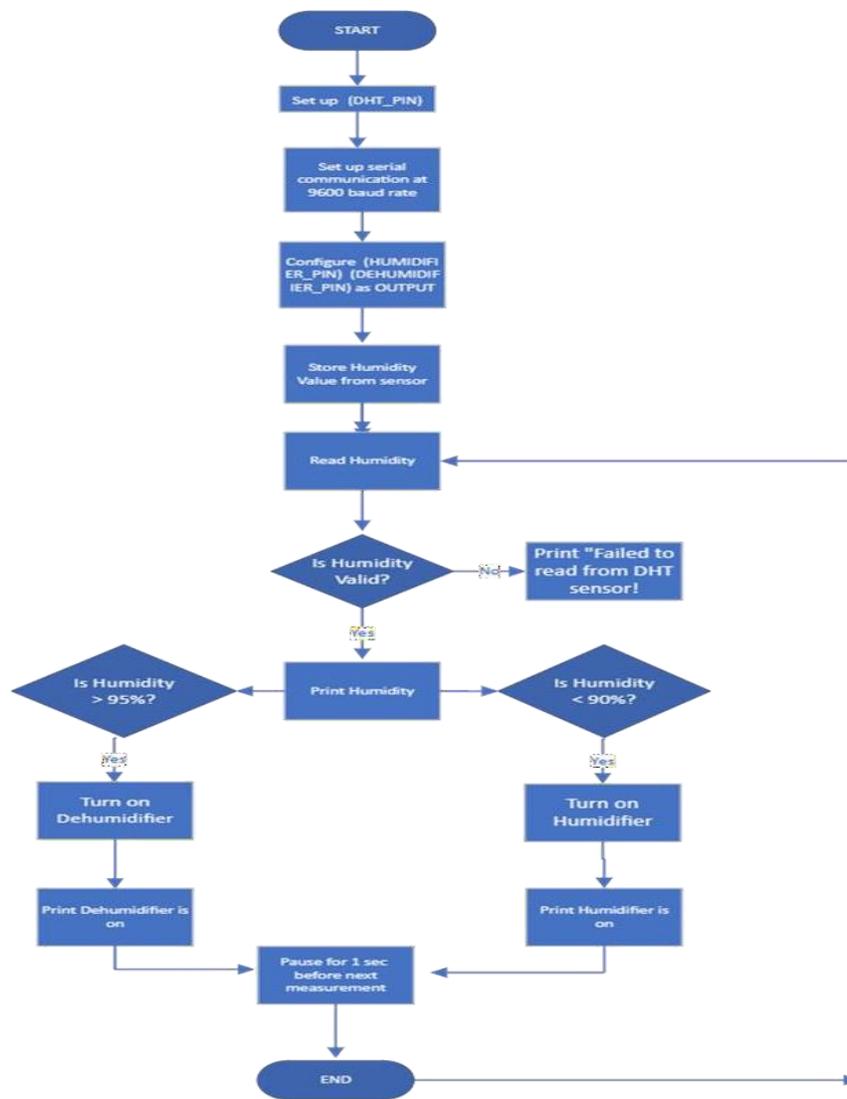
Figure 8. Software flow-chart

6.4. Testing & Validation

We created and tested the humidity control system on Wokwi, an online platform to simulate IoT projects. The project can be accessed from the following link, Wokwi. The testing was done in three phases.

1. **Phase One:**

- The humidity was deliberately maintained within the range of 90-95% to observe the system's response in sending feedback to the relay.
- During this test, it was observed that the system did not signal the relay when the humidity levels were within the specified range of 90-95%. This result indicates that the test was successful in identifying the system's behavior under these conditions.
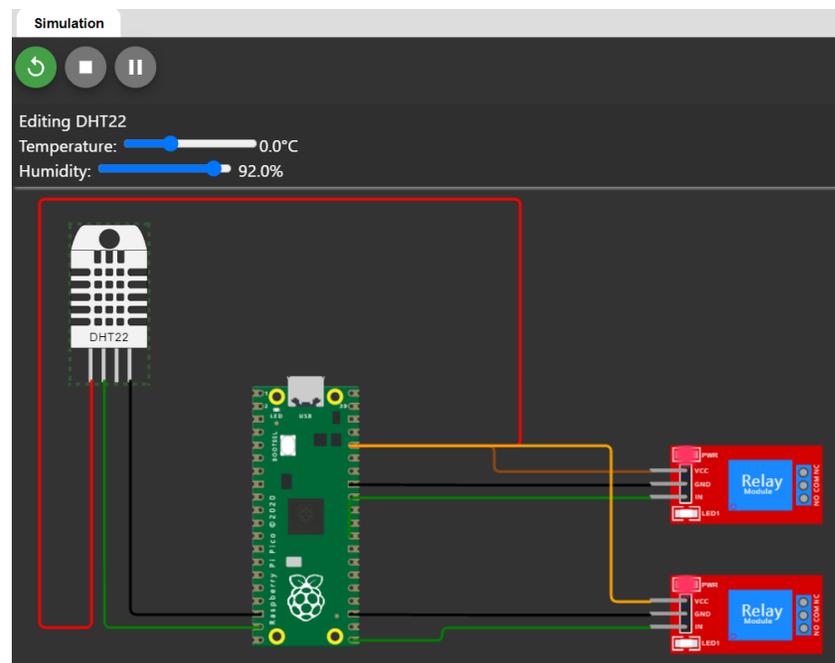

Figure 9. Simulation of the prototype with humidity in the range of 90-95%

2. **Phase two:**

- In this phase, the humidity was deliberately maintained within the range of 80-90% to assess the system's responsiveness and feedback mechanism. When the humidity levels dropped below 90%, the microcontroller promptly instructed the bottom relay to activate

the humidifier. This step confirmed the effectiveness of the test, demonstrating the system's ability to respond to lower humidity conditions.

- To provide a visual indicator of the humidifier's operation, an LED light on the bottom relay served as user feedback, illuminating to indicate that the humidifier was actively functioning.

- Upon reaching the desired humidity level of 90%, the microcontroller deactivated the signal sent to the relay. Consequently, this action turned off the humidifier, ensuring that the system operated efficiently and effectively in maintaining the specified humidity range.
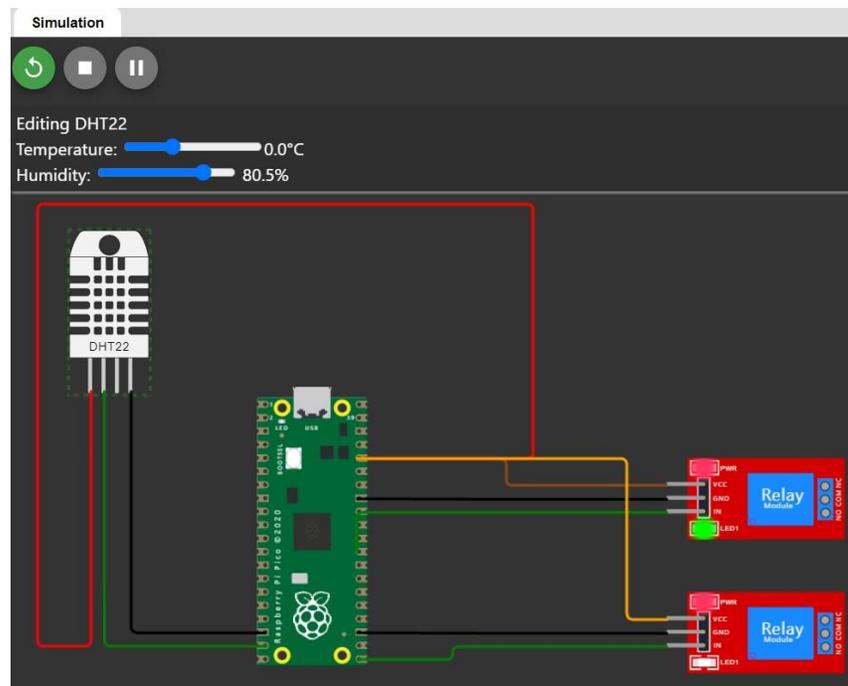

Figure 10. Simulation of the prototype with humidity < 90%

3. Phase three

- In this experiment, the humidity was deliberately adjusted to a range of 95-100% to observe the system's response and assess its feedback mechanism with the relay.

- Upon reaching humidity levels above 95%, the microcontroller effectively triggered the relay, activating the de-humidifier. This successful test demonstrated the system's ability to respond promptly to elevated humidity levels.

- To provide user feedback, an LED indicator was incorporated. When the de-humidifier was activated, the LED illuminated in the relay module on the top, serving as a visual confirmation for the user that the system was operational.

- Subsequently, once the humidity level decreased below the threshold of 95%, the signal to the relay was deactivated. Consequently, the de-humidifier was switched off, indicating the system's efficient response to changing environmental conditions.
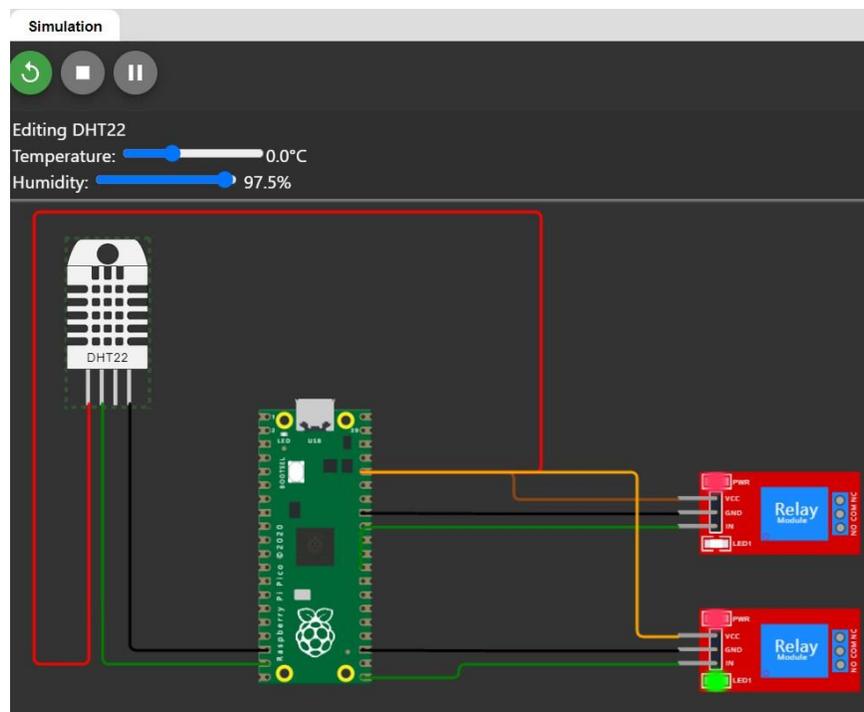

Figure 11. **Simulation of the prototype with humidity > 95%**

6.5. Expected vs actual outcomes

OBJECTIVE	EXPECTED OUTCOME	ACTUAL RESULTS
To create a system to maintain the humidity in the cellar.	A system to maintain the humidity with minimal components and budget.	Successfully tested a system to maintain the humidity with four components and a budget of $90.
To integrate the humidity control system to the existing application the client uses	A tab in the application especially made for humidity control	The integration of Raspberry Pi and the application was complex and required a lot of study. The team lacked knowledge and time.
To connect the relay to an actual humidifier or a dehumidifier and test the prototype.	The humidifier/dehumidifier switches on and off depending on the humidity level of the environment.	We have acquired the humidifier, but initial tests were not successful due to the lack of components.

Table 3. Expected vs actual outcomes.

7. Conclusions and Recommendations for Future Work

7.1 Lessons learned

Calibration Importance

- The calibration process using a 21-point calibration with Sodium Chloride and Silicon Moisture Absorber significantly improves the accuracy of the DHT22 sensor.

Operating Environment Considerations

- Operating in extreme temperatures requires additional insulation and regular inspections to ensure optimal system performance.

User-Friendly Design

- The user manual and system interface should be designed with non-engineers in mind, ensuring accessibility and ease of understanding.

7.2 Work Summary

1) Prototype Validation

- The humidity control system prototype successfully demonstrates the integration of a DHT22 sensor, Raspberry Pi, and relay modules for effective humidity management.

2) Software Algorithm Validation

- The software control algorithm effectively regulates the humidifier and dehumidifier based on the DHT22 sensor readings, maintaining the desired humidity levels.

7.3 Recommendations for future work

- Mobile Application Integration: Develop a user-friendly mobile application for remote monitoring and control of the humidity system, providing users with real-time data and alerts.

- Energy-Efficient Components: Investigate and incorporate energy-efficient components to optimize power consumption, extending the system's battery life.

- Enhanced User Interface: Improve the user interface of the control system, incorporating visual indicators and alerts for better user feedback.

- Cloud Connectivity: Implement cloud connectivity for data storage and analysis, enabling users to track historical humidity data and receive insights for long-term storage management.

- Integration with Home Automation Systems: Explore integration possibilities with popular home automation platforms, allowing users to seamlessly incorporate the humidity control system into their smart home ecosystems.

- User Feedback Mechanism: Integrate a user feedback mechanism, such as notifications or email alerts, to inform users of system status changes or potential issues.

- Improved Sensor Technology: Explore and integrate more advanced humidity sensors with higher accuracy and reliability to enhance the overall precision of the system.

8. Bibliography

[1] Wokwi - Online ESP32, STM32, Arduino Simulator, https://wokwi.com/ (accessed Dec. 18, 2023).

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[3] Raspberry Pi Foundation, "Teach, learn, and make with the Raspberry Pi Foundation," Raspberry Pi Foundation, https://www.raspberrypi.org/ (accessed Dec. 18, 2023).

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[7] R. (not verified) et al., "Root cellars: Types and storage tips," Almanac.com, https://www.almanac.com/content/root-cellars-types-and-storage-tips (accessed Dec. 18, 2023).

[8] seansgarden_ndtcvr, "Build a simulated root cellar with Raspberry Pi," Seans Garden, https://www.seansgarden.com/2017/07/11/simulated-root-cellar-with-raspberry-pi/ (accessed Dec. 18, 2023).

[9] "Raspberry pi 4: Humidity and temperature (DHT22) setup (no coding required)," YouTube, https://www.youtube.com/watch?v=4C1sa__-dzg (accessed Dec. 18, 2023).

9. APPENDICES

APPENDIX I: Design Files

Document Name	Document Location and/or URL	Issuance Date
Designing a Root Cellar.	https://open.library.ubc.ca/soa/cIRcle/collections/undergraduateresearch/18861/items/1.0108394	April 8, 2011
Newfoundland and Labrador Root Cellar Bibliography	https://www.mun.ca/ich/search-ich-collections/newfoundland-and-labrador-root-cellar-bibliography/	June 2011
ROOT CELLAR REPORTS	https://endeavourcentre.org/root-cellar-reports/	May 20, 2015
Cold Cellars for Year-Round Local Food and Farming	https://www.canr.msu.edu/hrt/uploads/535/78622/Root-Cellar-Handout-Diagram-6pgs.pdf	January, 2009
Root Cellar Monitoring	https://digitalcollections.trentu.ca/objects/tcrc-1102?solr_nav%5Bid%5D=002e67670e891887a88a&solr_nav%5Bpage%5D=20&solr_nav%5Boffset%5D=8	April, 2015

Table 4. Referenced Documents
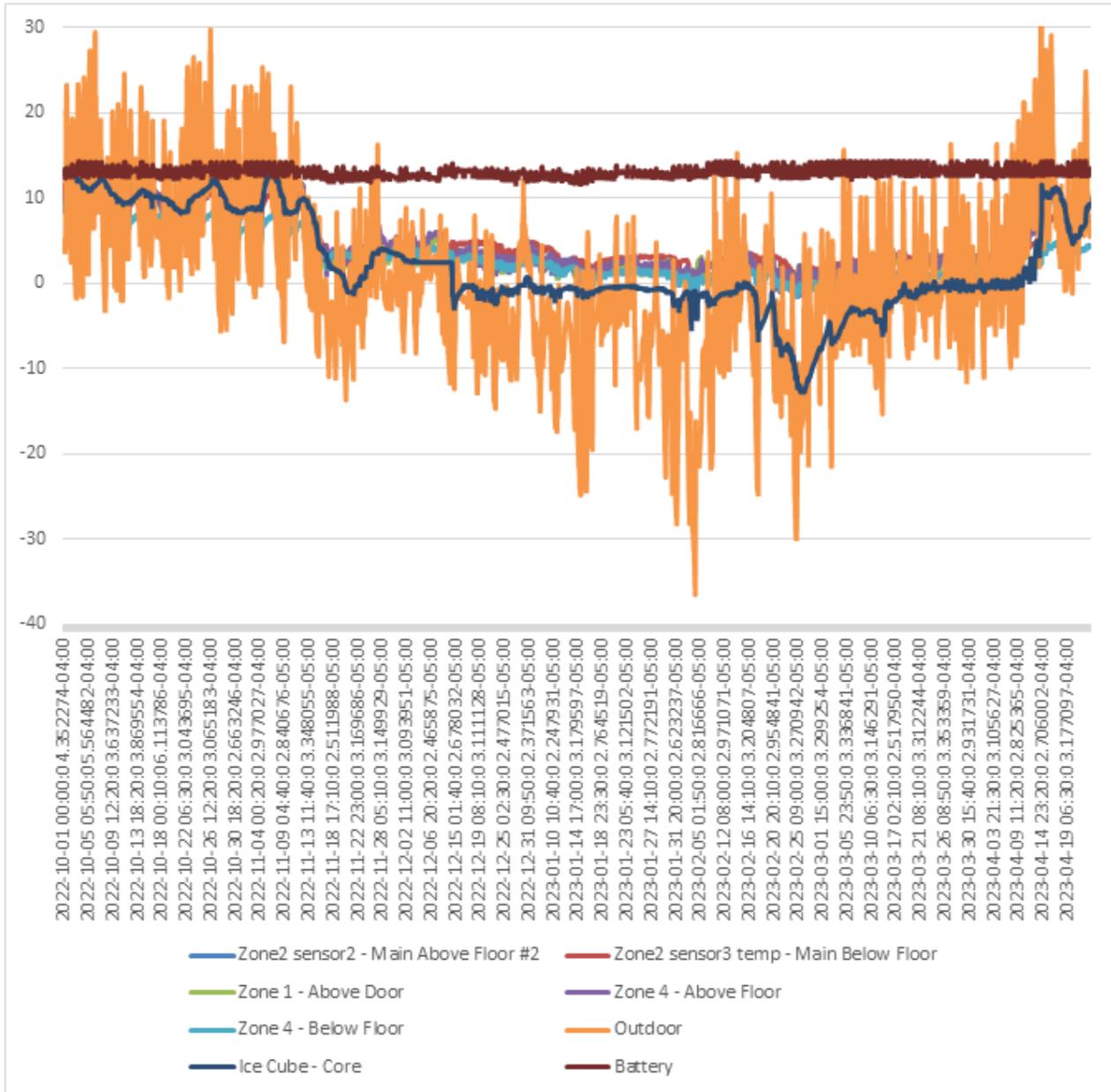
Figure 12. User-testing results collected by the client: Oct 2022 to April 2023

Program used for the prototype;

```
#include <Adafruit_Sensor.h>
#include<DHT.h>
#define DHT_PIN 14      // Pin where the DHT22 sensor is connected (GPIO14)
#define DHT_TYPE DHT22 // DHT22 sensor type
#define HUMIDIFIER_PIN 22 // Pin where the humidifier relay module is connected
(GPIO22)
#define DEHUMIDIFIER_PIN 16 // Pin where the dehumidifier relay module is
connected (GPIO16)

DHT dht(DHT_PIN, DHT_TYPE);

void setup()
{
Serial.begin(9600);
pinMode(HUMIDIFIER_PIN, OUTPUT);
pinMode(DEHUMIDIFIER_PIN, OUTPUT);
dht.begin();
}
void loop()
 {
float humidity = dht.readHumidity(); if (isnan(humidity)) {
Serial.println("Failed to read from DHT sensor!");
return;
}
Serial.print("Humidity: "); Serial.print(humidity); Serial.println("%");

// Turn on humidifier if humidity is less than 90% if (humidity < 90)
{
digitalWrite(HUMIDIFIER_PIN, HIGH);   // Turn on the humidifier
Serial.println("Humidifier is ON");
} else {
digitalWrite(HUMIDIFIER_PIN, LOW);   // Turn off the humidifier
Serial.println("Humidifier is OFF");
}
// Turn on dehumidifier if humidity is more than 95% if (humidity > 95) {
digitalWrite(DEHUMIDIFIER_PIN, HIGH);   // Turn on the dehumidifier
Serial.println("Dehumidifier is ON");
}
Else {
digitalWrite(DEHUMIDIFIER_PIN, LOW);   // Turn off the dehumidifier
Serial.println("Dehumidifier is OFF");
}
delay(1000); // Wait for 1 seconds before the next measurement
```

Figure 13. Existing unit

Fig: Home page of the user interface
Fig: Notifications page of the user interface
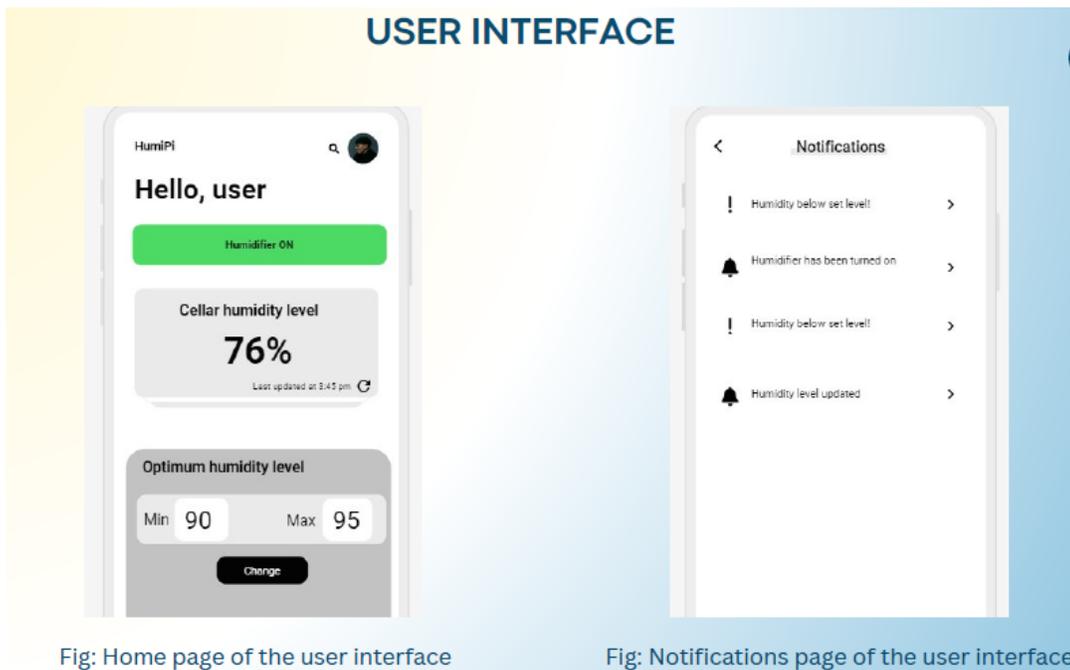
Figure 14. User interface for the phone app
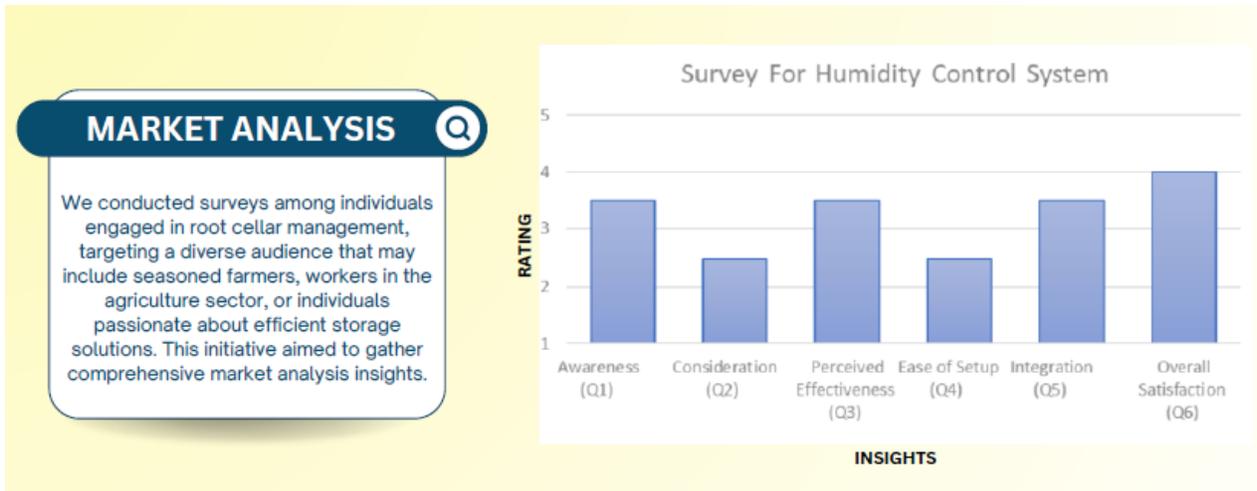
Figure 15. Market analysis
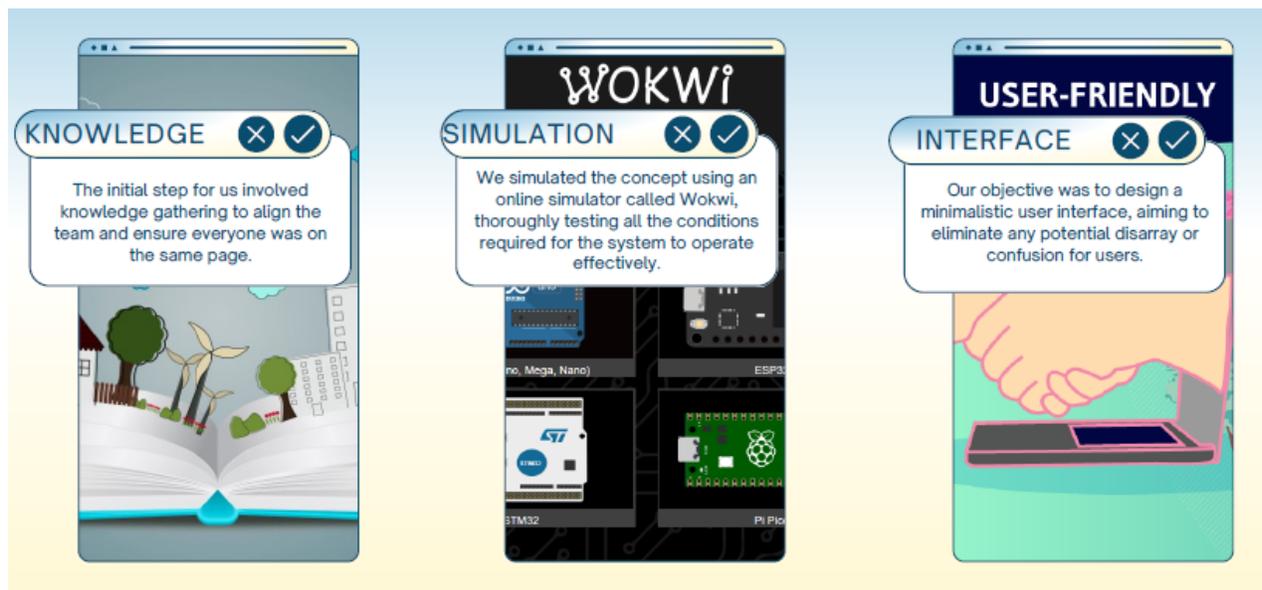
Figure 16. Steps for the completion of the prototype