<u>Low-Cost Weather Monitoring for Climate Resilience</u>

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Abstract:

The New York Department of Environmental Conservation faces the challenge of obtaining low-cost, accurate weather monitoring systems to understand climate change impacts on microclimates and foster data sharing. Climate change brings about unpredictable weather patterns, posing risks to our health, safety, and community well-being. Our solution aims to mitigate these risks by providing affordable weather monitoring systems accessible to homes and businesses, aiding in data collection and analysis to reduce the impact of extreme weather events. Furthermore, our system encourages data sharing, which contributes to a worldwide comprehension of weather patterns. Unlike existing solutions that are often expensive and complex, our product is a simplified, economical alternative. It does not heavily depend on external services, ensuring its accessibility to a wider audience. This makes our solution a practical choice for weather monitoring and climate change understanding.

1. **The Problem:**
    a. The New York Department of Environmental Conservation needs a low-cost and accurate weather monitoring system that can be used by homes and businesses so that they can better understand the impact of climate change on microclimates within New York State and foster a collaborative network of data sharing and analysis.

    b. The climate change is an increasing pressing issue, with wide range from severe weather to shift in seasonal pattern [1][2]. These climate changes can have a significant impact on local microclimate, which can impact on public health, safety, and welfare. The severe weather can lead to death and injury, such as floods, mudslides, tornadoes, typhoons, etc [3]. These events also impact on public infrastructure and communities people rely on for safety, health, and welfare. This project can help minimize the impact of extreme weather events and reduce risk. It also helps individuals to prepare for the extreme weather, which potentially reduces the risk of death and injury.[4] This project also helps with data sharing, which can contribute to global understanding of weather patterns.

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[1] https://news.un.org/en/story/2023/04/1135852

[2] https://www.nber.org/reporter/2021number4/economic-impact-climate-change-over-time-and-space

[3] https://www.niehs.nih.gov/research/programs/climatechange/health_impacts/weather_related_morbidity

[4] https://journals.ametsoc.org/view/journals/wcas/13/2/WCAS-D-20-0110.1.xml

2. Inspiration:

Two products currently available on the market have sparked our interest: the Sainlogic WS-0310 and AcuRite Iris 5-in-1 Home Weather Station. Both are powered by batteries. These stations collect real-time weather data both indoors and outdoors, measuring parameters such as temperature, air pressure, humidity, wind speed, and direction. This led us to consider: why not utilize the battery as the power supply of the system and utilize solar cells to charge the battery in the meantime.

We're eager to explore the integration of solar power into our climate monitoring system to ensure uninterrupted operation, even in remote areas or during power disruptions. In this article, we'll delve into the design and implementation of the power subsystem, highlighting its crucial role in effectively and sustainably powering the weather monitoring stations.

3. System Requirements

a. Use-Case Diagram

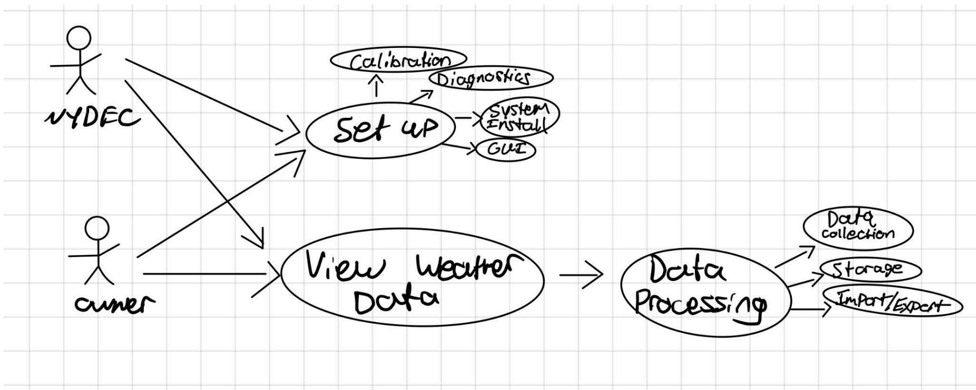


Figure 1: Use-case Diagram

b. Functional Requirements

1. Power Availability: The system needs to provide power for at least 18 hours.

2. Data collection: The system should be able to collect accurate weather data including humidity, temperature, wind speed and direction, precipitation, extreme weather, air quality, and UV index.

3. Data sharing: The system would let users share weather data with NYSDEC every hour without data loss to help to better understand the impact of climate change on microclimates within New York State

Non-Functional Requirements

1. Reliability: The system must be dependable in various weather conditions and be able to operate without malfunction

2. Data Accessibility: The system would provide an interface for users to access and view their data.

3. Scalability: The system should be scalable to accommodate future integration with additional solar panels or batteries as the weather monitoring system evolves.

c. Design Constraints

1. Budget limitation: The project design has a budget of $150 per team limiting the quantity and quality of parts that teams can purchase.

2. Resource limitation: This project will be designed by undergraduate students. The limitation of the skill, experience, and material will limit the design of the system.

3. Time limitation: The deadline for this project is April 21, 2024, which can lead to a limitation on design, deployment, and idealization.

4. System Design

a. Design Overview & Justification

	Options		
Criteria	Linear Power Distribution	Parallel Power Distribution	Solar-Centric
Cost	4	2	5
Reliability	3	4	1
Usability	5	5	1
Maintenence	4	3	4
Ease of installation	4	2	5
Power Consumption	3	5	1
Totals	23	21	17

Scaling from 1 (worst) to 5 (best):
Cost: How much would it cost to purchase the parts needed for each design.
Reliability: How long will the battery last under certain conditions.
Usability: How usable it will be for the homeowner or the NYSDEC specialist.
Maintenance: How often will it need to be maintained, calibrated etc.
Ease of Installation: How easy is it to install and set up?
Power Consumption: Is the amount of power consumption better or worse for this set up?

Alternate Designs:

1. Linear Power Distribution:
    - The system component exclusively draws power from the battery. The solar cell is solely responsible for charging the battery and does not supply power to any other components within the power system. The microcontroller will activate the sensor by providing power to it.

    - The benefit of this design is its reduced component count compared to parallel power distribution. However, a drawback is its potential difficulty in providing sufficient power during extended periods of adverse weather conditions.

2. Parallel Power Distribution:
    - The solar cell provides power to both the microcontroller and the battery. In instances where the solar cell cannot generate sufficient power due to shortage of light, the battery supplements power to the microcontroller, ensuring continuous operation.

    - In this design, parallel distribution offers the advantage of uninterrupted operation, as multiple power sources can simultaneously provide energy. This increases the system's potential to support power needs, even during long periods of adverse weather conditions. However, the downside of this design is its higher complexity. It needs more implementation time and additional components, resulting in increased costs for the overall design.

3. Solar-Centric Power Distribution:
    - The solar cell serves as the sole power source for all system components. Without the inclusion of a battery, the solar cell directly powers all components.

    - This design is the most cost-effective and quickest to implement compared to the other two designs. However, its main disadvantage is that the entire system will be non-functional when there is no sunlight

Justification:

- We opted for linear Power Distribution due to its efficiency in time, cost, and performance. With a limited budget of $150 and a tight one-month timeline for implementation, simplicity is key. While the linear design offers similar functionality to the parallel design, it may have slightly less continuous ability during prolonged adverse weather conditions. However, it requires fewer components and facilitates easier integration compared to parallel distribution. On the other hand, parallel distribution ensures uninterrupted operation by allowing multiple power sources to supply energy simultaneously, particularly beneficial during adverse weather. Yet, its complexity and longer implementation time result in increased costs. Meanwhile, the solar-centric design is the most cost-effective and quickest to implement. However, its primary drawback is its dependency on sunlight, leading to system downtime in the absence of sunlight.

Black Box

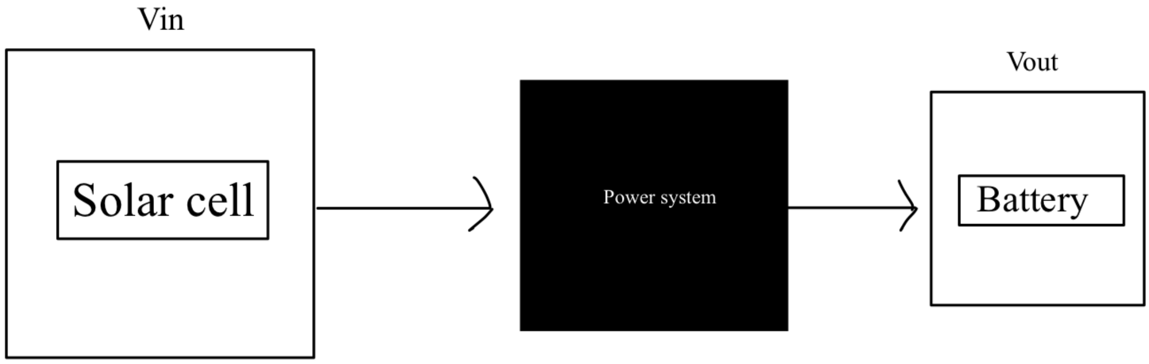


Figure 2: Black box diagram of the power system

Solar cell: The main power source and Vin of the power system
Battery: The output of the power system where the power is being stored

Logical Design: System Architecture

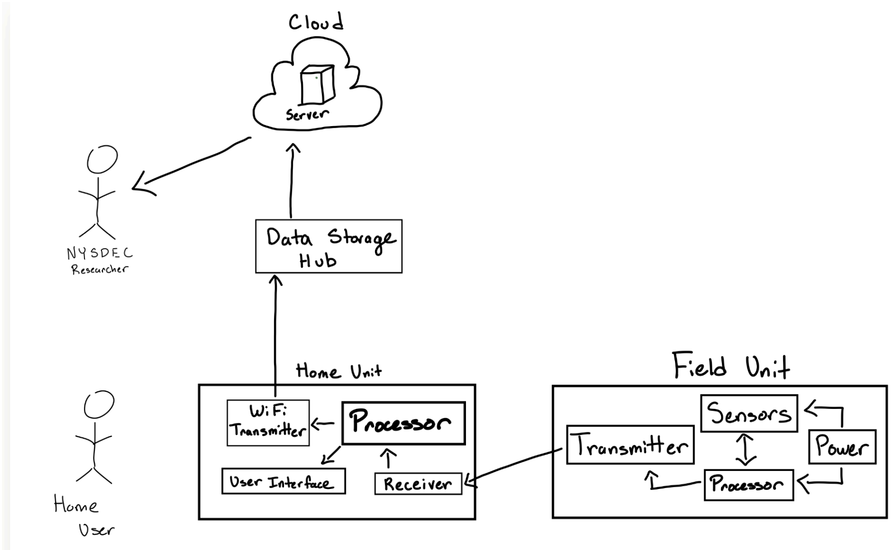


Figure 3: Logical Design

Power: The power component includes power sources such as batteries, solar panels, or electrical outlets that supply energy to the weather system's components. It ensures power supply to all system components for continuous operation, especially in remote or off-grid locations.
Sensors: The sensors will serve as the primary data collection for weather parameters like temperature, humidity, wind speed, and precipitation.
Processors: The central processing units will process and analyze data collected by the sensors. They will translate the raw data to meaningful weather info.

Receivers: The receivers are responsible for receiving data transmitted from the transmitters. They play a large role in ensuring the accuracy and weather data from the sensors and processors.
Transmitters: This will transmit the raw data given from the sensors to the processors. This enables the users to interact with the weather information. They'll see forecasts and alerts in a user-friendly manner on a display.
WiFi Transmitter: This transmitter will send data to the data hub and cloud, which will give NYSDEC access to the data.
Data Hub: This will serve as a central repository for storing and managing weather data collected and processed. It will serve as a local storage before the data is transmitted to the cloud.
Cloud Server: This component provides reliability and accessibility for storing large volumes of data and delivering weather forecasts and alerts over the internet.

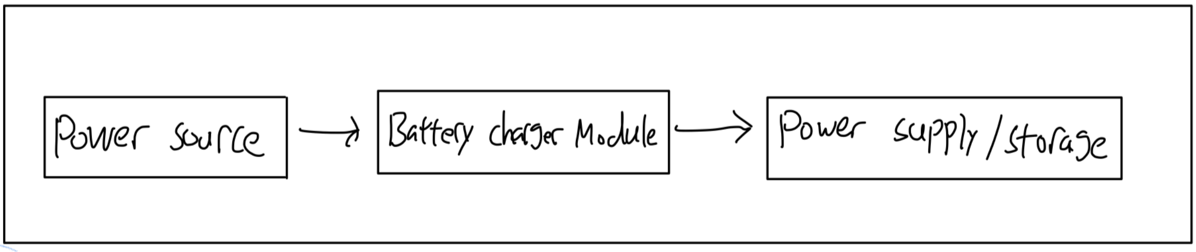
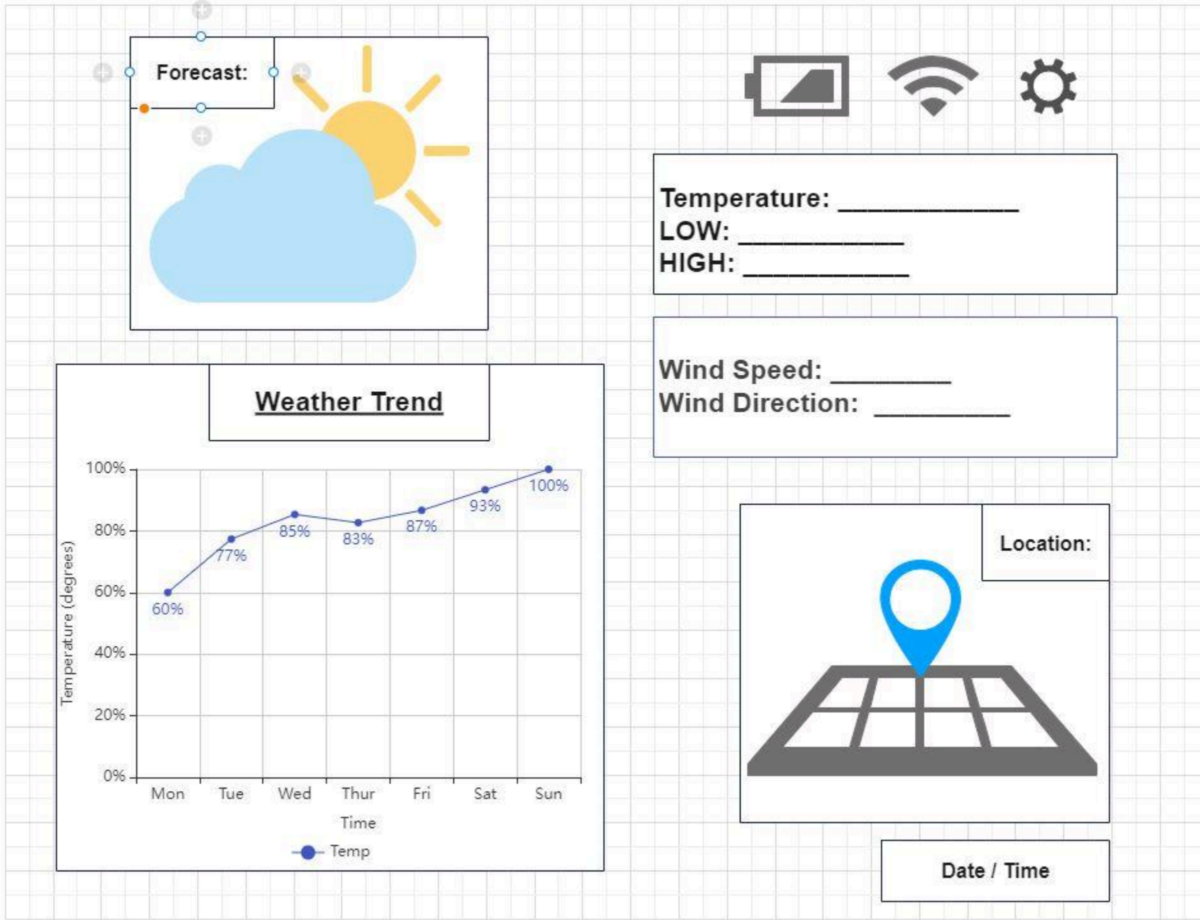


Figure 4: Power Unit

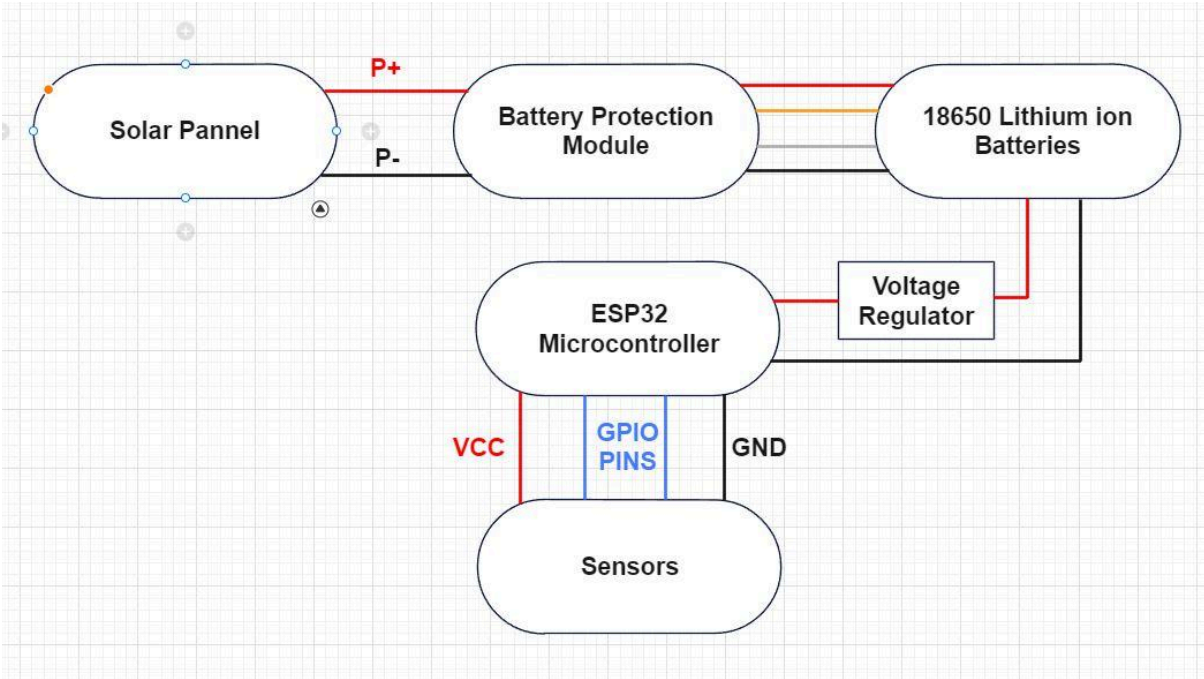
This unit shows the components integrated within the power system. The power source charges the power supply/storage unit through the battery charge module. Subsequently, the power supply/storage unit will provide all the power required for the system.

Wireframe Model:



Forecast: This section will tell us the mixed weather conditions, ie. partly sunny, cloudy etc.
Weather Trend: This section displays the weather trend over the past 7 days.
Setting: This section lets the user custom experience and preferences. It includes units of measurement, notification preferences, etc.
Temp / High / Low: Tells us the current temperature, and the high and low to be expected throughout the day.
Wind Direction / Speed : As the name says this section displays the direction of the wind and the speed of it.
Location: Displays the city, state, latitude and longitude.
Power status: This section displays the power left in the power supply unit.

Physical Design:



This physical design exemplifies the components slated for the implementation phase.

Components:

Solar Cells: 9 solar cells will be employed, connected series to form a solar panel producing a max voltage 18V (2V each) and a max current of 112.3 mA. The generated power from this panel will subsequently be directed to the battery protection module .

FIT 0869 Battery Protection Module: The battery protection module charges 3, 18650 Batteries in series together regulating the voltage and current to ensure the batteries receive a safe and efficient charge by stopping the solar cells from charging the batteries any further.

18650 Lithium-ion Battery x3: This is where the power will be held. The safety standard used for this is UL1642 which outlines, performance, various testing like mechanical, abuse, environmental, and thermal testing, Electrical performance and construction. We chose this battery because this was the most commonly used battery for charging purposes.

LM338 Voltage Regulator: The lithium Ion battery pack is connected in series producing 12V (4V each) so we need a Voltage Regulator to step down the voltage to 3.3V to prevent the ESP32 microcontroller from overloading.

ESP32 Microcontroller: The Esp32 will handle all the data collected from the sensors but since our focus is mainly the power subsystem, for testing purposes the ESP32 will have a different functionality to ensure that it can efficiently process and transmit sensor data while maintaining minimal power consumption.

Bill of Materials

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Item	**Purpose**	**Price**	**Links**
Solar Cells	Provides power to battery charger	$15.50	HERE
FIT0869 Battery Protection Module	Charges 3 Li-Ion batteries at a time cuts off when enough power is stored	$2.50	HERE
18650 Li-ion Batteries	Stores energy produced by solar panel and powers the ESP32	$25.00	HERE
3 Slot 18650 Li-ion Battery Holder	Holds 3 of the Batteries in series	$9.99	HERE
ESP32 Microcontroller	Receives power from the batteries and outputs to the sensors	$9.99	HERE
LM338 Voltage Regulator	Steps the voltage down to needed voltage supply	$5.38	HERE
Total	$68.36		

Gantt Chart