The Backyard Forest

A Microclimate Study

Brent Reynolds, Matt Rice, Anna Ransom

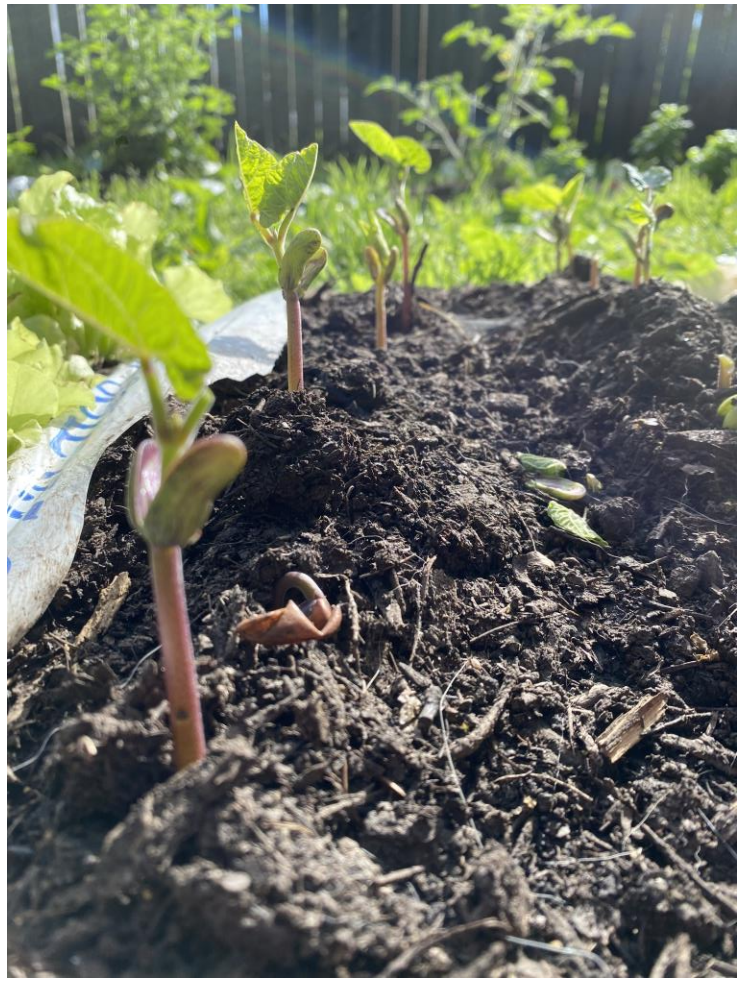
Introduction: Adjusted Project Goals

How does the microclimate of Anna's backyard compare to the weather observations at Bowman Field Airport?

- **Build** a small-scale backyard weather station that ~~integrates a solar panel for sustainable power generation~~ uses a battery.
- **Use WSN** (Wireless Sensor Networks) to transmit collected data to ~~Bellarmine's computer lab~~ Anna's house.
- **Compare** the microclimate data collected from Anna's backyard to a local airport's weather data fetched from ~~weather.gov~~ Open-meteo API.

Review of Real-World Applications

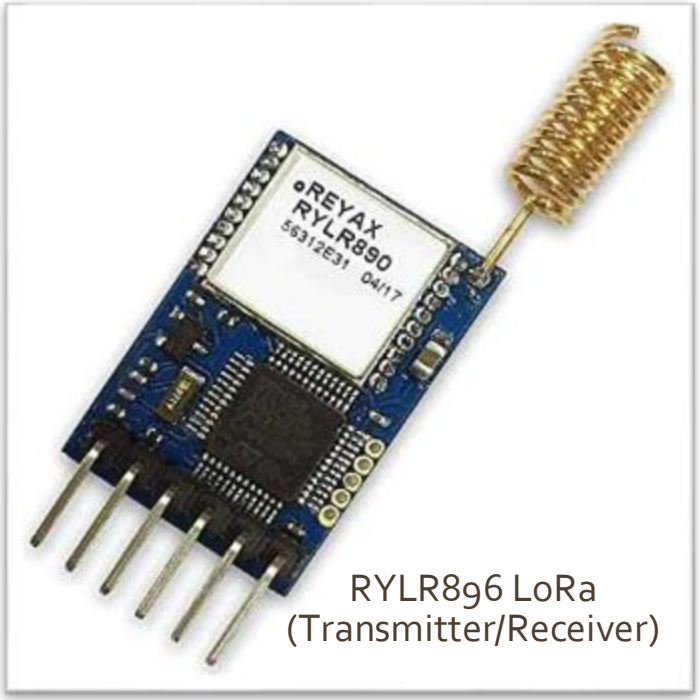
- Personal Use: Helping backyard gardeners select the best crops for their microclimate.
- Smart Cities: Collecting environmental data to better understand local "urban heat islands" and their effects.
- Climate Studies: Contributing to larger-scale environmental research by comparing localized data with official weather stations.



Component Selection

Foundation 🤖✨

Microcontroller, Transmitter/Receiver, Breadboard



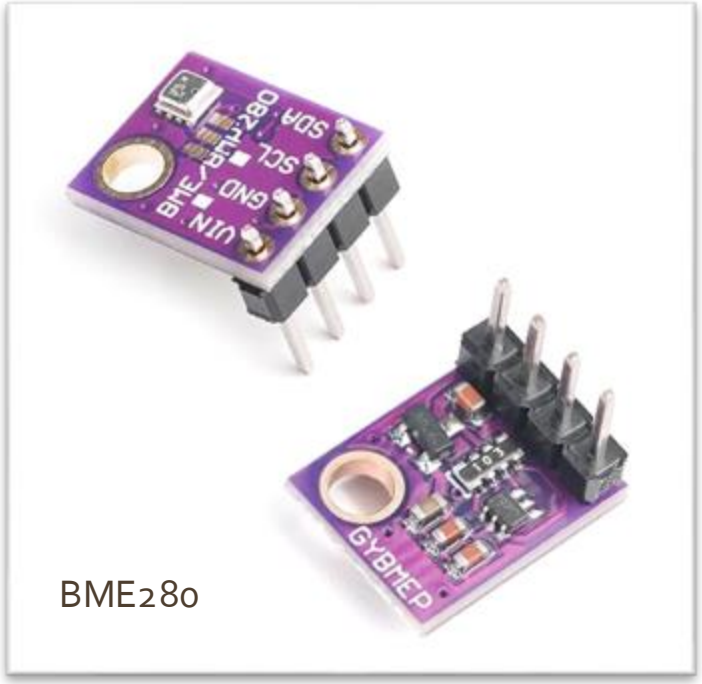
RYLR896 LoRa
(Transmitter/Receiver)

ESP32

Breadboard

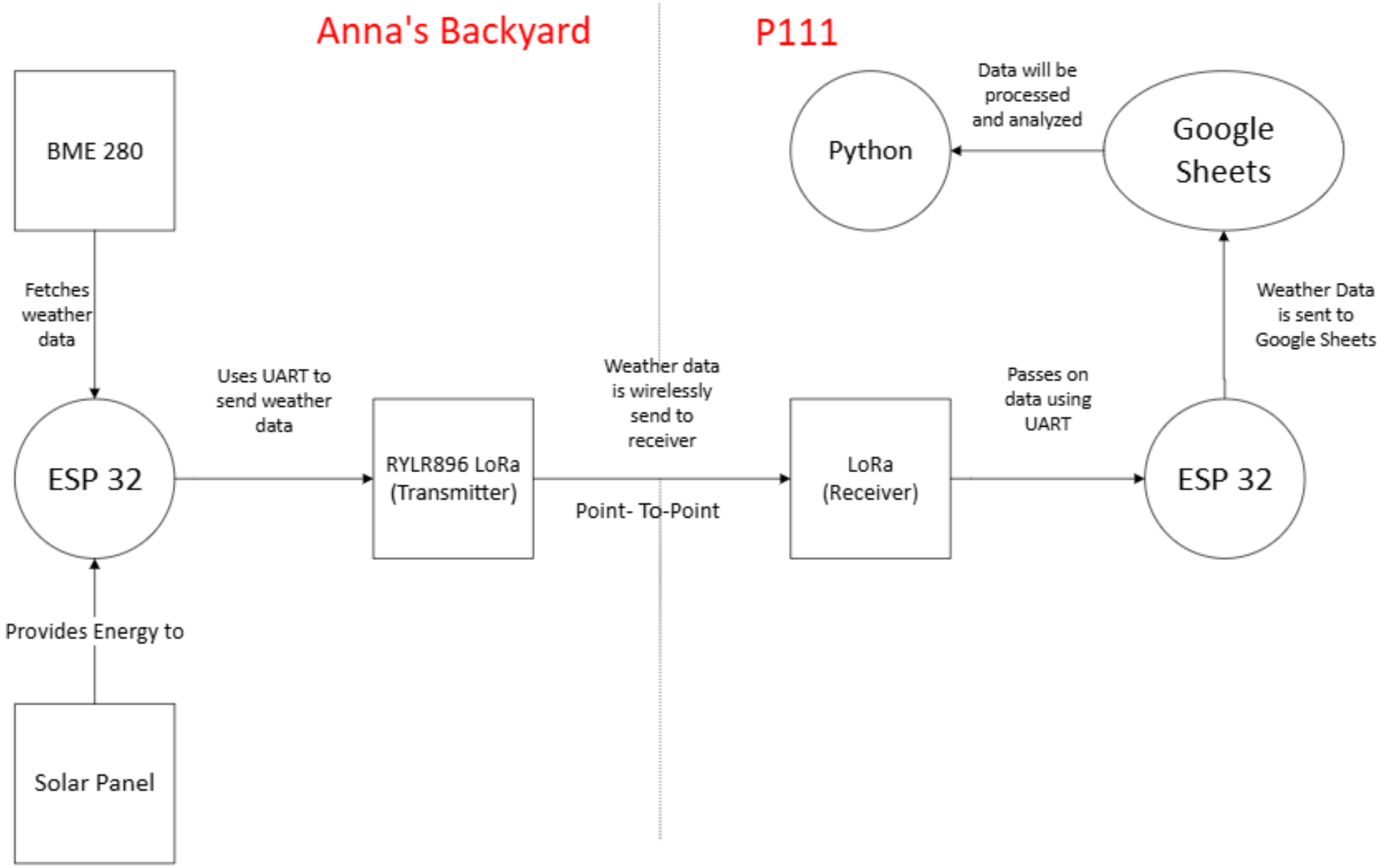
Weather Sensor 🌡️🌧️

Temperature, Humidity, Atmospheric Pressure

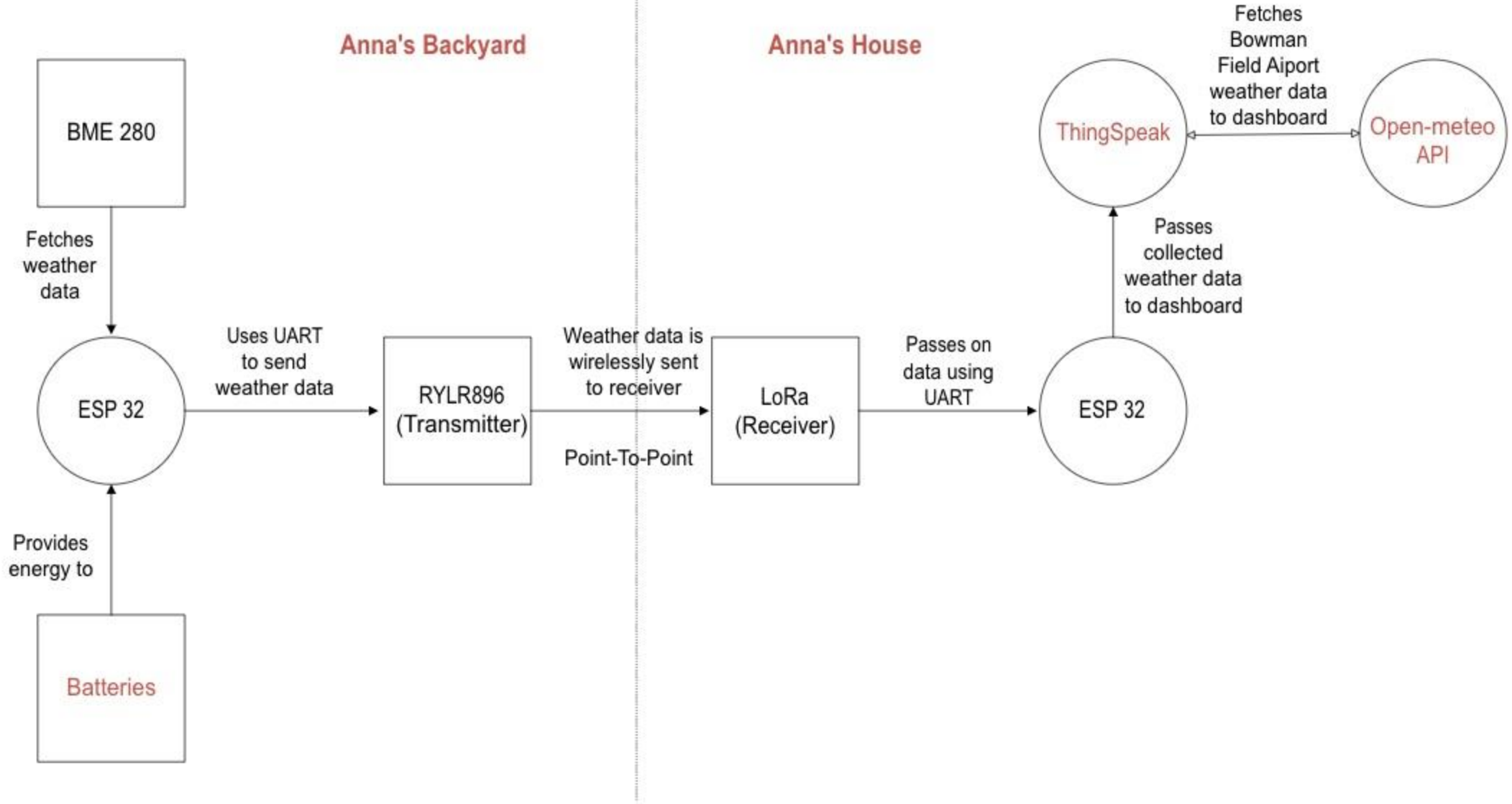


BME280

Initial Topology Design & Data Collection



Updated Topology Design & Data Collection



Additional Software

Open-meteo is an easy-to-use, open-source API software that provides weather data sourced from the National Weather Service.

ThingSpeak™

ThingSpeak is a cloud-based data collection and analysis service for IoT projects.

Range Testing

Obstructed

Location: Pasteur 111

Range: 100 meters

Packet Loss: ~50%

Latency: 1000 ms

Received Signal Strength: -157 dBm

Unobstructed

Location: Bellarmine Parking Lot

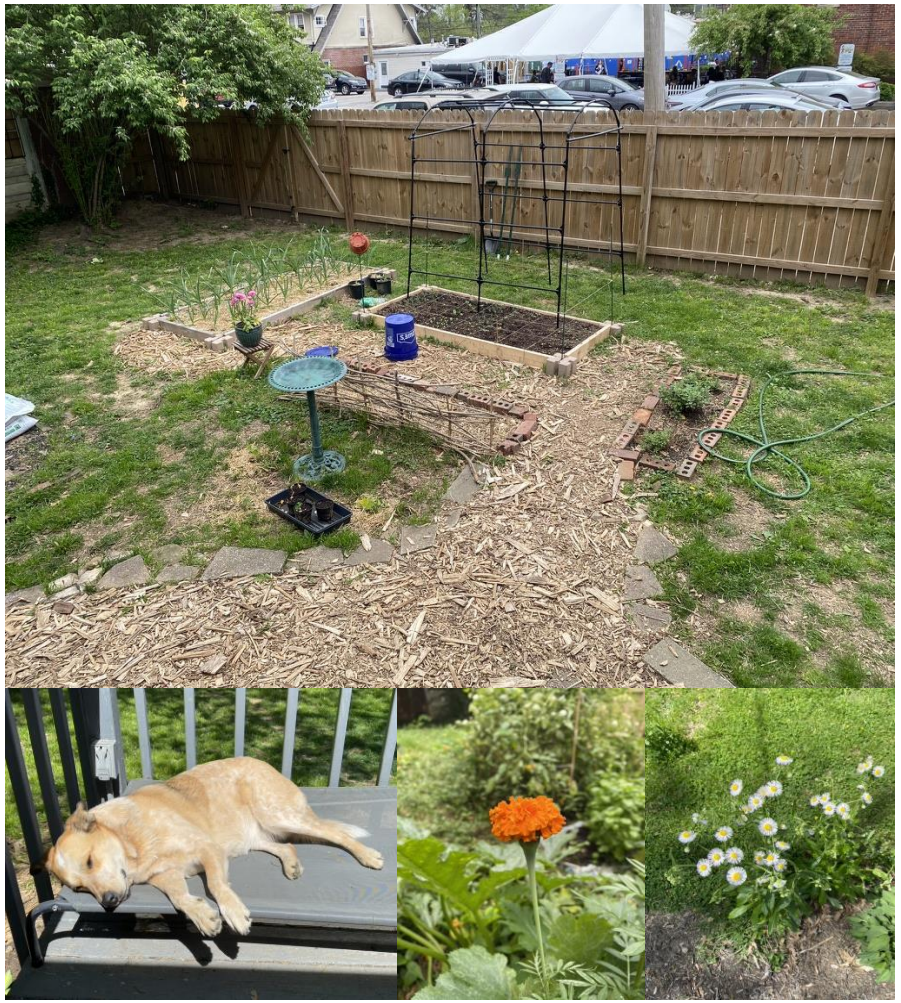
Range: 200 meters

Packet Loss: ~25%

Latency: 1000 ms

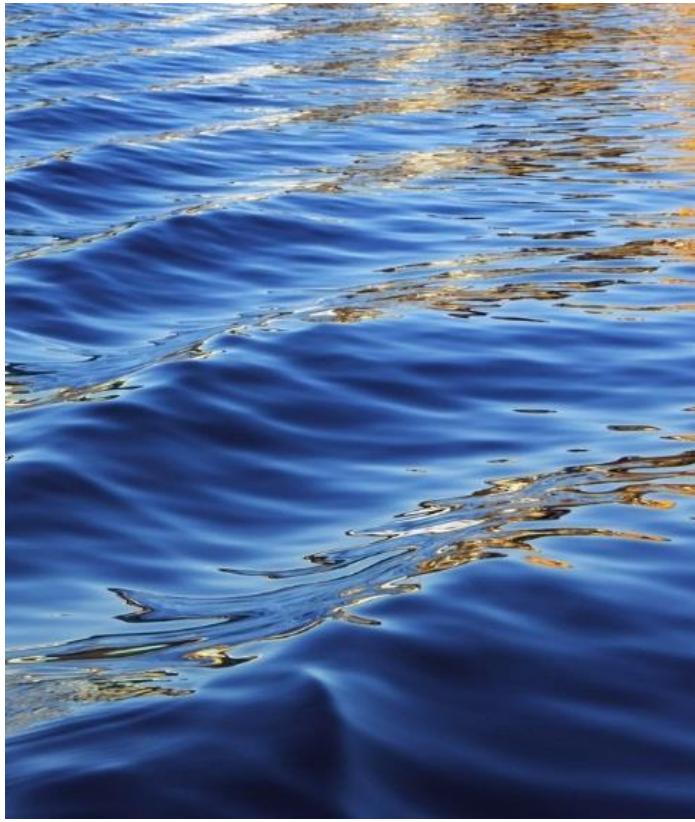
Received Signal Strength: -157 dBm

On-site Installation Day

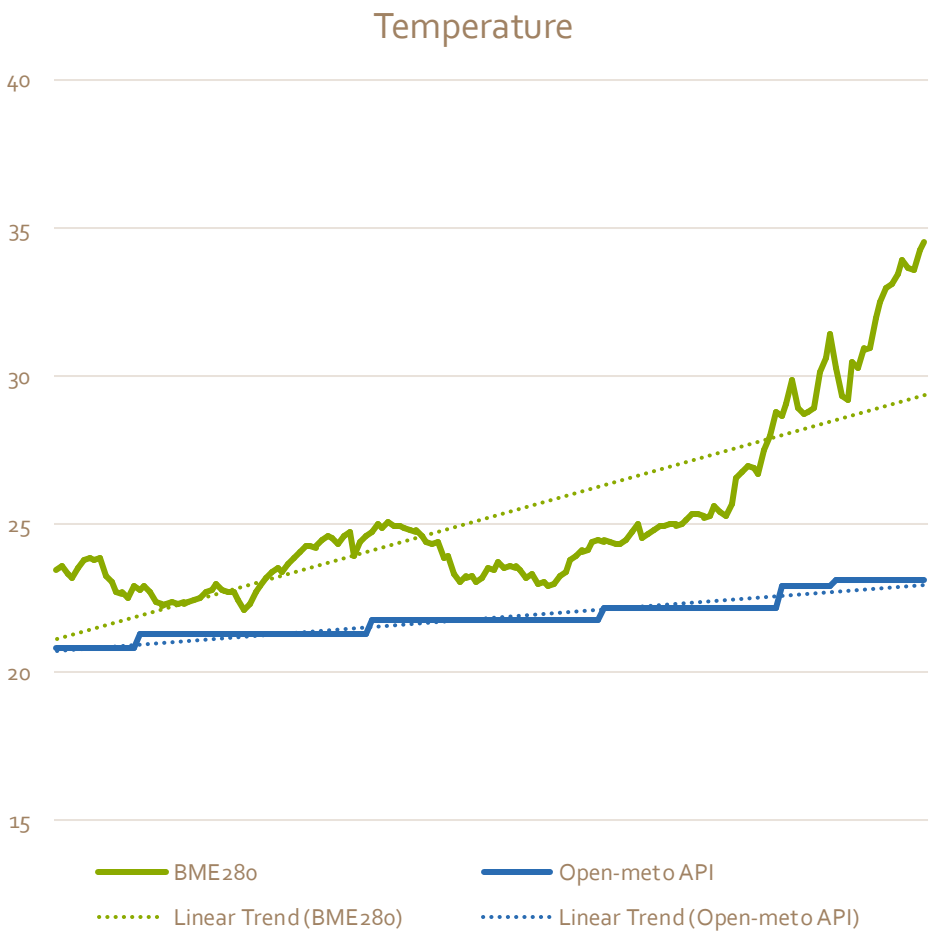


Climates Compared

BME280 vs. API: Data Insights on Temperature, Humidity, and Pressure



Temperature Comparison



Temperature Range:

Anna's Backyard (BME280):

23.5°C to **34.55°C**

Bowman Field (Open-meteo API):

20.8°C to **23.1°C**

Key Sensor Insight:

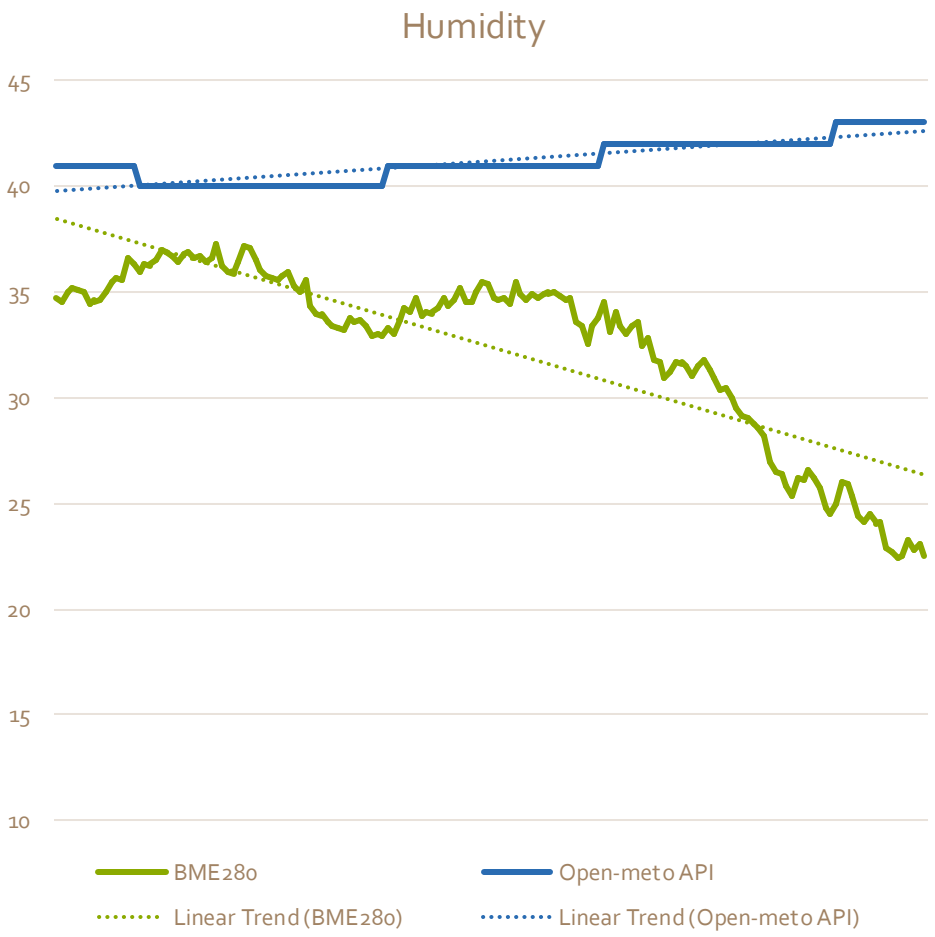
The BME280 data is more dynamic and shows a larger variation in temperature. This indicates real-time readings of direct environmental changes.

The **Open-meteo API** has a smoother, more stable output with a smaller range. This may indicate smoothed or averaged values.

Key Environmental Insight:

Anna's Backyard is hotter than Bowman Field.

Humidity Comparison



Humidity Range and Trend:

Anna's Backyard (BME280):

34.46% to **37.22%**

Bowman Field (Open-meteo API):

41% to **40%**

Key Sensor Insights:

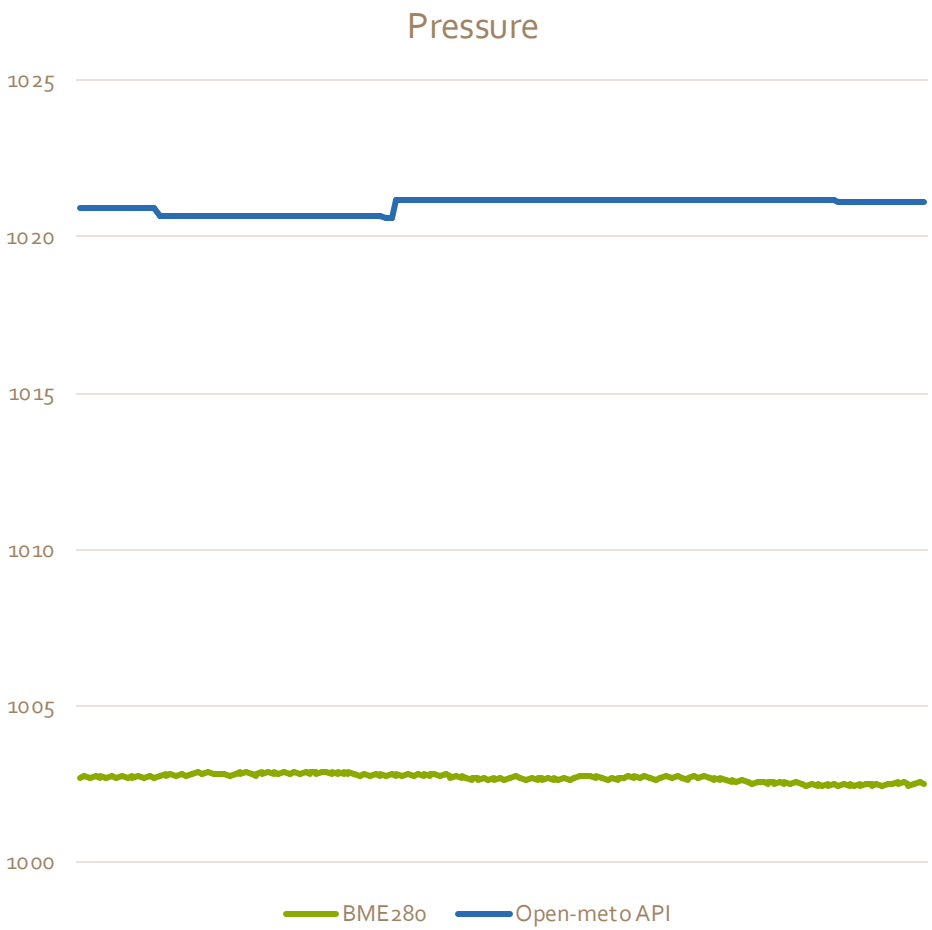
The **BME280** data shows more immediate fluctuations.

The **Open-meteo API** is less sensitive to rapid shifts.

Key Environmental Insight:

Anna's Backyard loses humidity faster than Bowman Field.

Pressure Comparison



Pressure Range:

Anna's Backyard (BME280):

1002.7 hPa – 1020.6 hPa

Bowman Field (Open-meteo API):

1020.6 hPa – 1020.9 hPa

Key Sensor Insights:

The **BME280** data shows more subtle changes.

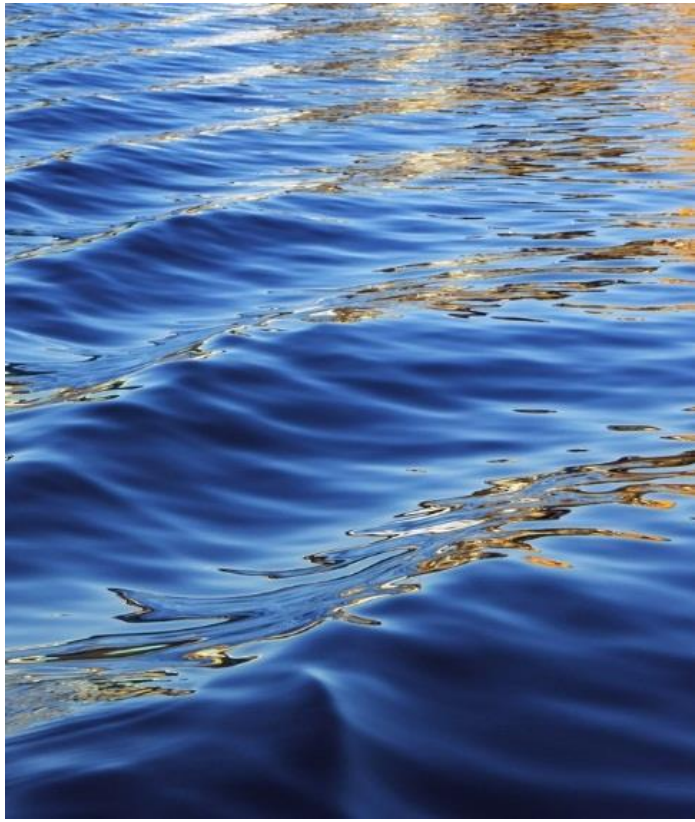
The **Open-meteo API** provides a less reactive value.

Key Environmental Insight:

Anna's Backyard has lower air pressure compared to Bowman Field.

Conclusions

What does this mean?



Does the data show a Backyard Microclimate?

Tiny p-values indicate **statistically significant** differences between Bowman Field and Anna's Backyard.

- Temperature p-value: 8.37×10^{-11}
- Humidity p-value: 7.64×10^{-14}
- Pressure p-value: 3.79×10^{-27}

The differences between the two data sets are **likely real** and not just random.

Possible causes for variance:

- Calibration differences
- Sensor quality
- Environmental placement
- 🌱 A microclimate! 🌱

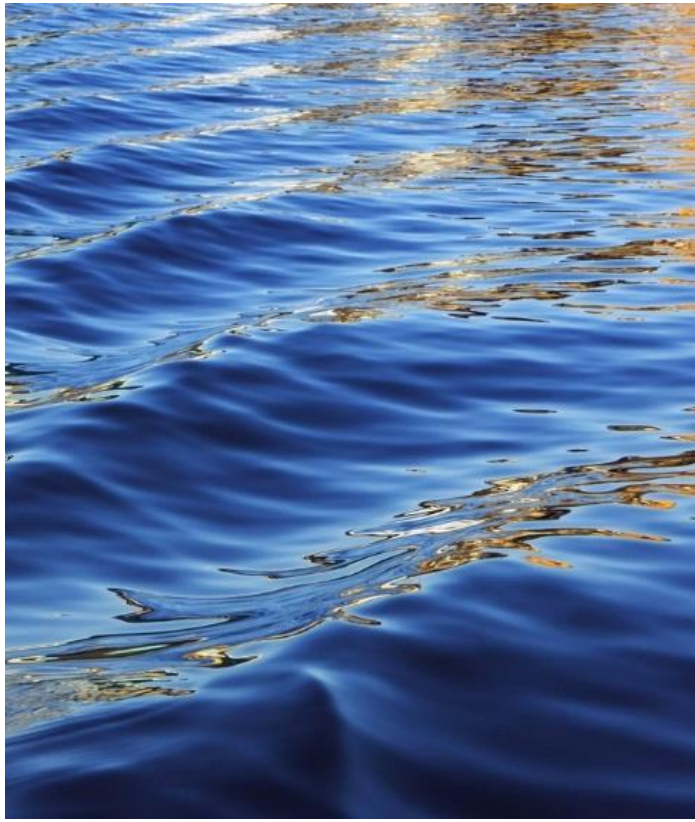
How could we confirm if there is a microclimate?

Rule out other possibilities.

- **Sensor placement:** test the BME280 sensor in multiple locations to test sensor sensitivity to hyper-local environmental changes. Compensates for possible large difference based on environmental placement.
- **Long-term monitoring:** test the sensor for longer periods of time and through multiple seasons.
- **Build multiple sensors:** deploy additional sensors in different locations for more data. Compensates for possible calibration issues with a single sensor.

Urban Heat Islands

A possible cause of the Backyard Microclimate?



What is an Urban Heat Island (UHI)?

A UHI is an urban area with significantly higher temperatures than surrounding rural areas due to human activities and infrastructure.

Significant UHI can mean localized areas of lower pressure due to high temperature.

UHIs typically have higher humidity.

Open Questions

Is it possible at a small scale?

Key Factors

- **Surface Modification**: asphalt and concrete absorb and retain more heat than natural surfaces.
- **Reduced Vegetation**: fewer trees and green spaces reduce cooling from evapotranspiration.
- **Energy Consumption**: increased use of air conditioning, vehicles, and industrial activities release waste heat.
- **Air Pollution**: emissions from vehicles and industries trap heat in the atmosphere.

Visualizing Test Environments