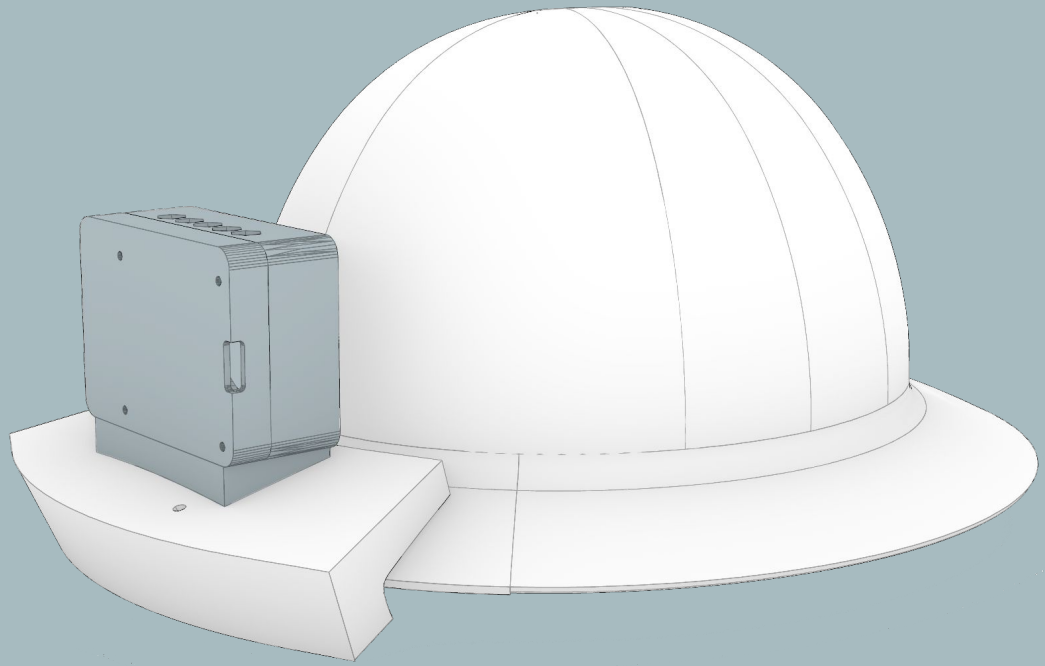
Hard Hat Safety Sensors



AARON ROMBACH, ICARUS FERNANDES, KATELYN OWENS

Worker Safety

Construction is one of the most hazardous industries:

- Leading contributor to workplace injuries and fatalities.
- High exposure to heavy machinery, heights, confined spaces, and unpredictable environments.

OSHA Statistics

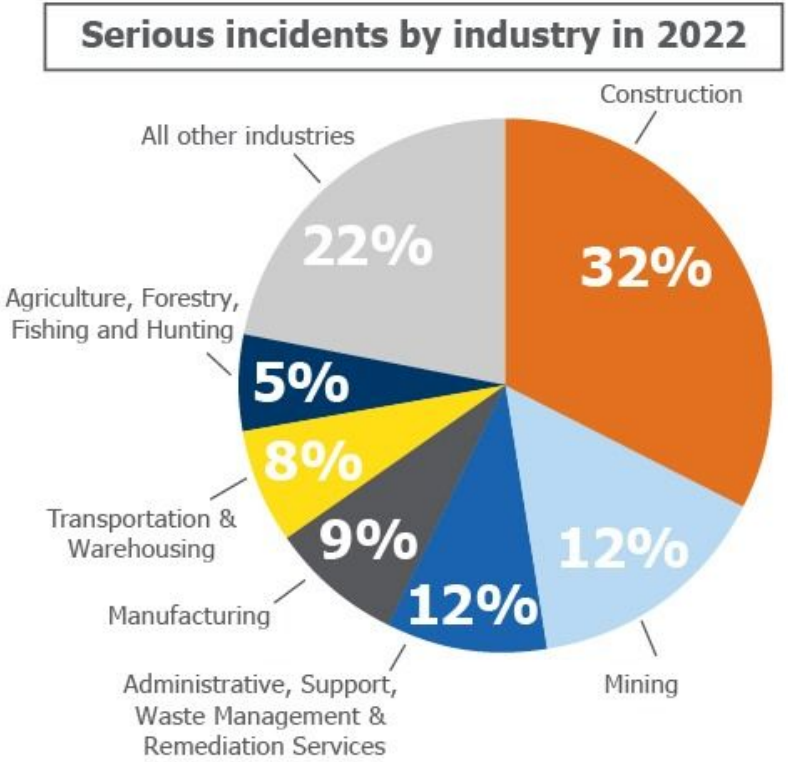
- The construction industry accounts for ~20% of worker deaths in the U.S. annually
- 5,283 fatal work injuries in 2023
- A rate of 3.5 fatalities per 100,000 full-time equivalent workers
- 2.6 million non-fatal injuries reported in 2023

Common Causes of Injury/death

- Falls
- Being struck by objects
- Electrocution
- Environmental Conditions
- Exposure to harmful environments/chemical

Importance of Proactive Safety Monitoring

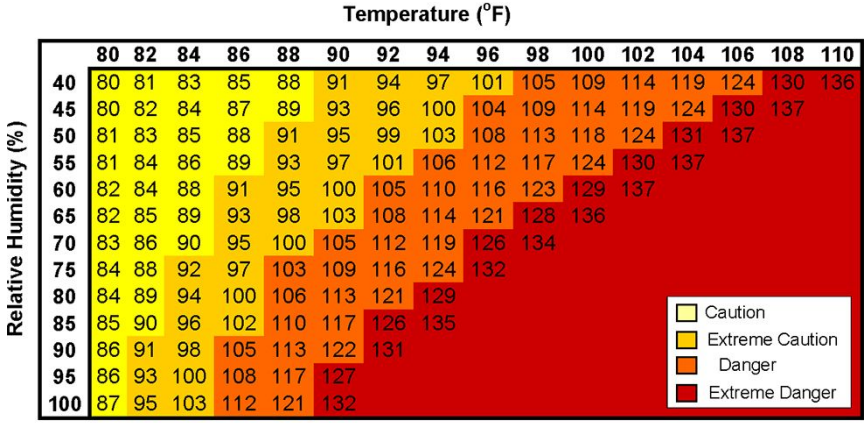
- PPE and protocols help—but environmental awareness is often reactive or insufficient.
- Need for smarter, real-time hazard detection.



https://www.texasmutual.com/blog/posts/2023/01/safety-alert-january-2023

Hazards our system will monitor:

- **Temperature:** Risks of heat exhaustion or hypothermia; OSHA standards require monitoring.
- **Humidity:** High humidity intensifies heat stress and impairs cooling; low humidity can cause respiratory irritation.
- **VOC (Volatile Organic Compounds):** Emitted by construction materials, paints, adhesives—can cause headaches, nausea, long-term organ damage.
- **CO2:** Indicator of poor ventilation; high levels reduce cognitive performance and can cause dizziness, fatigue, or unconsciousness.



Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

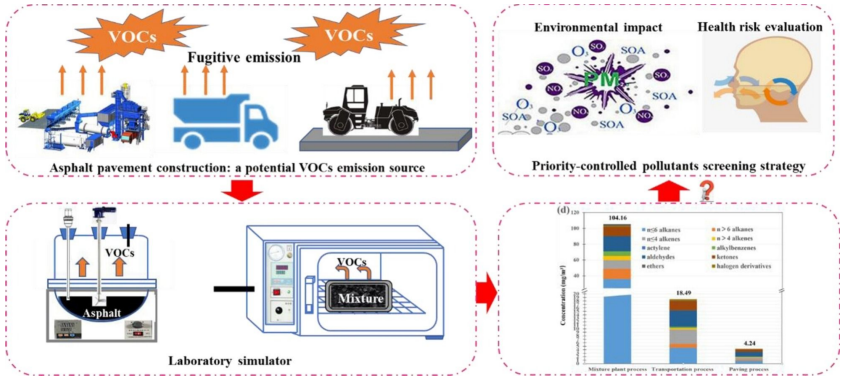
https://www.ohsa.com.au/wp-content/uploads/2017/08/980x510-heatindexchart.png

Why monitor environmental conditions?

- Heat stress, poor air quality, and gas exposure are major health threats, especially in enclosed or hot outdoor environments.

Why real-time alerts matter:

- Environmental changes can be rapid and unpredictable.
- Real-time alerts allow workers to take immediate action—ventilate, hydrate, evacuate, etc



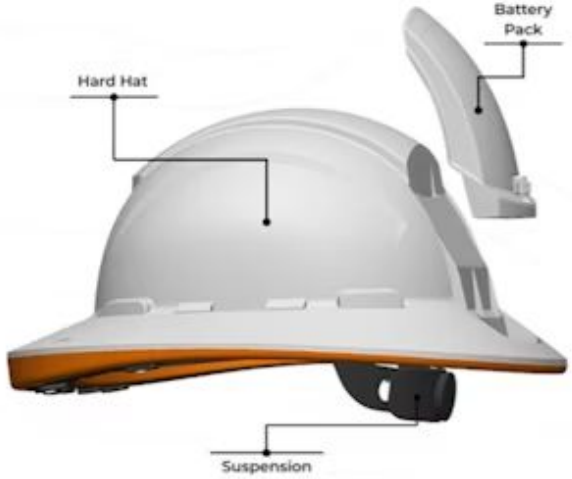
https://www.sciencedirect.com/science/article/pii/S0304389420308931

Existing Models

https://www.dezeen.com/2016/01/27/daqri-smart-construction-helmet-augmented-reality-wearable-technology/

DAQRI Hardhat Sensor

- Augmented reality (AR)
- Sensor Suite
- Visualize data overlays, access remote guidance, and improve situational awareness



https://www.equipmentworld.com/technology/article/15114656/cats-connected-worker-puts-safety-in-a-hard-hat

Guardhat Hardhat Sensor

- Real-time location tracking
- Environmental monitoring
- Fall detection
- Proximity to hazardous zones
- Instintaneous alters

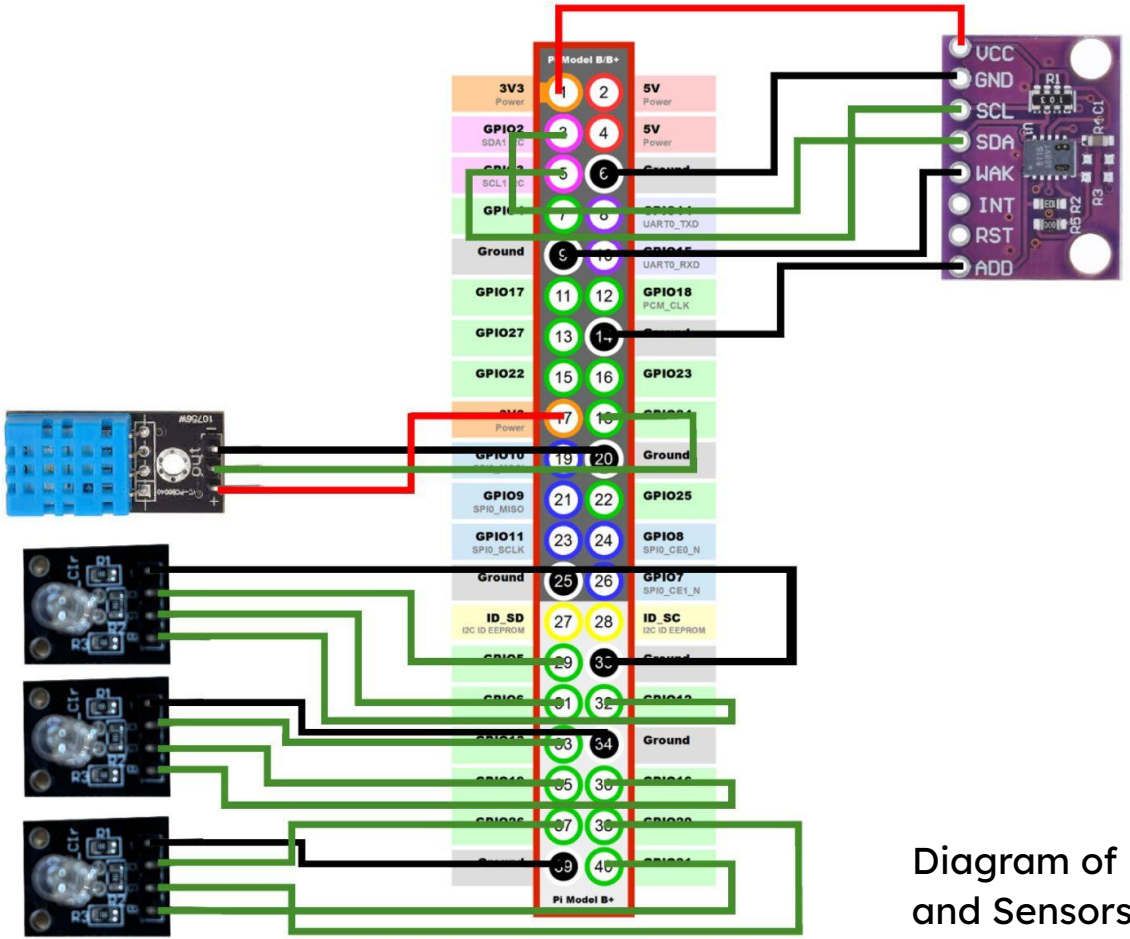
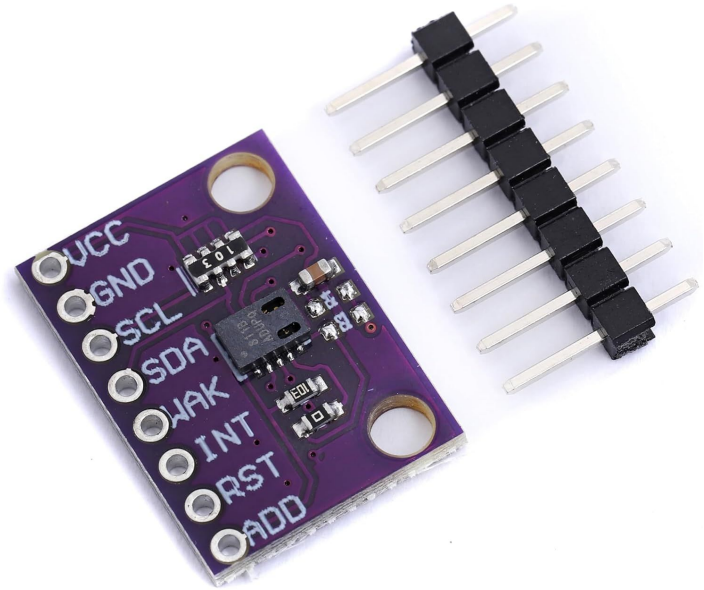


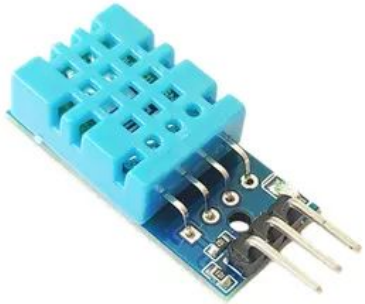
Diagram of Raspberry Pi and Sensors Connections

Tools



CCS811 Air Quality Sensor Module

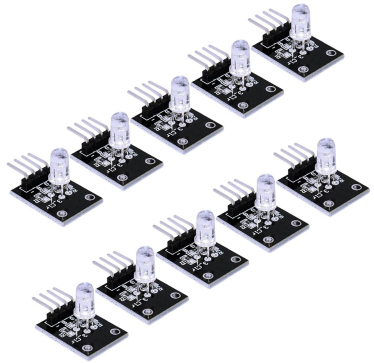
Digital gas sensor solution that measures indoor air quality, specifically detecting levels of total volatile organic compounds (TVOCs) and equivalent CO_2 (eCO_2) concentration



DHT11 Sensor

Detects the temperature and humidity of the space.

Misc. Tools



RGB LED Module

Hardhat

Jumper Wires

Solar Powered Battery Bank

RGB LED MODULE

It is used to display to the user the environmental conditions sensed by the DHT11 and CSS811 sensors.

JUMPER WIRES

Connects the sensors to the Raspberry Pi

SOLAR POWERED BATTERY BANK

Used to power the Raspberry Pi

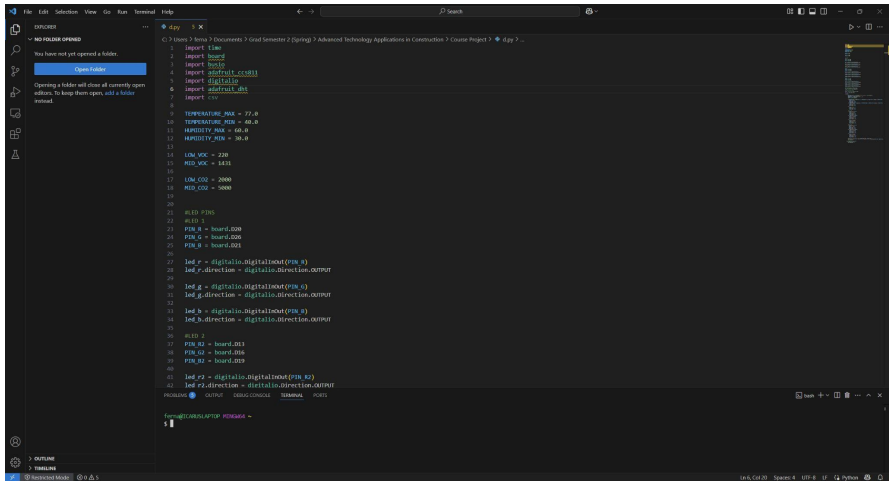
HARDHAT

Holds all of the tools.

VS Code

Visual Studio Code (VS Code):

- Free, Open-source, cross-platform source code
- Developed by Microsoft
- Designed to be lightweight
- Highly customizable interface



Libraries:

- Pip install adafruit-circuitpython-ccs811 pi-sht1x
- Sphinx sphinx-rtd-theme Adafruit-PlatformDetect
- Pip install smbus2
- Pip install adafruit-circuitpython-dht
- Pip install RPi.GPIO
- Pip install adafruit-blinka

Troubleshooting – Checking if CSS 811 Sensor is Connected

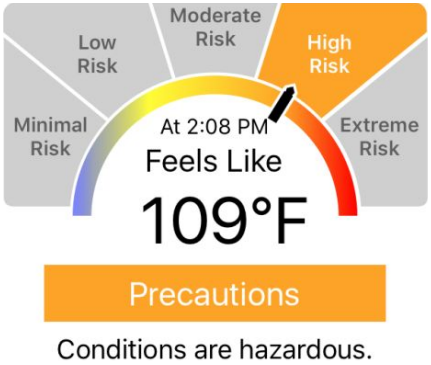
Option 1 ():
Run **sudo i2detect -y 1** and the response after running this should be

```
     0 1 2 3 4 5 6 7 8 9 a b c d e f
00:                         -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- 5a -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

If connected properly, and if it is not connected properly not nothing will appear.

Option 2:
Run **sudo i2cget -y 1 0x5a 0x20** and if the sensor is connected and properly running it should show 0x81 if it is not connected or there is an error it responds as 0xff.

Data Sources



Temperature

While OSHA does not have a specific numerical standards for ideal temperature ranges on construction sites, it does, require workers to be protected from extreme temperatures.

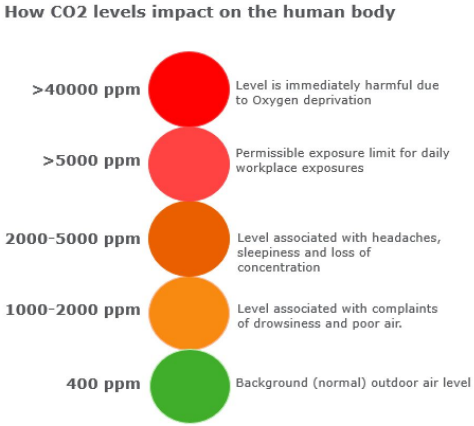
Humidity

While OSHA doesn't have specific humidity standards for construction sites, but it does provide guidance for maintaining comfortable and healthy indoor air quality.

Index Category	Index Value	TVOC (ppb)
Good	0 - 50	0 - 220
Moderate	51 - 100	221 - 660
High	101 - 150	661 - 1430
Very High	151 - 200	1431 - 2200
Very High	201 - 300	2201 - 3300
Very High	301 - 500	3301 - 5500

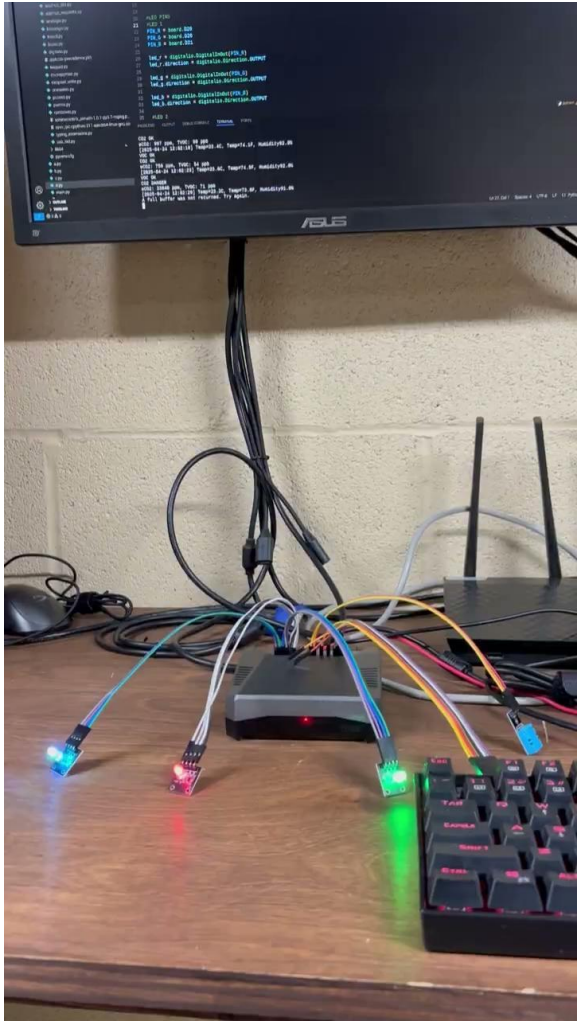
VOCs

OSHA has set specific standards for VOC focusing on worker exposure and hazard control. The standards are measured in permissible exposure limits (PELs) in parts per million.



CO2

OSHA has set a standard for carbon dioxide as 5,000 parts per million (PPM) over an average 8-hour work day. Short term exposure (15 minutes or less) can reach up to 30,000 PPM. 100,000 PPM or higher can be fatal.



Temperature/ Humidity

OSHA recommends a safe temperature range of 40°F-77°F
OSHA recommends a safe humidity range of 30-60
Green Light: 40°F-77°F and humidity 30-60
Blue Light: 40°F-77°F and humidity not 30-60 or temperature not 40°F-77°F and humidity 30-60.
Red Light: Neither temperature or humidity in their respective ranges

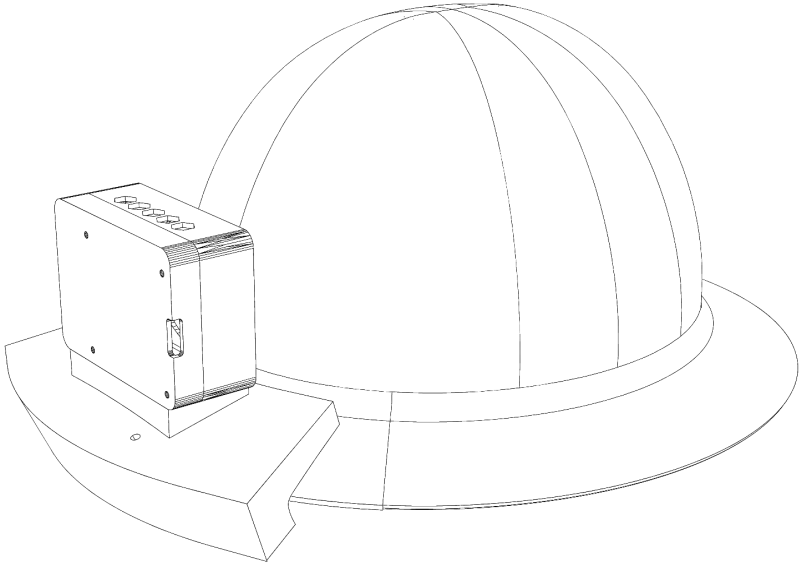
VOC

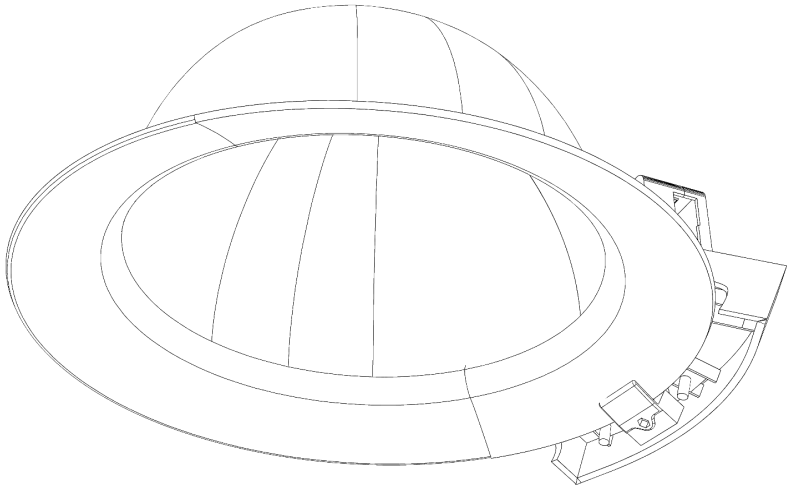
OSHA recommends a safe VOC range of 220-1431
Green Light: 220 or less
Blue Light: 220-1431
Red Light: 1431 or more

CO2

OSHA recommends a safe CO2 range of 2000-5000
Green Light: 2000 or less
Blue Light: 2000-5000
Red Light: 5000 or more

Data Gathered





Hard Hat Safety Sensor Design

Our hard hat safety sensor design uses an engineered clip mechanism to clip to any hard hat. This allows for the sensor to attach to all hardhats without damaging the hat. This reduces costs and increases accessibility. The sensors and raspberry pi is enclosed within a 3D printed case to protect it from the elements without impeding on their ability to operate.

Benefits of Sensors

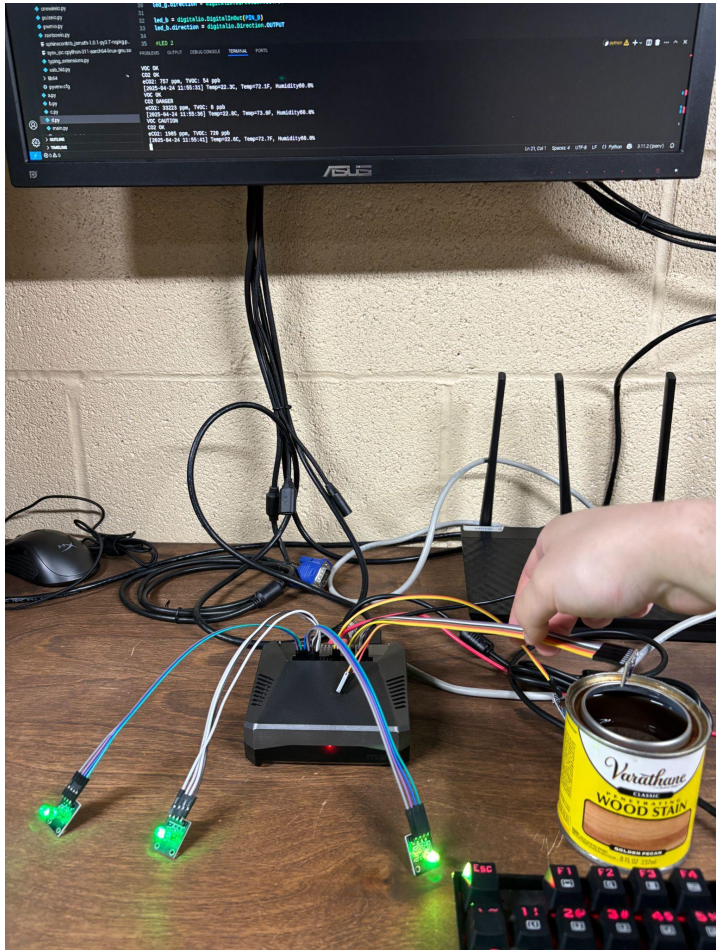
When working the sensors are able to provide reasonably accurate information that gets displayed to the user to see its environmental status.

Issues of the Sensors

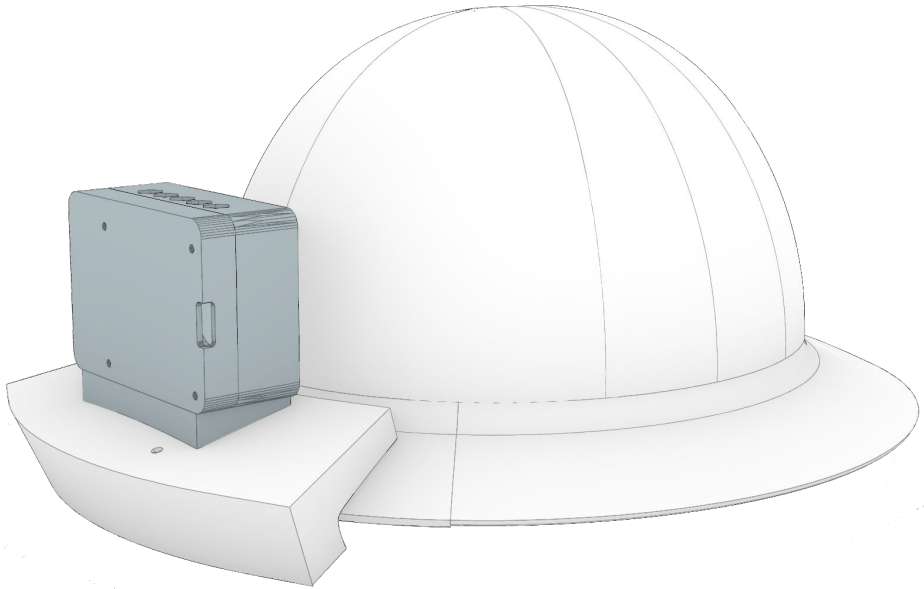
There were issue between between the sensor and the Raspberry Pi Zero 2 W the sensor as there were communication issues through the I2C between the CSS811 sensor and the Raspberry Pi.

Things that Could be Improved

Make so good conditions the RGB LED's are off instead of green so it is less of a distraction to the workers. Find better LED's that can display colors correctly, as the current LED yellow sometimes seems green depending on which direction it is being viewed from.



Conclusion



The Hard Hat Safety Sensor system represents a significant step forward in proactive worker protection on construction sites. By integrating real-time monitoring of environmental hazards such as temperature, humidity, VOCs, and CO_2, our design empowers workers with immediate, visual feedback—helping prevent accidents before they happen. This project not only demonstrates the feasibility of compact, wearable safety tech but also highlights opportunities for continued refinement, including improved sensor integration and enhanced user feedback.

Our solution shows that with accessible components and thoughtful design, we can make safety smarter, more responsive, and more inclusive for everyone in the construction industry.

Thank You

Sources:

- Wheeler, Andrew. “Daqri Is Closing Up Shop.” Engineering.com, 9 Oct. 2019, www.engineering.com/daqri-is-closing-up-shop/.
- OSHA. “ Severe Injury Reports.” Occupational Safety and Health Administration, June 2024, www.osha.gov/severe-injury-reports.
- Espada, Mariah. “Guardhat HC1 Communicator: The 100 Best Inventions of 2020.” Time, Time, 19 Nov. 2020, time.com/collection/best-inventions-2020/5911407/hc-1-communicator/.
- OSHA. 2023. Winter weather - cold stress. Occupational Safety and Health Administration. https://www.osha.gov/winter-weather/cold-stress
- OSHA. (n.d.). Heat - heat hazard recognition. Occupational Safety and Health Administration. https://www.osha.gov/heat-exposure/hazards
- Smith, D. (2024, August 27). Understanding TVOC: What you need to know about volatile organic compounds. Kaiterra. https://learn.kaiterra.com/en/resources/understanding-tvoc-volatile-organic-compounds
- Typical CO2 levels at Home Tester. CO2 Meter. (2024, August 27). https://www.co2meter.com/blogs/news/co2-levels-at-home-tester

AARON ROMBACH, ICARUS FERNANDES, KATELYN OWENS