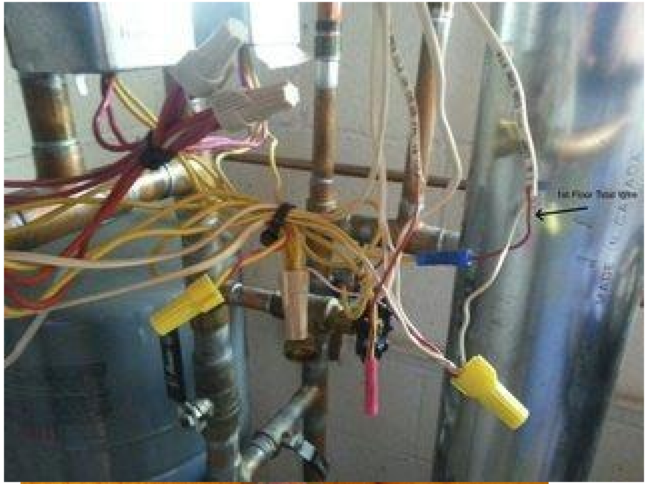
TeachEngineering

Ignite STEM learning in K-12

Indoor Environments and Living Walls

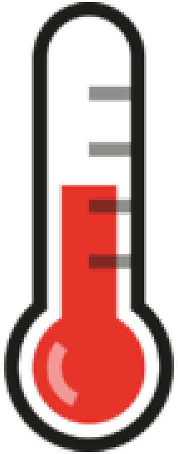
Heating and cooling

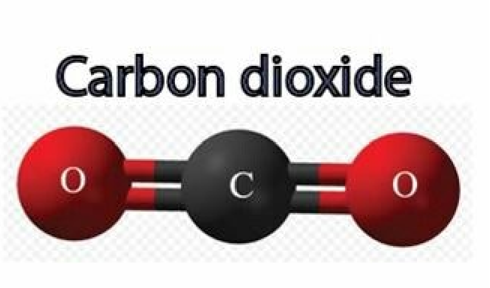
Human comfort



Body heat increases overall room temperature

Temperature, humidity and carbon dioxide



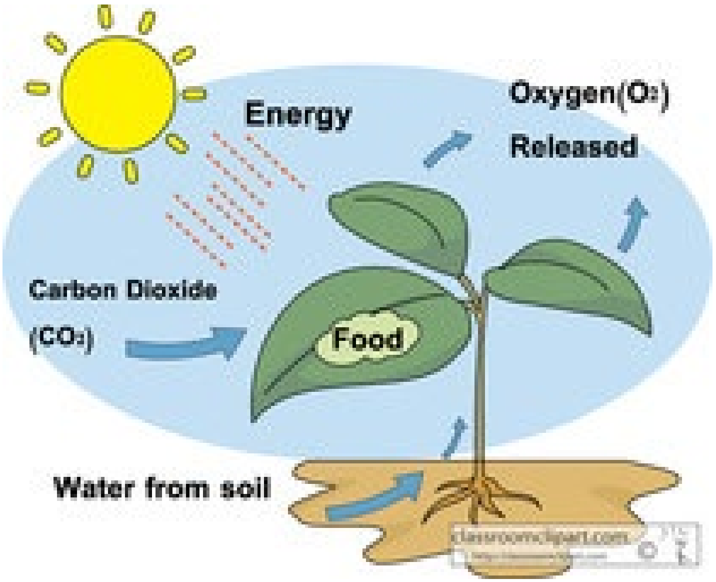


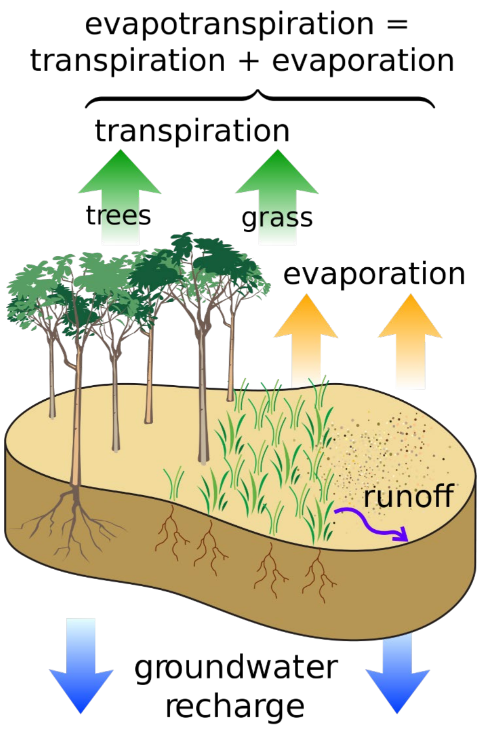
Examples of living walls

https://www.ypsbotanicals.com/gallery/living-wall-projects/

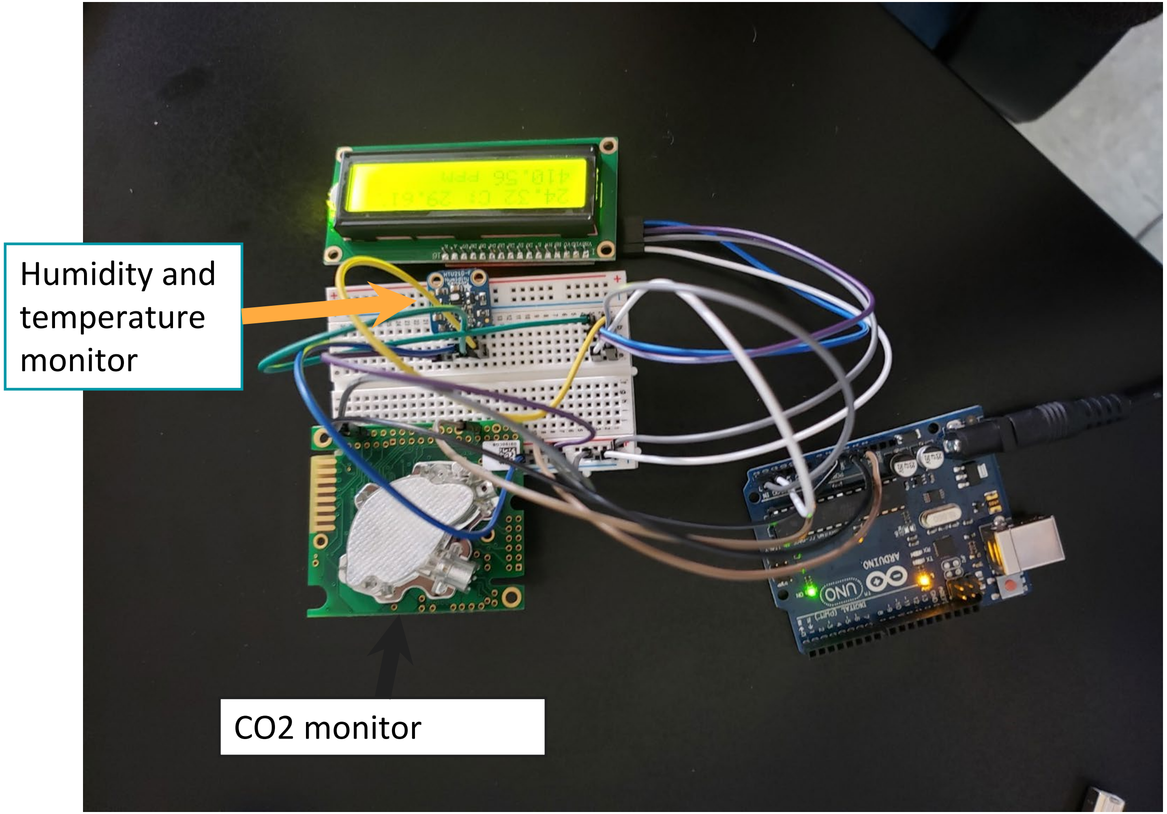
https://livewall.com/

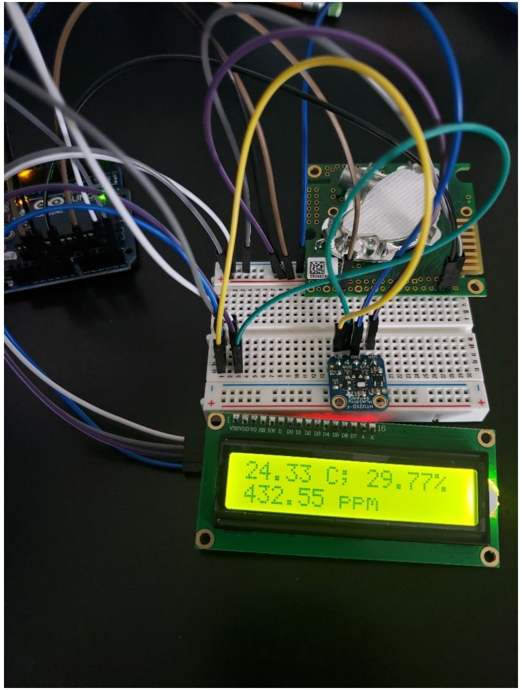
Photosynthesis & evapotranspiration



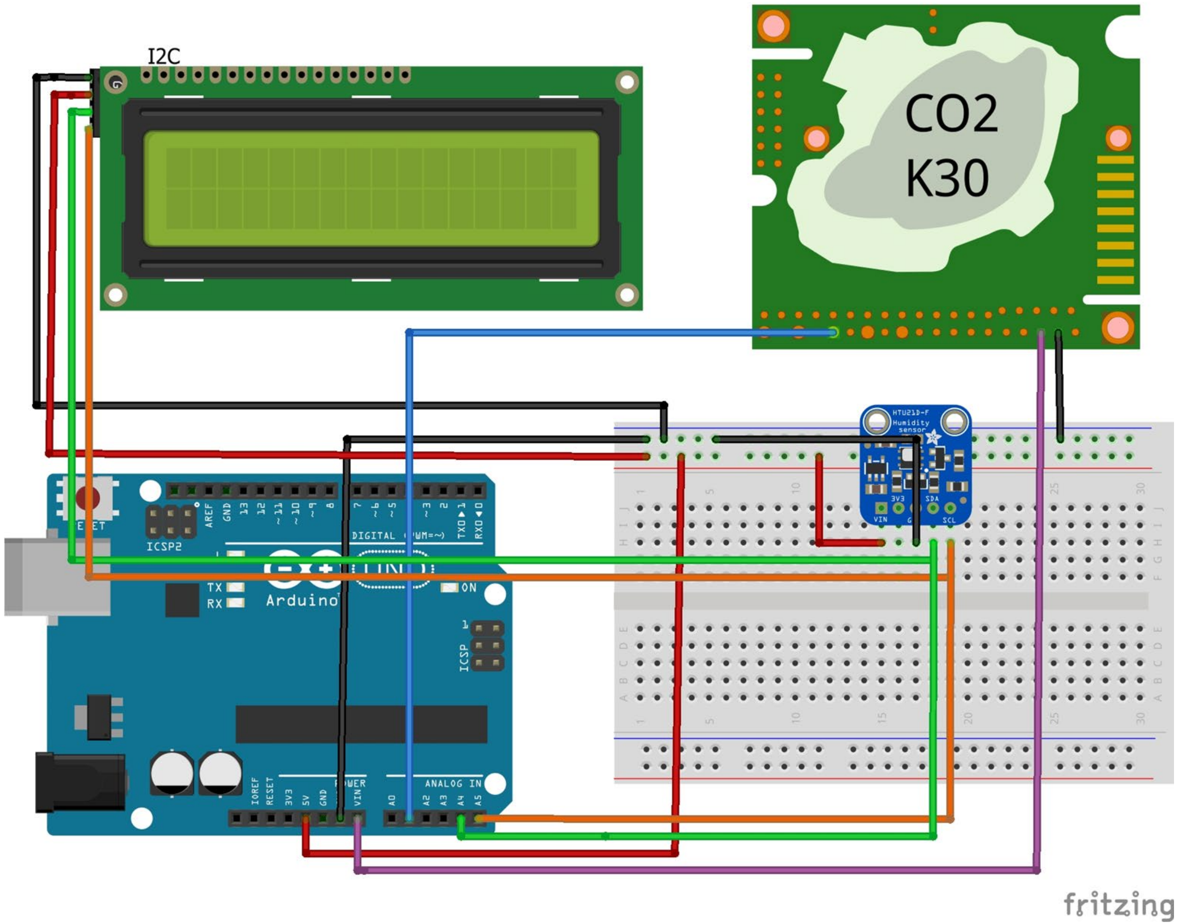


Monitoring with sensors





Fritzing diagram



Living Wall Day 2

Brainstorming

- Where would be a good location for a living wall?
    - Remember: we want it somewhere it could be helpful, for example:
        - Improving the ambient humidity or CO_2 levels
        - Improving aesthetics or as a beautification project
        - What are some other ways a living wall can help an environment?

Observations

- List a few ideal spaces for the living wall, and consider the following questions:
  - What type of light does this area receive?
  - How large of an area is it?
  - Who would get to see it?
  - What do you know about this area in terms of usage?
  - Are there devices that would increase the amount of CO_2 or humidity in this area?
- Now, write a proposal based of this data.

Data gathering

- Using the Arduino that you built to monitor you will need to collect a varied amount of data. You will need at least 30 points of data.
- Calculate the average of temperature, relative humidity, and CO_2. **If you complete this you can calculate the standard deviation of your data.

Average Chart

Location								
Average Temp								
Average RH								
Average CO_2								

Living Wall Day 3

Data analysis

What trends do you see with the chart?

What is it about that location that is the same or different?

Could we graph this data to show the information more clearly?

How to find the right spot?

This website is great for showing where the optimal zone is for relative humidity temperature AND air flow.

Things to know:

- Operative temperature—What is the temperature?
- Air speed—Is there a breeze?
- Humidity—How much water is in the air?

https://comfort.cbe.berkeley.edu/

Example: Regulations Data Table for CO_2

TABLE C-1 Comparison of Regulations and Guidelines Pertinent to Indoor Environments [a]
(The user of any value in this table should take into account the purpose for which it was adopted and the means by which it was developed.)

	Enforceable and/or Regulatory Levels			Nonenforced Guidelines and Reference Levels			
	NAAQS/EPA (Ref. C-4)	OSHA (Ref. C-5)	MAK (Ref. C-2)	Canadian (Ref. C-8)	WHO/Europe (Ref. C-11)	NIOSH (Ref. C-13)	ACGIH (Ref. C-1)
Carbon dioxide		5000 ppm	5000 ppm 10,000 ppm [1 h]	3500 ppm [L]		5000 ppm 30,000 ppm [15 min]	5000 ppm 30,000 ppm [15 min]
Carbon monoxide [c]	9 ppm [g] 35 ppm [1 h] [g]	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8 h] 25 ppm [1 h]	90 ppm [15 min] 50 ppm [30 min] 25 ppm [1 h] 10 ppm [8 h]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde [h]		0.75 ppm 2 ppm [15 min]	0.3 ppm 1 ppm [i]	0.1 ppm [L] 0.05 ppm [L] [b]	0.1 mg/m^3 (0.081 ppm) [30 min] [p]	0.016 ppm 0.1 ppm [15 min]	0.3 ppm [C]
Lead	1.5 $\mu g/m^3$ [3 months]	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30 min]	Minimize exposure	0.5 $\mu g/m^3$ [1 yr]	0.050 mg/m^3	0.05 mg/m^3
Nitrogen dioxide	0.05 ppm [1 yr]	5 ppm [C]	5 ppm 10 ppm [5 min]	0.05 ppm 0.25 ppm [1 h]	0.1 ppm[1 h] 0.02 ppm [1 yr]	1 ppm [15 min]	3 ppm 5 ppm [15 min]
Ozone	0.12 ppm [1 h] [g] 0.08 ppm	0.1 ppm	j	0.12 ppm [1 h]	0.064 ppm (120 $\mu g/m^3$) [8 h]	0.1 ppm [C]	0.05 ppm[k] 0.08 ppm[l] 0.1 ppm [m] 0.2 ppm [n]
Particles [e] <2.5 µm MMAD [d]	15 $\mu g/m^3$[1 yr] [o] 35 $\mu g/m^3$ [24 h] [o]	5 mg/m^3	1.5 mg/m^3 for <4 µm	0.1 mg/m^3 [1 h] 0.040 mg/m^3 [L]			3 mg/m^3 [C]
Particles [e] <10 µm MMAD [d]	150 $\mu g/m^3$ [24 h] [o]		4 mg/m^3				10 mg/m^3 [C]
Radon				800 Bq/m^3 [1 yr]			
Sulfur dioxide	0.03 ppm [1 yr] 0.14 ppm [24 h] [g]	5 ppm	0.5 ppm 1 ppm [i]	0.38 ppm [5 min] 0.019 ppm	0.048 ppm [24 h] 0.012 ppm [1 yr]	2 ppm 5 ppm [15 min]	2 ppm 5 ppm [15 min]
Total particles [e]		15 mg/m^3					

a. Numbers in brackets [ ] refer to either a ceiling or to averaging times of less than or greater than eight hours (min = minutes; h = hours; y = year; C = ceiling, L = long-term). Where no time is specified, the averaging time is eight hours.
b. Target level is 0.05 ppm because of its potential carcinogenic effects. Total aldehydes limited to 1 ppm. Although the epidemiological studies conducted to date provide little convincing evidence that formaldehyde is carcinogenic in human populations, because of this potential, indoor levels should be reduced as much as possible.
c. As one example regarding the use of values in this table, readers should consider the applicability of carbon monoxide concentrations. The concentrations considered acceptable for nonindustrial, as opposed to industrial, exposure are substantially lower. These lower concentrations (in other words, the ambient air quality standards, which are required to consider populations at highest risk) are set to protect the most sensitive subpopulation, individuals with pre-existing heart conditions.
d. MMAD = mass median aerodynamic diameter in microns (micrometers). Less than 3.0 µm is considered respirable; less than 10 µm is considered inhalable.
e. Nuisance particles not otherwise classified (PNOC), not known to contain significant amounts of asbestos, lead, crystalline silica, known carcinogens, or other particles known to cause significant adverse health effects.
f. See Table C-2 for the U.S. EPA guideline.
g. Not to be exceeded more than once per year
h. The U.S. Department of Housing and Urban Development adopted regulations concerning formaldehyde emissions from plywood and particleboard intended to limit the airborne concentration of formaldehyde in manufactured homes to 0.4 ppm. (24 CFR Part 3280, HUD Manufactured Home Construction and Safety Standards). In addition, California Air Resources Board Regulation §93120, entitled "Airborne Toxic Control Measure to Reduce Formaldehyde Emissions from Composite Wood Products" has specific chamber-based requirements for composite wood products sold in California [C-47].
i. Never to be exceeded
j. Carcinogen, no maximum values established
k. TLV for heavy work

Recommendations

Industry standards recommend that a level of 1000 ppm carbon dioxide not be exceeded in classrooms.

WHY?

1. Higher levels of CO_2 have been found to positively correlate with increased student sickness and absenteeism.
2. High CO_2 levels are indicative of poor air circulation that also results in high levels of dust, dander, germs, microbes and other particles.
3. High levels of CO_2 in an enclosed area reduces the amount of oxygen to the brain resulting in drowsiness and poor student performance.

Sources: https://www.uft.org/your-rights/safety-health/environmental-health-and-safety/building-hazards/carbon-dioxide
https://www.trane.com/commercial/Uploads/PDF/520/ISS-APG001-EN.pdf
https://www.co2meter.com/blogs/news/7334762-indoor-air-quality-ihe-classroom

Where should the living wall go?

Location								
Average Temp								
Average RH								
Average CO_2								

Your assignment is now to use the data the entire class used and write an argument where you think this wall should go!

Please type your response. It should be clearly stated what location your choice is. You will need to support your choice using the data collected. Explain in detail how/why you have come to your decision. You may also choose to do more research and add that into your response for evidence. Cite your sources.