Great Basin Unified
Air Pollution Control District

AB 617 Grant Report
Community Air Protection Program

Final Grant Report for G18-CAPP-11

Fiscal Years 18/19, 19/20, 20/21
Grant Term 2019-2021

Report Date: June 25, 2021

Prepared by
Chris Howard

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1.0 District's AB617 Annual Report – 2019-2021 Grant

As described in the Community Air Protection Blueprint (October 2018), the Great Basin Unified Air Pollution Control District's (District) goal for the program is to conduct community-level air quality monitoring, especially in those communities where little or no air quality monitoring has been conducted in the past. The District, though low in population density (2 persons/square mile), nonetheless has concerns that the air pollution impacts to those rural communities need to be evaluated. The AB617 program grant award has provided the resources to address this need. This document constitutes the District's final report for the G18-CAPP-11 grant. Prior annual reports related to this grant are appendices to this report. This report covers the time period from January 16, 2021 to June 30, 2021.

2.0 Background and Previous Work Completed

The following summarizes the activities documented in the prior two annual reports.

2019 Work Completed:

- Developed community monitoring program.
- Installed Purple Airs in five (5) strategic communities: Benton, Big Pine, Bishop, Markleeville, and Woodfords.
- Provided public outreach through development of the Low-cost Sensor webpage and public presentations.
- Development of Zero-air kit to quality control Purple Airs prior to deployment.

2020 Work Completed:

- Sensor maintenance and quality assurance.
- Purple Air installation at ten (10) additional communities, bringing the total to fifteen (15).

3.0 Summary of Current Work Completed

2021 Work Completed:

From January 16, 2021 to June 30, 2021 the following tasks associated with the Community Monitoring program were completed.

Work in the prior two years established a geographically and strategically placed network of low-cost air quality monitors (Purple Airs) in communities throughout Inyo, Mono, and Alpine Counties. The program continued in 2021 to perform maintenance on the Purple Air deployments, which included laser counter replacement and interfacing with Purple Air hosts to troubleshoot connectivity issues.

Recognizing the extensive buildout of the Purple Air network in communities throughout the District, we turned our attention to an underserved sector of the population: recreationalists. The Eastern Sierra is home to world-renowned rugged terrain offering numerous hiking, cycling, and

climbing opportunities. Often, these heavily trafficked recreation areas are challenging to monitor due to their remote locations in mountainous terrain. These locations frequently lack power service and/or cellular service. Some of the recreation areas, such as Whitney Portal and Tioga Pass, the east gate to Yosemite National Park, often see hundreds or thousands of people per day. In addition, when wildfire smoke fills the valleys, these recreation areas are often above the smoke and are used by residents and visitors as clean air refuges.

To monitor and broadcast air quality in these remote locations, GBUAPCD staff designed and constructed an air quality monitor capable of operating without line power or cellular service. These remote-deployable devices are based on Purple Air sensors and will be seasonally deployed to areas popular with recreationalists. In addition, these remote-deployable devices will be used to monitor prescribed burns adjacent to communities. Funds allocated in this grant funding cycle allowed for the design, acquisition, and construction of two remote-deployable devices. We anticipate the construction of additional units in forthcoming grant funding cycles. The attached Appendix C is a detailed GBUAPCD whitepaper on the design and construction of the remote-deployable devices.

4.0 Program Costs: January 16, 2021- June 2021

This document covers the time period from January 16, 2021 to June 30, 2021. Disbursement of the remaining funds in this grant were requested and provided in March 2021 in the amount of $23,548.09. All funds provided in this grant were expended during the grant period.

COSTS	
Staff Hours *Please see Attachment A for details*	$10,709.28
Additional Expenses (Travel, Sensors, Supplies) etc. *Please see Attachment B for details*	$13,471.78
Total Cost Performed by District for this period	$24,181.06

- The total G18-CAPP-11 grant has funds for $36,994.00.
    - The first disbursement request was for $3,714.34.
    - The second disbursement request was for $9,731.57.
    - The remaining funds were disbursed in March 2021, $23,548.09.
    - The costs spent toward the $23,548.09 was $24,181.06, an in-kind overage of $632.97.
- Billing toward G19-CAPP-11 and G20-CAPP-11 has not yet commenced. It is anticipated that billing toward G19-CAPP-11 will commence July 1, 2021.

ATTACHMENT A- Staff Time and Expense Details

AB 617 Staff Hours January 16, 2021 to June 30, 2021

Pay Period (only payperiods with hours shown)	Ann Logan		Kim Mitchell		Chris Lanane		Chris Howard		Travis Powell	
	HOURS	COST	HOURS	COST	HOURS	COST	HOURS	COST	HOURS	COST
1/16-1/31/21	5	$399.60	0	$0.00	0	$0.00	2	$159.84	0	$0.00
2/1-2/15/21	0	$0.00	0	$0.00	0	$0.00	1	$79.92	0	$0.00
2/16-2/28/21	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
3/1-3/15/21	0	$0.00	0	$0.00	0	$0.00	0	$0.00	15	$1,198.80
3/16-3/31/21	0	$0.00	0	$0.00	0	$0.00	15	$1,198.80	12	$959.04
4/1-4/15/21	0	$0.00	0	$0.00	0	$0.00	3	$239.76	13	$1,038.96
4/16-4/30/21	0	$0.00	0	$0.00	0	$0.00	0	$0.00	5	$399.60
5/1-5/15/21	0	$0.00	0	$0.00	0	$0.00	2	$159.84	10	$799.20
5/16-5/31/21	0	$0.00	0	$0.00	0	$0.00	0	$0.00	12	$959.04
6/1-6/15/21	0	$0.00	0	$0.00	0	$0.00	6	$479.52	11	$879.12
6/16-6/30/21	0	$0.00	0	$0.00	0	$0.00	12	$959.04	10	$799.20
SUBTOTALS	*5*	*$399.60*	*0*	*$0.00*	*0*	*$0.00*	*41*	*$3,276.72*	*88*	*$7,032.96*

TOTAL STAFF HOURS	**134**	FY 19/20 Staff Hourly Rate $75.67 (Jan 1 to June 30, 2020)
TOTAL STAFF COST	**$10,709.28**	FY 20/21 Staff Hourly Rate $79.92 (July 1, 2020 to Jan 30, 2021)

ATTACHMENT B - Staff Time and Expense Details			
AB 617 Expenses January 16, 2021 to June 30, 2021			
Date	Cost	Category	Details
2/3/2021	$3,030.42	Equipment	10 Purple Airs & counter pairs (CBH) PO2020/21-50CBH
4/12/2021	$124.74	Equipment	Amazon, cables, routers, power supply adapter (TP) c/c
4/12/2021	$1,537.19	Equipment	Renogy - Batteries, connectors, panel (TP) c/c PO2020/21-72TP
4/13/2021	$661.45	Equipment	INS - Sierra wireless airlink Raven (TP)
4/14/2021	$179.24	Equipment	DigiKey, connectors, adapters
4/20/2021	$1,326.75	Equipment	Ground Control - Hughes 9502 M2M BGAN terminal & antennas
4/20/2021	$510.47	Equipment	Solar Panel Store- Solar panel, battery box (TP)
4/23/2021	$114.62	Equipment	Adafruit, cables for rasperri pi
4/23/2021	$19.36	Equipment	Adafruit, cables for rasperri pi
4/23/2021	$111.88	Equipment	Amazon, 10 AWG/gauge, screws
4/23/2021	$97.86	Equipment	Amazon, 10 AWG/gauge, screws
5/6/2021	$38.31	Equipment	Adafruit, cable, raspberry pi
5/7/2021	$55.43	Equipment	Amazon, electronics for raspberry pi, power supply adapter
5/14/2021	$75.43	Equipment	ground Control - Hughes 9502 IDU strap & Cable
5/14/2021	$16.95	Equipment	Adafruit, cable, sensor
5/14/2021	$8.30	Equipment	ACE, screws
5/17/2021	$2.26	Equipment	ACE, screws
5/19/2021	$31.49	Equipment	Amazon, DROK voltage regulator
5/21/2021	$100.24	Equipment	McMaster-Carr screws,aluminum sheet (GD) for TP
5/25/2021	$40.31	Equipment	McMaster-Carr screws,aluminum sheet
5/25/2021	$7.62	Equipment	Verizon, telemetry line start up
5/26/2021	$1,502.72	Equipment	Campbell Scientific, tripod, enclosure
5/20/2021	$461.52	Equipment	INS - PO2020/21-80TP antenna, cables
6/2/2021	$23.91	Equipment	Amazon, DROK voltage regulator
6/2/2021	$70.72	Equipment	Adafruit, OLED display Stemma
6/3/2021	$9.78	Equipment	Amazon, USB cable charger
6/9/2021	$49.57	Equipment	Adafruit, Sensor & cable
6/11/2021	$38.88	Equipment	Adafruit, Sensor & cable
6/14/2021	$28.14	Equipment	Amazon, connectors
6/14/2021	$41.42	Equipment	Amazon, IP67 connector
6/14/2021	$19.46	Equipment	Amazon, 2pin connector
6/16/2021	$16.29	Equipment	Amazon, 3-pk short USB ext cable
6/22/2021	$41.42	Equipment	Amazon, USB3.0 circular connector
6/22/2021	$38.92	Equipment	Amazon, 2pin connector
6/23/2021	$140.16	Equipment	Adafruit, connectors, cables
6/24/2021	$1,511.09	Equipment	Campbell Scientific, tripod, enclosure
6/24/2021	$1,387.46	Equipment	Renogy - Batteries, connectors, panel (TP) c/c PO2020/21-72TP
	$13,471.78	**Total Expenses**	

Great Basin Unified Air Pollution Control District

AB 617 Grant Report
Community Air Protection Program

Annual Grant Report for G18-CAPP-11

Fiscal Grant Term 2019-2021 Grant
Fiscal Year 18/19

Report Date: January 31, 2020
Revised: February 5, 2020

Prepared by
Ann Logan, Christopher Lanane

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1.0 District's AB617 Annual Report – 2019-2021 Grant

As described in the Community Air Protection Blueprint (October 2018), the Great Basin Unified Air Pollution Control District's (District) goal for the program is to conduct community-level air quality monitoring, especially in those communities where little or no air quality monitoring has been conducted in the past. The District, though low in population density (2 persons/square mile), nonetheless has concerns that the air pollution impacts to those rural communities need to be evaluated. The AB617 program grant award has provided the resources to address this need. This document constitutes the District's first annual report for the 2019-2021 grant covering from February to December 2019. The steps taken during this period while implementing the program are described in detail below.

2.0 Background

In 2018, the District outlined a community monitoring program. The first step in the process of designing the monitoring portion of the community air protection program involved the identification of communities by District staff in which monitoring would be conducted. The next step was the development of a set of criteria that would be used to determine when monitoring would be conducted in a given community. The District developed a ranking system, based on the criteria, to aid in the decision-making process for monitor deployment. Communities identified as the highest priority were ranked as Tier 1 locations. The criteria developed by the District to aid in ranking the communities for monitor deployment are as follows:

a) What communities have had little or no monitoring in the surrounding area?
b) What communities have experienced the highest particulate matter (PM) impacts either from windblown dust and/or from wildfires?
c) What communities have expressed concerns about those impacts?
d) What communities have a public space, e.g., school, day-care center, fire station, where a PM monitor could be installed?
e) What communities/public spaces have consistent line power and internet service for the PM monitor?
f) What communities/public spaces are receptive to such an installation?

In 2018, the District deployed Purple Air PA-II PM sensors in the following community locations based on the District's criteria:

1. Benton, Mono County
2. Big Pine, Inyo County
3. Bishop, Inyo County
4. Markleeville, Alpine County
5. Woodfords, Alpine County

The Purple Air PA-II-SD sensors, which contain an SD card, were procured by the District for installation at existing District PM monitoring stations to use as quality control check sensors for the community monitoring network. Some of these locations are also within communities and provide additional data to permanent monitoring stations. These sensors have been deployed at the following sites:

1. Bishop/NCORE Monitoring Station, White Mountain Research Center, Inyo County
2. Keeler Monitoring Station, Keeler, Inyo County
3. Lee Vining Monitoring Station, Lee Vining, Mono County
4. Mammoth Monitoring Station, Mammoth Lakes, Mono County

3.0 Summary of Work Completed and Work in Progress

From February 2019- December 2019 the following tasks associated with the Community Monitoring program were completed or work was started.

- **Communication and Public Outreach**
  In 2018, District staff developed a webpage specific to the Community Air Protection Program and the District's use of low-cost sensors. The page provides an explanation of the purpose and limitations of low-cost sensors. Additionally, it has a link to all sensor data within the District boundaries. In 2019, District staff have shared this resource at Governing Board meetings, with other agencies' public information officers, and interested members of the public. Additionally, the sensor data are used in conjunction with permanent and portable District monitors and other resources for health advisories and in providing real time data to the public. District staff continues to work on a routine basis to ensure this webpage is up to date and that all of the District's sensors are active and reporting data.

- **Sensor Maintenance**
  In 2019, several sensors required replacement or maintenance. Issues have ranged from complete failure, to divergence of sensor channels to connection and reporting issues. District staff was responsive to identifying and resolving all issues in 2019 to ensure the community monitors were active.

- **Development of Zero Air Test Kit and Quality Assurance Work**
  District monitoring staff developed, tested and implemented a Zero Air Test Kit for use with the Purple Air sensors in response to issues with the divergence of the sensor channels from each other and after subsequent discussions with Air Quality researcher Jim Ouimette. The Test Kit allows for a basic level of quality assurance verification before sensor deployment or in responses to observed divergences in the channels within each sensor. Several sensors that displayed issues were tested and under zero air conditions still displayed a divergence in concentrations between channels and were then returned to the manufacturer. In the future, all sensors to be deployed will be tested prior to installation to ensure that the sensors to be deployed in community locations are ready to provide reliable data. Additional work has also occurred in 2019 to compare the low cost sensor data to the data collected from the District's FRM/FEM monitors.

- **Additional Monitoring Locations**
  Staff identified additional communities where monitors have not yet been deployed that may be suitable candidates. More planning to develop plans and timelines will occur in the Spring of 2020, with additional sensor deployments occurring shortly thereafter.

4.0 Program Costs February - December 2019

This document covers the time period from grant execution, February 2019, to December 2019. A grant disbursement request form is being submitted along with this report.

Task	Staff Time Worked (Feb- Dec 2019)	Cost
Staff hours (billed at $72.6423 per hour for all staff) • Sensor equipment and site maintenance • Development, Testing and Implementation of Zero Air test kit • Data management, analysis and FRM/FEM comparison • Website Updates/Revisions • Planning Meetings	47	$3414.19
Additional Expenses (Mounting equipment, installation materials, Zero air Test kit, Travel) etc.	n/a	$ 300.15
Total Cost Performed by District for this period	--	$3,714.34
Invoiced to CARB	--	**$3,714.34**

The 2019-2021 grant has funds for $36,994.00. This will be the first disbursement request. Following disbursement there will be $33,279.66 remaining in the grant funds.

Great Basin Unified Air Pollution Control District

AB 617 Grant Report
Community Air Protection Program

Annual Grant Report for G18-CAPP-11

Fiscal Year 18/19
Grant Term 2019-2021

Report Date: January 27, 2021

Prepared by
Ann Logan

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As described in the Community Air Protection Blueprint (October 2018), the Great Basin Unified Air Pollution Control District's (District) goal for the program is to conduct community-level air quality monitoring, especially in those communities where little or no air quality monitoring has been conducted in the past. The District, though low in population density (2 persons/square mile), nonetheless has concerns that the air pollution impacts to those rural communities need to be evaluated. The AB617 program grant award has provided the resources to address this need. This document constitutes the District's second annual report for the G18-CAPP-11 grant. This report covers the time period from January 1, 2020 to January 15, 2021.

2.0 Background and Previous Work Completed

In 2018, the District outlined a community monitoring program including the identification of communities by District staff in which monitoring would be conducted and the development of a set of criteria that would be used to determine when monitoring would be conducted in a given community. In 2018 and 2019, the District deployed Purple Air PA-II PM sensors in twelve locations including communities and at existing District PM monitoring stations to use as quality control check sensors for the community monitoring network. The District also developed a webpage specific to the Community Air Protection Program and the District's use of low-cost sensors. Additional work included sensor maintenance, quality assurance work with the sensors, development of a zero air test kit and work to identify additional monitoring locations. Additional details can be found in previous grant reports.

3.0 Summary of Work Completed and Work in Progress

From January 1, 2020 to January 15, 2021 the following tasks associated with the Community Monitoring program were completed or work was started.

- **Sensor Maintenance and Quality Assurance Work**
  In 2020, several sensors required replacement or maintenance. Issues have ranged from complete failure, to divergence of sensor channels, to connection and reporting issues. District staff was responsive to identifying and resolving all issues in 2020 to ensure the community monitors were active. Additional work has also occurred in 2020 to compare the low cost sensor data to the data collected from the District's FRM/FEM monitors.

- **New Monitoring Locations**
  In 2020, Purple Air sensors were deployed in the following 15 community locations:

Location	*County*	*Site Name*	*Deployment Date*
Pickel Meadows	Mono	MWTC - Pickel Meadows	9/5/20
Aspendell	Inyo	Aspendell	9/16/2020
Bishop/Meadowcreek	Inyo	Meadowcreek	10/7/2020
Chalfant	Mono	Chalfant Big Trees	10/8/2020
Death Valley	Inyo	Cow Creek DVNP	10/9/2020
Crowley Lake	Mono	CrowleyLake	10/14/2020
Olancha	Inyo	Olancha	10/15/2020
Fort Independence	Inyo	Fort Independence	10/16/2020
Starlite	Inyo	Starlite	10/16/2020
Deep Springs College	Inyo	Deep Springs College	10/27/2020
Alabama Hills	Inyo	AlabamaHills	11/6/2020
Lone Pine	Inyo	Lone Pine Monitor	11/12/2020
Lone Pine Downtown	Inyo	Lone Pine Downtown	12/9/2020
Round Valley	Inyo	Round Valley	12/29/2020
Coso Junction	Inyo	Coso Junction	10/15/2020 (V1) 10/22/2020 (V2)

  Staff have identified a few remaining community locations with the District and will work to deploy sensors in the coming year.

4.0 Program Costs January 2020- January 2021

This document covers the time period from January 1, 2020 to January 15, 2021. A grant disbursement request form is being submitted along with this report.

COSTS	
Staff Hours *Please see Attachment A for details*	$8,634.16
Additional Expenses (Travel, Sensors, Supplies) etc. *Please see Attachment A for details*	$ 1,097.41
Total Cost Performed by District for this period	$9,731.57
Invoiced to CARB	**$9,731.57**

The G18-CAPP-11 grant has funds for $36,994.00.
The first disbursement request was for $3,714.34.
This is the second disbursement request.
Following this disbursement there will be $23,548.09 remaining in the grant funds.

ATTACHMENT A- Staff Time and Expense Details

AB 617 Staff Hours January 1, 2020 to January 15, 2021

Pay Period (only payperiods with hours shown)	Ann Logan		Kim Mitchell		Chris Lanane		Chris Howard		Travis Powell	
	HOURS	COST	HOURS	COST	HOURS	COST	HOURS	COST	HOURS	COST
1/16-1/31/20	3	$227.01	0.5	$37.84	0	$0.00	0	$0.00	0	$0.00
4/16-4/30/20	0	$0.00	0	$0.00	1.5	$113.51	0	$0.00	0	$0.00
5/1-5/15/20	3.5	$264.85	0	$0.00	2	$151.34	0.75	$56.75	16	$1,210.72
6/1-6/15/20	2	$151.34	0	$0.00	0	$0.00	0	$0.00	0	$0.00
6/16-6/30/20	0	$0.00	0	$0.00	0	$0.00	0	$0.00	3	$227.01
10/1-10/15/20	0	$0.00	0	$0.00	0	$0.00	20	$1,598.40	15	$1,198.80
10/16-10/31/20	2.5	$199.80	0	$0.00	0	$0.00	6	$479.52	8	$639.36
11/1-11/15/20	2	$159.84	0	$0.00	0	$0.00	4	$319.68	0	$0.00
12/1-12/15/20	0	$0.00	0	$0.00	0	$0.00	5	$399.60	0	$0.00
12/16-12/31/20	0	$0.00	0	$0.00	0	$0.00	4.5	$359.64	0	$0.00
1/1-1/15/21	7.5	$599.40	0	$0.00	0	$0.00	3	$239.76	0	$0.00
SUBTOTALS	*20.5*	*$1,602.24*	*0.5*	*$37.84*	*3.5*	*$264.85*	*43.25*	*$3,453.35*	*42*	*$3,275.89*

TOTAL STAFF HOURS	**109.75**
TOTAL STAFF COST	**$8,634.16**

FY 19/20 Staff Hourly Rate $75.67 (Jan 1 to June 30, 2020)
FY 20/21 Staff Hourly Rate $79.92 (July 1, 2020 to Jan 15, 2021)

AB 617 Expenses

Date	Cost	Category	Details
10/16/20	$32.66	Travel	Gas for Purple Air Installation in Independence
10/16/20	$41.10	Travel	Gas for Sensor Install/Maintenance
11/25/20	$203.06	Supplies	Supplies to repair existing units
11/25/20	$814.13	Sensors	3 New Purple air units
1/6/21	$6.46	Shipping	Shipping charges
TOTAL EXPENSES	**$1,097.41**		

DEPLOYABLE PURPLEAIR UNIT

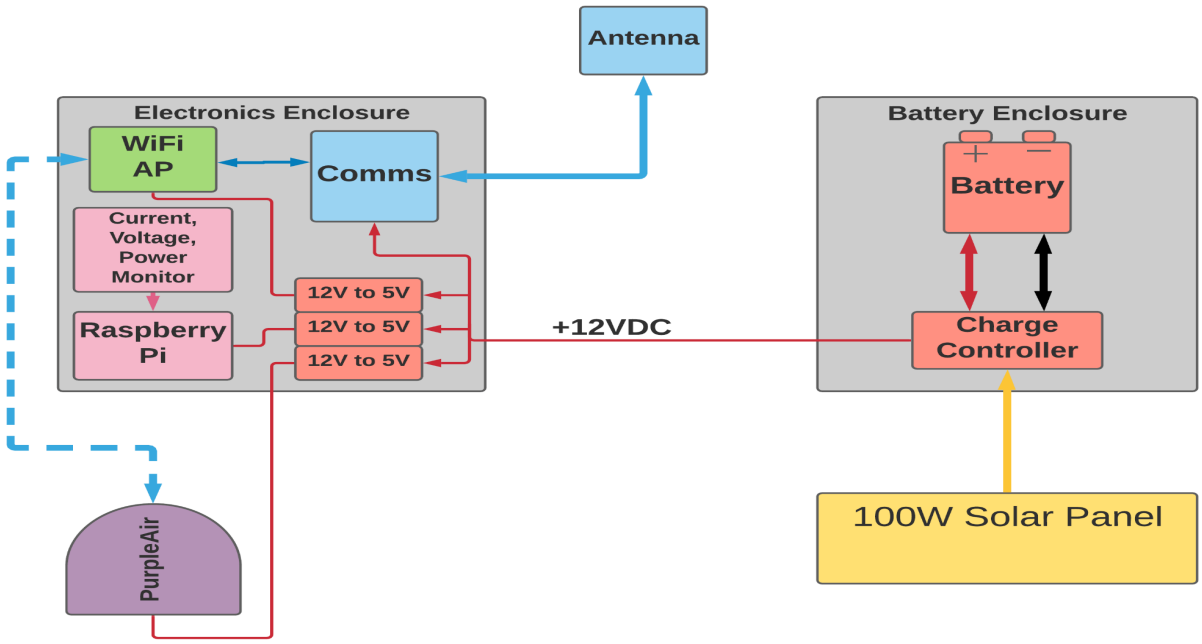
Prepared by: Travis Powell
Revised: 6/17/2021

INTRODUCTION:

The District currently has 3 EBAM units for deployment to smoke-affected areas throughout Inyo, Mono, and Alpine counties. These units rely on line power, which limits deployments to hosts who are willing to provide access to power. Due to the requirement for line power, our EBAM units cannot be deployed to high-use recreational areas. Furthermore, they cannot be used in the event of a public power safety shutoff. In order to better serve the tens of thousands of visitors to the Eastern Sierra, a deployable system designed with its own power and communication system will increase the District's ability to monitor smoke impacts throughout the Eastern Sierra.

DESIGN PROPOSAL:

In order to deploy this system remotely, it must be capable of providing power and communication. Below is a basic block diagram of the system:



Power will be generated using solar panels and a solar charge controller in conjunction with a single battery. The battery will be housed in an enclosure separate from the electronics. Communications will be achieved through the use of a satellite terminal or cellular modem.

The PurpleAir unit requires a WiFi network in order to share data to the Cloud, where it is then uploaded for public viewing on the PurpleAir map. Therefore, this system also requires a WiFi access point. The charge controller provides 12-volts, which is required for both the satellite terminal and cellular modem. The PurpleAir and WiFi access point require 5-volts via micro-USB, which will be provided by a 12-volt to 5-volt converter. Note that there is no need for an independent data logger, since data collection and export are both handled by the PurpleAir. However, a Raspberry Pi will be used to monitor voltages, current, and power draws of the system. Diagnostic data from the system will be pushed from the RaspberryPi to our internal server at the Bishop office. For safety, 20-amp fuses will be placed between the solar panels and charge controller, and between the battery and charge controller. The Raspberry Pi, 12-volt to 5-volt converters, satellite terminal or cellular modem, and WiFi access point will be housed in a weather-resistant electronics enclosure. The battery enclosure, electronics enclosure, PurpleAir, solar panels, and satellite antenna will be mounted to a single, 10-foot tall tripod.

Preliminary calculations show that the power consumption of the system equates to approximately 10-watts per day with a satellite terminal and 6-watts per day with a cellular modem. This assumes data transmission every 10-minutes. Data transmission should be limited to, at most, every 10-minutes due to maximum power usage while transmitting (the satellite terminal uses 20-watts while transmitting and 4-watts while idle, and the cellular modem uses 6-watts while transmitting and 1-watt while idle). The PurpleAir unit can be programmed to transmit every 2, 10, 30, or 60-minutes depending on our needs. It may be the case that we need to transmit less frequently based on the specific characteristics of the system (i.e. deployment location). PurpleAir has informed me that they are capable of changing the data upload frequency via firmware updates that they implement on individual PurpleAir units. For 10-minute transmission and 3 days of autonomy, the minimum power requirements for the system with a satellite terminal are a 150-watt solar panel, or combination of panels providing 150-watts, and a 100 amp-hour battery. For 10-minute transmission and 3 days of autonomy, the minimum power requirements for the

system with a cellular modem are a 50-watt solar panel and a 100 amp-hour battery.

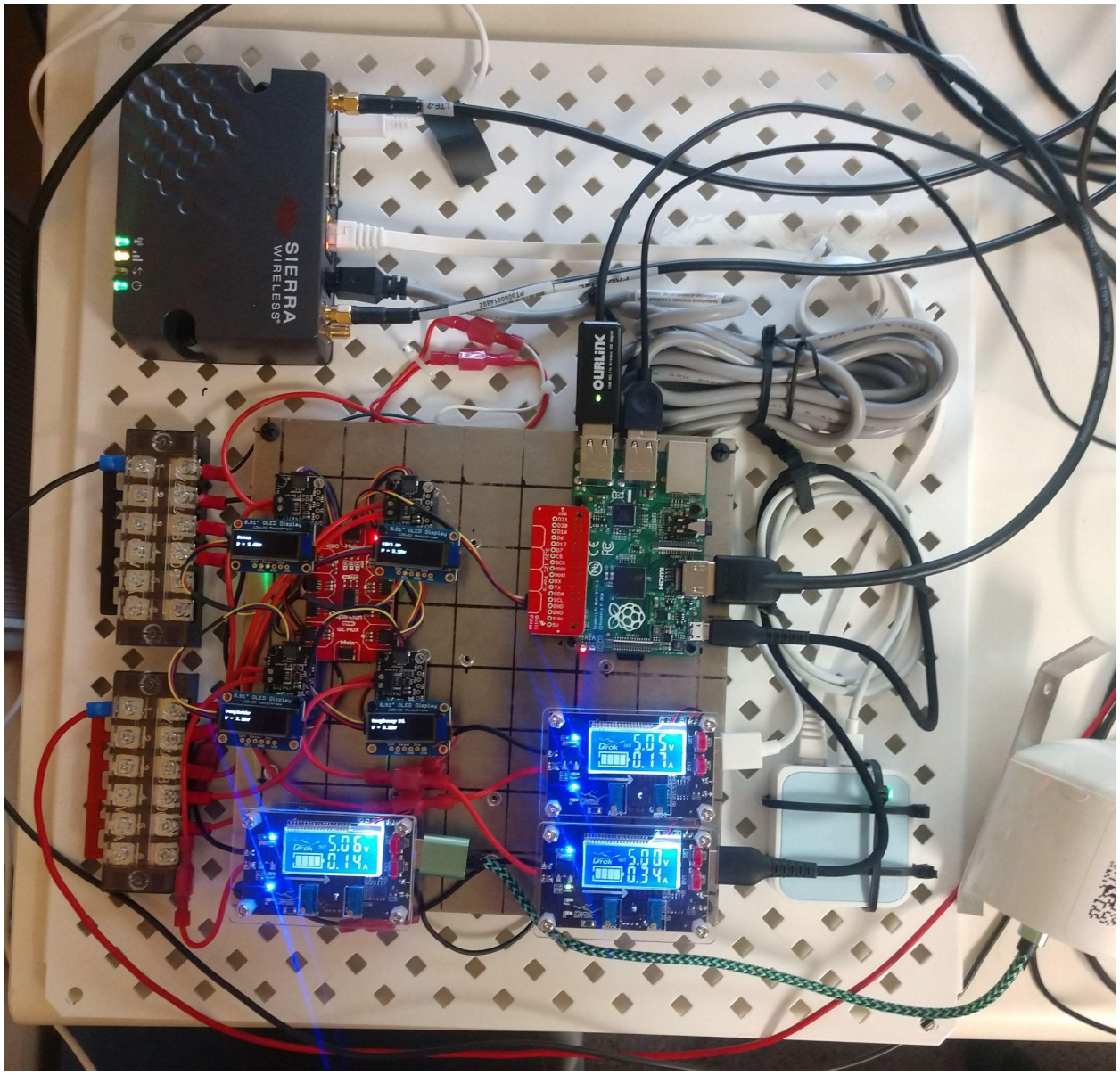
BENCH TEST:

I acquired all of the components necessary for a prototype using the cellular Modem as the communication device for a bench test powered by a linear power supply. The initial design required several changes to accommodate the design requirements. The largest changes seen in the bench test are the addition of an I2C multiplexer board to allow communication with multiple I2C devices (i.e. the current/voltage/power measuring boards), and 3 separate voltage and current adjustable 12-volt to 5-volt converters. The addition of the multiplexer board allows us to communicate with up to 64 devices over I2C. These sensors can include additional gas sensors, current/voltage/power sensors, accelerometers or gyrometers, LED displays, etc. The addition of the multiplexer means we can measure current, voltage, and power from each device within the electronics enclosure. The 12-volt to 5-volt converters each have a USB output and screw terminal outlet. Only the USB output is used in this prototype. Because the USB output voltage is adjustable, the USB output is powered off by default to protect USB devices in the event the voltage is accidentally set too high. This offers us downstream protection for our electronics in the event of power issues with the battery or charge controller. However, this means that someone will need to physically turn on each converter to restore power to the USB devices. Each converter has an LED display which displays the set voltage and current usage. The set voltage and current can be adjusted via two potentiometers and a small flathead screwdriver.

Initial testing shows that the power consumption of the prototype using the cellular modem averages roughly 6W. This is inline with my initial calculations; however, this is not using the power saving feature of the cellular modem. Therefore, we can expect less power consumption if we were to enable this feature, but it may not be necessary. Further testing with the battery, charge controller, and solar panels will give us a better idea of any changes we should make to the power settings of the modem.

Below is an image of the bench test:

Appendix C: Remote-Deployable Air Quality Monitor Technical Information



PRICING:

Below is a list of required items and prices required for a full prototype. The items listed below have been acquired.

Battery Box Enclosure For Off-Grid Solar	16"x16"x10" battery box, can be mounted to poles (3" pipe)	268	1

Solarland Solar Panel Mount Side of Pole Adjustable for 2 panels	Pole mount for 2 panels	150.25	1
Solar connector waterproof in-line fuse holder w/ fuse	RNG-CNCT-FUSE15	17.49	4
Tray Cable, battery to charge controller with 3/8in lugs	RNG-TRAYCB-8FT-10	16.99	1
12V 100Ahr smart lithium iron phosphate battery [Renogy]	RBT100LFP12S-G1	889.98	1
Rover LI 20 Amp MPPT Solar charge Controller	RNG-CTRL-RVR20	109.99	1
100 Watt 12 Volt MonoCrystalline Solar Panel (Compact Design)	RNG-100D-SS	121.98	2
Solar Y Branch Connectors MMF + FFM Pair		12.99	2
Solar panel to charge controller adaptor kit	RNG-AK-10FT-10	19.99	2
Solar connectors for solar panels 5 Pairs Male And Female		9.99	2
Solar connector assembly tool		6.99	1
CM110	10 ft stainless steel tripod with grounding kit	800	1
ENC16/18	16" x 18" electronics enclosure	556	1
Raspberry Pi B+	Current and Voltage monitoring. Gives us options for further diagnostic monitoring and system control. Can also be used as WiFi AP	29.95	1
QWIIC Mux breakout for I2C devices	Allows talking to same I2C device without changing I2C addresses	11.95	1
QWIIC Mux hat for Raspberry Pi	Breakout to GPIO on Raspberry Pi, from Mux	7.5	1
USB WiFi module for Raspberry Pi	Use RP as WiFi AP	12.95	1

SD card with Raspbian OS	Required when using RP as wiFi AP. Out of stock as of 3/19/2021	9.95	1
I2C breakout for voltage and current monitor with plug and play capable cables (female for connection to pins on Raspberry Pi)	Monitor voltage and current (as much as 3.2A with .8A resolution, which seems almost useless)	10.9	4
Battery Cables bulkhead [2 pin]	CNLINKO, IP67, Amazon	17.89	1
Solar Panel Cables bulkhead [3 pin]	CNLINKO, IP67, Amazon	19.89	2
USB to micro b Cables, (up to 3.1A)	Amazon, for all devices	8.98	1
USB male to female, from voltage converter to USB bulkhead connector for purpleair	Amazon	8.99	1
USB bulkhead connector for PurpleAir	CNLINKO, IP67, Amazon	38.09	1
12V to 5V	Voltage converter	13.99	3
TP-Link NL300	WiFi AP	29.99	2
Terminal Blocks	6 position, dual row, 400V and 25A	12.49	1
Hughes 9502 M2M BGAN	Satellite Terminal	999	1
Antenna Mounting Kit - universal pole	Mount for Hughes Antenna	99	1
Hughes 9502 IDU securing strap	Mounting bracket for terminal	27	1
Bulkhead TNC to Type N bulkhead cable	Cable for interior of electronics enclosure	19.37	1
Raven AirLink RV50X	Cellular Modem	589	1
Parsec Pro ST IP67 2-1 Antenna	Antenna for Raven	127.3	1
Parsec Pole mount Antenna Bracket	Mounting bracket for antenna	75.05	1
SMA-Female Bulkhead connectors	bulkhead connectors for antenna	75.05	2
SMA cables	From raven to bulkhead connectors	29.95	2

Total (Cellular)	4543.48		
Total with Tax	4861.5236		
Total (Satellite, no data plan)	4686.5		
Total with Tax	5014.555		

Note that this does not include a data plan for the satellite terminal. At the moment, it is difficult to know exactly how much data we will require. The Hughes 9502 M2M BGAN uses TCP/IP, which has significant overhead for data transmission. The bulk of our data usage will come from this overhead. There is no data plan needed for the cellular modem since we can use our unlimited plan via Verizon.

FURTHER CONSIDERATIONS:

Monitoring wildfire smoke impacts in high-use recreational areas requires coordination with both the USFS and BLM. I have not yet contacted either agency to discuss regulations that may impact remote monitoring.

CONCLUSIONS:

A quick look at the PurpleAir map reveals a lack of air quality monitors throughout the mountains of the Eastern Sierra. This blank space represents remote wilderness that, while not inhabited year round, is visited by tens of thousands of people each year. EBAM units are helpful in informing the public of wildfire smoke impacts in communities; however, their reliance on line power severely limits our ability to monitor wildfire impacts in these high-use recreational areas. The system described above will allow us to expand our monitoring capabilities to include these areas during wildfire season.