AUDIT & MANAGEMENT AMAS ADVISORY SERVICES

Internal Audit Report

Campus Power Utility Reliability

Report No. SC-22-05
November 2022

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Approved
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Table of Contents

I. EXECUTIVE SUMMARY

Audit and Management Advisory Services has completed a review of the campus power utility reliability. This review was included on the FY22 internal audit plan. The purpose of this audit was to test controls for effective and efficient management of power utility for the campus to ensure reliability of continuous power and response to power interruptions to minimize interruptions to campus operations, especially to research.

Whenever a power disruption occurs, it clearly causes significant costs to research on campus and these costs take many different forms. These costs to research includes fiscal cost from damaged equipment, instruments, and samples; cost to productivity and potentially mission failure due to lost experiments or simply due to the inability to use one's laboratory facilities during or in the aftermath of outages; and sometimes the losses are irreplaceable such as if unique samples are lost as a result of outages. The challenge of accurately quantifying the overall cost of a power disruption to the campus is difficult and ultimately, we could not determine an effective way to do so with any degree of accuracy. Instead, we present anecdotes within this report from researcher interviews and will say simply that the cost of every disruption is clearly significant both fiscally and from a mission fulfilment standpoint. Furthermore, Appendix B (page 21) provides additional notes collected from interviews regarding many of these anecdotes, which can hopefully give leaders some perspective about the cost of disruptions.

Measuring the frequency of power disruptions is also important for risk management and fortunately this aspect is more quantifiable with available data. We collected metering data for the period March 1st 2020 – August 2nd 2022 (about 29 months), to help us gauge the relative frequency of outages. These outages generally take one of three forms:

- The outages of cogeneration power alone, with PG&E utility power remaining online is, by far, the most common form of disruption. Fortunately, it is also has the least severe impact to campus operations when it occurs. During this 29 month period, metering data showed the cogen plant was down for either planned or unplanned outages of around 54 hours on average per month, with some form of outage occurring nearly every month of the period reviewed. While these outages are relatively common, the impact of cogeneration outages alone is also relatively minor assuming PG&E power remains online. However, it is noteworthy that the more often cogeneration power is offline, the greater risk exposure the campus has of total power loss if PG&E power also goes offline during this time.

- The next most common occurrence is the outage of PG&E power, with cogeneration power remaining online. This type of outage is much more impactful to the campus for two reasons: 1st), because the cogeneration plant alone does not produce enough power to fulfill all the campus energy needs during peak demand, some campus functions will be disrupted if PG&E power goes offline during this time.; 2nd) many facilities do not receive cogeneration power during outages and are therefore totally reliant on PG&E power and standby generators as backup. Generators themselves can not fully satisfy all the power needs of researchers in many cases. Furthermore backup generators take some time to kick in leaving a short window of time in which no power is provided during a PG&E outage. Therefore damage to research occurs every time PG&E power is lost even if standby generators and the cogeneration plant work as intended. In total, we identified 31 PG&E outages during the 29 month period we reviewed. While this specific methodology does not identify the length of the outages, as previously noted many researchers interviewed indicated that even very short outages are harmful and, in fact, numerous researchers indicated that a high frequency of outages is actually generally more harmful than longer, but fewer outages.

- The most catastrophic form of power disruption is when cogeneration and PG&E power are lost concurrently. While this did not occur frequently in the period we reviewed, the consequences are clearly high. During the 29 month period reviewed, the campus had 24 hours of total power loss (with the exception of backup generators) during 21 separate incidents varying in length. A large portion (18 of the 24 total hours) occurred in the summer of 2020.

Despite these outages, our review did find a number of controls we reviewed are in place to help combat these disruptions to electrical power. These included fairly well documented plans for power outages, clear roles and responsibilities, using a process to identify potential areas of risk to critical power infrastructure, and the inherent redundancy provided by the model of on-campus generated power with PG&E as a supplemental source. While we found these processes identified above appeared to be followed during unplanned outages, it was also clear from interviews with research community members that the current communication protocols being followed did not adequately meet their needs.

A. Communication For Planned and Unplanned Power Outages

During interviews with over a dozen research community members, nearly every individual indicated they would prefer communication be improved in regards to planned and unplanned power disruptions

The turbine that produces the majority of the on-campus generation requires regular maintenance and service to be provided by a specialized contractor. We have not found any evidence that the quality of the work provided by the contractors is of concern. However, campus leaders should ensure that any future contracts we have with contractors for this vital piece of infrastructure include provisions related to timely service and allow the campus to exercise adequate oversight over the quality of service provided.

In addition, we identified some area of risk associated with emergency generator maintenance records which requires management corrective action to address a particular control weakness related to how preventative maintenance is documented. Without strong documentation controls over generator maintenance, the risk of generator failure during outages is elevated.

B. Preventative Maintenance Documentation for Generators

Preventative maintenance records were often not fully completed in accordance with the specified steps in the preventative maintenance procedures.

Agreement was reached with management on recommended actions to address risks identified in these areas. The observation and related management corrective actions are described in greater detail in section III.

II. INTRODUCTION

Purpose

The purpose of this audit was to test controls for effective and efficient management of power utility for the campus to ensure reliability of continuous power and response to power interruptions to minimize interruptions to campus operations, especially to research. This audit was included on the campus FY22 Internal Audit Plan.

Background

The campus uses a combination of electric power provided from on-campus sources (via, the campus cogeneration plant and two solar panel arrays) and utility provided power (via Pacific Gas and Electric). The campus cogeneration plant and solar arrays provide uninterrupted power for the campus, laboratory life/safety systems, and sensitive instruction and research equipment. These systems are supplemented by the electricity supplied to the campus by PG&E, which reduces the campus' utility expenses. The byproduct heat of the cogeneration operation is used to preheat water for three boilers that provide hot water for space heating of buildings in the central campus, thus reducing the amount of purchased energy required for heating.

The cogeneration system is capable of producing about 4.4 MW of electricity using a single, gas-fired combustion turbine generator (A Solar Turbines brand "Mercury 50"). The recovered exhaust heat is used for hot water production that can then be used for things such as building heat on the campus core. The existing cogeneration engine, fuel system and generator were upgraded to its current state in the summer of 2015 replacing a nearly 30 year old system that was capable of producing about 2.6 MW of electricity.

The East Remote parking solar array came online in 2019. A 1.2 megawatt battery is currently in the planning stages to be installed in the East Remote.

The electrical distribution on campus is divided into four distribution feeders: A1, A2, B1, and B2. Generally, buildings that conduct a lot of power-dependent research are found on the A1 feeder. This segregation of buildings into various distribution networks allows prioritization of power when availability is limited.

Physical Plant has the primary responsibility of maintaining the power reliability on campus.

Scope

During the audit, we:

- Interviewed key personnel
- Reviewed planning documents.
- Collected data on power outages from PG&E and the cogeneration plant.
- Reviewed maintenance data related to the cogeneration plant.
- Collected data on backup and standby power generators on campus.
- Collected and analyzed maintenance documentation related to generators.

III. Results

Current State of Campus Power Disruptions

Whenever a power disruption occurs, it clearly causes significant costs to research on campus and these costs take many different forms. These costs to research includes fiscal cost from damaged equipment, instruments, and samples; cost to productivity and potentially mission failure due to lost experiments or simply due to the inability to use one's laboratory facilities during or in the aftermath of outages; and sometimes the losses are irreplaceable such as if unique samples are lost as a result of outages. The challenge of accurately quantifying the overall cost of a power disruption to the campus is difficult and ultimately, we could not determine an effective way to do so with any degree of accuracy. Instead, we present anecdotes within this report from researcher interviews and will say simply that the cost of every disruption is clearly significant both fiscally and from a mission fulfilment standpoint. Furthermore, Appendix B (page 21) provides additional notes collected from interviews regarding many of these anecdotes which can hopefully give leaders some perspective about the cost of disruptions.

The frequency of disruptions, however, is a more feasible to quantify. The UC Santa Cruz campus currently experiences relatively frequent power disruptions, which has a significant impact on researchers who rely on consistent and reliable power. In this section I will discuss the three forms in which outages occur listed in order of least-to-most severe:

- Outages of cogeneration power, with PG&E utility power remaining online.
- Outages of PG&E utility power, with cogeneration remaining online.
- Outages of PG&E and cogeneration power simultaneously.

The UCSC Energy Department, within Physical Plant, is responsible for tracking electric consumption for the purpose of billing on-campus customers for usage. Using the metering data collected, it is possible to determine cogeneration plant power generation, generation from the East Remote and McHenry Library solar arrays, as well as PG&E utility consumption. The metering data does have some limitations:

- The most notable limitation is that the data is collected in 15 minute increments with the consumption averaged over that period of time. This is problematic for identifying very short outages lasting less than 15 minutes. While the metering data will show a large dip in power consumption if it lasts more than a few minutes, the granularity of the data makes it difficult to identify every outage, especially when these outages occur at night when consumption is already relatively low.
- The data also has some amount of data reliability issues, though we think these issues are relatively manageable for the purposes of this analysis. For instance, there are a number of instances where identical consumption values would be recorded over the course of several hours, suggesting issues with the meter data collection during that time period. There are also some periods of time when data is not recorded at all. Again, the overall impact of these issues is relatively minor – we estimate duplicated and missing data impacts in the neighborhood of a fraction of one percent of the data.

- We do not have a way to determine if the values presented in metering data is fully accurate. Therefore it is possible that inaccurate metering data could result in inaccurate conclusions using the data. We did match some outages presented in metering data to email traffic which supported the outage in order to give us some comfort in the data. However it was not feasible for us to confirm each outage with email traffic and therefor our analysis is dependent on the data being reliable.

We collected metering data for the period March 1st 2020 – August 2nd 2022 (about 29 months), to help us gauge the relative frequency of outages for the three forms of outages previously identified.

Outages of cogeneration power, with PG&E utility power remaining online.

The outages of cogeneration power alone, with PG&E utility power remaining online is, by far, the most common form of disruption. Fortunately, it is also the least severe form of electric disruption to the campus.

The cogeneration plant turbine produces a fairly consistent amount of electricity by design. It typically produces around 4,100 kW with variations typically not exceeding a few hundred kWs according to metering data. Based on the consistency of this output, it is a fairly straight-forward process to identify when the cogeneration plant is not producing power from metering data. As previously mentioned, the metering data was collected as an average of a 15-minute intervals. Therefore, if we only flagged values where the meter data showed 0 kW for the period we would miss disruptions that occurred partway through this interval. Therefore, we chose to flag instances in which metering data fell below 2000 kW, less than half of the normal turbine output, as an indicator that a disruption had occurred. The results are as follows:

Turbine Meter readings under 2000kW during 15 minute interval				
	Turbine Down %	Hours Turbine Down	Unique Incidents	Notes
Mar-20	0.00%	0.00	0	
Apr-20	0.10%	0.75	1	
May-20	0.10%	0.75	1	
Jun-20	8.62%	62.00	1	
Jul-20	1.51%	11.25	10	
Aug-20	23.89%	177.50	4	
Sep-20	0.35%	2.50	3	
Oct-20	2.82%	21.00	3	
Nov-20	8.84%	63.75	1	
Dec-20	2.07%	9.00	6	
Jan-21	0.97%	7.25	8	
Feb-21	0.11%	0.75	1	
Mar-21	28.48%	211.50	1	
Apr-21	0.03%	0.25	1	
May-21	17.98%	133.75	1	
Jun-21	61.88%	445.25	0	<-Started prior month
Jul-21	2.65%	19.75	4	
Aug-21	0.00%	0.00	0	
Sep-21	10.63%	76.50	2	
Oct-21	6.18%	46.00	4	
Nov-21	0.31%	2.25	1	
Dec-21	5.38%	40.00	5	
Jan-22	4.91%	36.50	2	
Feb-22	3.94%	26.50	3	
Mar-22	12.08%	89.75	4	
Apr-22	4.62%	33.25	7	
May-22	8.94%	66.50	2	
Jun-22	0.73%	5.25	3	
Jul-22	2.35%	17.50	1	
Aug-22	0.00%	0.00	0	
Total		1607.00	80	
Monthly Avg:	7.35%	53.57	2.67	
Median Value	2.74%	20.38	2.00	

It is important to note that this methodology using metering data does not distinguish between planned and unplanned outages.

While these outages are relatively common, the impact of cogeneration outages alone is also relatively minor assuming PG&E power remains online. If PG&E power remains online end-users should experience no disruptions in power, though it is possible they may experience a power surge during the brief transition. Faculty we interviewed generally indicated that this form of power disruption was generally not very disruptive assuming instruments are on surge protectors.

However, the more often cogeneration power is offline, the greater the risk of total power outage occurring to research if PG&E power also goes offline.

Outages of PG&E utility power, with cogeneration remaining online.

The next most common occurrence is the outage of PG&E power, with cogeneration power remaining online. This type of outage is far more impactful to the campus for two interrelated reasons:

- The cogeneration plant alone does not produce enough power to fulfill all the campus energy needs during peak demand during the day. Therefore, some campus functions will always be disrupted if PG&E power goes offline during peak demand.
- Many facilities, including the Physical Sciences Building (PSB) building for example, do not receive cogeneration power during outages due to capacity and technical limitations on the cogeneration plant and are therefore totally reliant on PG&E power and standby generators as backup. Standby generators themselves are not designed to produce enough power to satisfy all the energy needs of researchers in many cases. For example, there are a number of very expensive and sensitive biochemistry research equipment within the PSB building that are simply not able to be connected to backup generators due to their very high energy current demands and therefore operate with no backup. Furthermore, by design standby generators do not power on instantly, but rather take around 30 seconds to a minute to power up. This window of time between power going offline and the standby generator coming up is harmful to research that requires constant power.

Research personnel interviewed that conduct research in buildings that are not on cogeneration power indicated that even short disruptions in PG&E power are harmful. In many cases an outage lasting only a minute can be just as harmful as one lasting an hour. Many faculty researchers interviewed reported that these short disruptions can cause damage to instruments and can also ruin experiments that are currently running. They reported that they have made significant investments, often measured in the tens of thousands of dollars, into installing backup power supply units in order to bridge this short gap between power going out and when backup generators kick in.

Identifying PG&E outages using metering data is more challenging than that of the cogeneration plant due to the variable nature of the demand for PG&E power. Often times demand for PG&E power can drop very low at night, for example. If an outage occurs at night, when demand is already low, it is sometimes difficult to tease out if an outage actually occurred. Further complicating matters is that energy provided by on-campus solar arrays contribute to the energy needs of buildings on campus. There are cases, such as on weekends, when solar arrays along with the cogeneration plant provide much of the power needs to campus and therefore PG&E usage reflected in metering data may drop to zero despite there not being any actual outage occurring. Unfortunately, if PG&E power goes offline, these solar arrays are not able to serve as a backup power source for the campus.

Therefore, it was necessary to be conservative with the methodology in determining the frequency of PG&E outages. Our methodology was as follows:

- Combine PG&E and solar energy production together.
- Identify instances in which this total is less than 10kW during a 15 minute interval.
- For these instances determine if there was a sharp drop in power from the prior 15 minute interval of more than 100kW

While it is not out of the question for power demands from PGE to drop below 10kWs and it’s not uncommon for power demand to drop by more than 100kW within a 15-minute interval, the combination of these two factors occurring at the same time is likely to be driven by an outage rather than normal operations.

Using this conservative methodology, I identified a minimum of 22 outages during the 29-month period from March 1st 2020 – August 2nd 2022.

Separately, we counted instances not identified above in which the total campus power usage (including cogeneration power) dropped below 1000kW. 1000 kW is far below the demand for campus even in off-peak hours and indicates that the campus is not getting adequate power via PG&E as well. These cases may be missed in the conservative methodology we used above in cases where solar production may be high (but is unusable during the outage), or when some intermittent power is coming through the lines, but not in a stable manner. Using this methodology, we identified another 9 instances during the same period of time.

In total, we identified 31 outages during the 29-month period from March 1st 2020 – August 2nd 2022. While this specific methodology does not identify the length of the outages, as previously noted many researchers interviewed indicated that even very short outages are harmful. Most indicated that a high frequency of outages is actually more harmful than fewer longer outages.

Outages of PG&E and cogeneration power simultaneously.

The most catastrophic form of power disruption is when cogeneration and PG&E power are lost concurrently. While this does not occur frequently, the consequences are obviously high.

With the loss of both PG&E and cogeneration power, buildings become entirely reliant on standby generators for power. As previously mentioned, these generators do not work instantly, they often can take 30 seconds or a minute to come online leaving a window in which instruments and equipment will go offline if not powered by an uninterruptible power supply (UPS). These UPS units were commonplace for the faculty I interviewed – several faculty members mentioned that they have spent tens of thousands of dollars investing in these units simply to deal with this short window between the outage occurring and the standby generators coming online.

A further risk in this scenario is that standby generators are prone to failure. This report identifies an MCA related to generator maintenance which is important to address to help mitigate this risk.

Identifying when the campus loses both cogeneration and PG&E power is a relatively simple process using metering data. We used the same methodology for the cogeneration plant outage, except we compared the sum total of all power against a 2000kW threshold. As previously mentioned, the metering data was collected as an average of a 15-minute intervals. Therefore, if we only flagged values where the meter data showed 0kW for the period we would miss disruptions that occurred partway through this interval. The results are as follows:

Total power under 2000kW	Number of Hours	Unique Incidents
Mar-20	0.00	0
Apr-20	0.00	0
May-20	0.00	0
Jun-20	9.00	1
Jul-20	5.00	6
Aug-20	4.00	3
Sep-20	0.00	0
Oct-20	0.00	0
Nov-20	0.00	0
Dec-20	1.75	2
Jan-21	0.00	0
Feb-21	0.25	1
Mar-21	0.00	0
Apr-21	0.25	1
May-21	0.00	0
Jun-21	0.00	0
Jul-21	0.50	2
Aug-21	0.00	0
Sep-21	0.00	0
Oct-21	0.00	0
Nov-21	0.00	0
Dec-21	0.00	0
Jan-22	0.25	1
Feb-22	0.00	0
Mar-22	0.75	1
Apr-22	1.50	1
May-22	0.25	1
Jun-22	0.50	1
Jul-22	0.00	0
Aug-22	0.00	0
Total	24.00	21

As shown in the table above, during the 29-month period the campus had 24 hours of total power loss (with the exception of standby generators) during 21 separate incidents. Clearly this is a frequent problem on this campus.

Planning Controls

While we generally found the planning controls we specifically reviewed for electrical outages were fairly well developed, a large portion of the research community we interviewed indicated that they were not satisfied with the communication they received concerning outages generally. Specifically, we found:

- Roles and responsibilities during outages appear to be relatively well laid out and logical in various documentation we reviewed.

- There are standing plans developed that identify specific technical steps that need to be performed during outages in order to provide backup power to key assets and to quickly restore normal power. These procedures also identify key individuals to be notified of outages. While we found these processes appeared to be followed during unplanned outages it was clear during interviews with research community members that the current communication protocols being followed did not adequately meet their needs. We will discuss this further in the next section.

- Generally there is a clear and effective process to identify priorities for power delivery during outages, however there is a limited capacity to get all power-sensitive research equipment on the prioritized feeder. On the main campus, the four distribution feeders can be used to prioritize power delivery during outages. Many (but not all) of the buildings that contain research that requires continuous power (e.g. those on Science Hill) are primarily on the A-1 as their "preferred" feeder which generally gets a higher priority during disruptions to power.

  It is, however, noteworthy that due to various technical constraints, such as the capacity of the cogeneration plant, not all research that is power-sensitive is able to be placed on the A-1 as their primary feeder. This is the case of the Physical Sciences Building, which is primarily on the A-2 feeder (with A-1 as its alternate feeder.) The Physical Sciences Building contains a large number of very expensive, high-energy using instruments, that are sensitive to power losses. Faculty within the Physical Science Building report that they frequently lose power from PG&E, which directly impacts their research both in terms of damage to equipment and to lost time associated with restarting experiments that are ruined during the outages.

<table>
<tr><th>A.</th><th colspan="2">Communication During Planned and Unplanned Power Disruptions</th></tr>
<tr><td colspan="3">During interviews with over a dozen research community members, nearly every individual indicated they would prefer communication be improved in regards to planned and unplanned power disruptions</td></tr>
<tr><td colspan="3">Risk Statement/Effect</td></tr>
<tr><td colspan="3">Without timely, sufficient, and clear communication regarding power disruptions, research personnel are at higher risk to damaging impacts to their research efforts.</td></tr>
<tr><td colspan="3">Agreement</td></tr>
<tr><td>A.1</td><td>The AVC for Physical Planning Development and Operations, will coordinate with the Vice Chancellor for Research, CP/EVC, Dean of PBSci, and the Dean of Engineering to generate an agreement on communication protocols for each eventuality related to outages as well as cogeneration maintenance.</td><td>Implementation Date
June 30, 2023
Responsible Manager
Associate Vice Chancellor
Physical Planning Development & Operations
Tony Cobb</td></tr>
</table>

A. Interviews with Research Personnel Regarding Planned and Unplanned Power Disruptions

We interviewed over a dozen research community members from PBsci, BSOE, and with the Vice Chancellor of Research to determine what feedback they had regarding outages that occurred on the UC Santa Cruz main campus.

By far the most frequent criticism the research community had regarding the outages was that they believed communication was generally not adequate. In fact, all but one individual we spoke to thought that communication regarding power outages was inadequate. However, many of these individuals also noted that, while communication could be improved, they also believe that communication has been a bit better recently than it had been in years past. In regards to the specific communication elements they thought were lacking, research community members broadly identified the following areas of concern:

- Often faculty members reported they did not know in advance when the cogeneration plant would be offline for maintenance (leaving their research at greater risk during this time if PG&E were to also go offline).

- Faculty members indicated that they would appreciate very timely information and some indicated they would appreciate more timely information even if the information was incomplete. For instance a number of faculty members indicated that it would be helpful for them to receive a “Cruz-Alert” style text message whenever power is lost so they can immediately take actions to protect their research if, for example, certain experiments are running. Follow-up emails with more detail about the extent and causes of the outage would be appreciated later.

- A number of faculty members report that they rarely get information on the ultimate determination made regarding the causes of outages.

- Some faculty members also indicated that they would often not have clear information on whether standby generators were working properly during outages. Not knowing the status of standby generators has implications on faculty that use UPS devices. These devices are able to bridge the gap in power if standby generators run successfully during PG&E outages, but they often do not have the capacity to last over the period of a prolonged disruption.

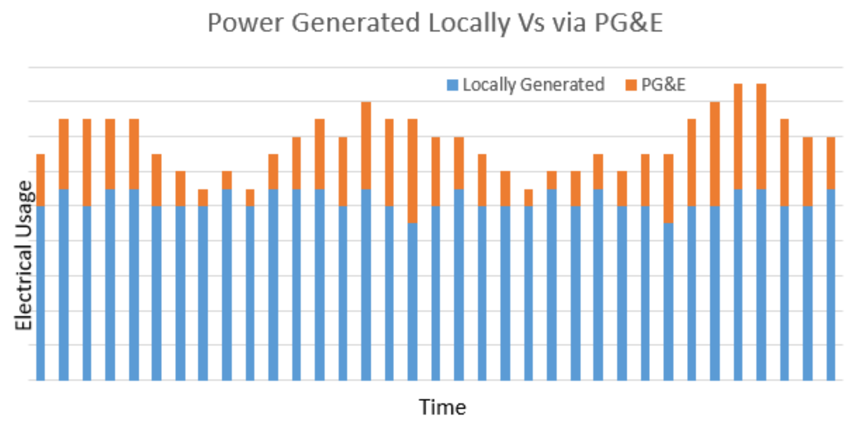
- Other faculty members indicated they would appreciate if they could see the status of power on campus via some sort of web portal. For context, the campus does have a live dashboard for solar generation accessible online.

While we found that the processes PPDO has outlined regarding notifying individuals during outages generally was followed, it is clear that research personnel would appreciate timelier and clear communication regarding planned and unplanned power disruptions. Due to the high costs associated with damage to equipment, instruments, and the cost in lost research time during outages, strong communication between PPDO and the science community would certainly be beneficial to mitigate these costs. Therefore, the AVC for Physical Planning Development and Operations should work with the science community to determine what sort of information protocols would be beneficial to researchers for the various scenarios which may play out in terms of outages and cogeneration maintenance.

On campus electrical generation

As discussed in the background section, the campus uses a combination of electric power provided from on-campus sources (via, the campus cogeneration plant and two solar panel arrays) and utility provided power (via Pacific Gas and Electric). The on-campus generation of electrical power can be thought of as the primary source of power for the campus, with PG&E serving as a supplemental source of power during periods of higher demand or as a backup source of power in the event that on-campus generation goes offline.

The amount of power generated on campus by the cogeneration plant is somewhat rigid, while PG&E power provides more flexibility in terms of output. Specifically, the power generated from the cogeneration plant is relatively stable, it generally provides a relatively consistent amount of power that does not change based on actual electrical demand. The solar arrays provide a variable amount of power depending on the time of day, time of year, and cloud coverage. While these power sources meet a significant portion of the electrical demand on campus, they are not flexible in meeting peek energy demands as it is impossible to “ramp up” electrical production as needed using these on campus sources. Therefore, PG&E-provided power as a supplement is useful in that it allows the campus to dynamically meet the power demands on campus during peak loads. The chart below gives a simple illustration of how on campus power and PG&E power are used in combination to meet the campus’ energy needs.



It is important to note that under the current model being used by the university, on-campus generation is not currently sufficient to power the campus alone. Therefore, any disruptions in power from PG&E will cause disruptions in some on-campus electrical distribution. This may be mitigated a bit from backup generators in some cases, however the backup power generation from generators simply does not have the capacity to make up this shortfall. Furthermore, many of the backup generators on campus are fairly static and it would likely be difficult to repurpose them to do anything other than power the very narrow function they were intended to. Alternatively, PG&E's capacity to power the campus in the event of a cogeneration plant power outage should be adequate assuming power flowing from the utility is not also disrupted.

With the potential for future utility power outages due to natural disasters including wildfire risks, the model being used by campus of on-campus generation supplemented by the utility is certainly logical. However, during the audit, several risks were identified with this model. While we did not identify specific management corrective actions related to these risks, it would be beneficial for campus leaders to be aware of them:

- The turbine that produces the majority of the on-campus generation requires regular maintenance and service to be provided by a specialized contractor. We have not found any evidence that the quality of the work provided by the contractors is of concern, but it is certainly important to ensure contractors are continuing to performing their work well. This risk is made a bit more significant because the maintenance work required on the turbine is generally only provided by a single contractor. Other maintenance work related to the compressor could potentially be performed by multiple contractors. We did hear some testimonial evidence, that the speed in which particular contractors can respond to issues that arise is less than ideal, but this was from only one individual's point of view. Therefore, campus leaders should ensure that any contracts we have with contractors for this vital piece of infrastructure include provisions related to timely service and allow the campus to exercise adequate oversight over the quality of service provided.

- Again, the turbine is the primary source of on-campus power generation and therefore is something of a single point of failure for on-campus generation, which may not be ideal from a redundancy stand-point. The development of other renewable power generation on campus in the form of the solar arrays does mitigate this risk a little. However, the bulk of energy production on campus will continue to come from the cogeneration plant. Furthermore these renewable sources have their own unique risks associated with them.

- The turbine produces greenhouse gases. Therefore, there is some reputational risk associated with its carbon footprint.

Electrical Distribution Infrastructure

The campus's electrical distribution infrastructure is also an important consideration when evaluating potential risks of power interruptions. As the electrical infrastructure of the campus ages, it is important that the campus maintain visibility of the condition, and therefore potential risks associated with its electrical infrastructure.

One positive way the campus is maintaining visibility of the risks associated with its electrical infrastructure is by including electrical infrastructure in the campus's planned maintenance master schedule. For example, various pieces of high voltage infrastructure are identified on the high voltage planned maintenance schedule. Emergency backup generators are also included in regular planned maintenance (discussed in the following section of this report).

Another good source of information on the state of the campus infrastructure is the systemwide "Integrated Capital Asset Management Program" (ICAMP) asset inventory and condition assessment. The ICAMP database is comprised of directly identified asset replacement needs through visual inspection of asset conditions and characteristics using a systemwide, standardized asset catalog. The goal is for the UC system is to have a risk-prioritized list of building asset system and component replacements that will help identify opportunities to avoid unplanned interruptions to the institution's mission. Asset replacement risk prioritization is factored by two parts: the likelihood and the impact of an asset failure.

As of February 2022, the ICAMPs system identifies about $21 million in electrical distribution opportunities for replacement, of which about $4 Million is categorized as a "Priority 1" opportunity indicating the system should be addressed within the next year:

Priority	Total Cost
Priority 1 - Currently Critical (Within 1 Year)	$ 3,991,378.64
Priority 2 - Potentially Critical (Year 2)	$ 4,063,915.99
Priority 3 - Necessary-Not Yet Critical (Years 3-5)	$ 13,027,545.19
	$ 21,082,839.82

While the ICAMP database is a great way to measure risk based on condition assessments, it would likely also be beneficial to keep track of the age of our various infrastructure on the campus. The age of assets is a fairly simple but effective way to identify potential risks of asset failure. According to UCOP, an age-based replacement assessment module for ICAMP is in development, so it may be beneficial for UCSC to participate in using that system when it is completed.

B.	Generator Maintenance	
Preventative maintenance records were often not fully completed in accordance with the specified steps in the preventative maintenance procedures.		
Risk Statement/Effect		
If the PM-20 is not followed precisely, there is a risk that vital preventative maintenance steps could be missed or not performed correctly.		
Agreement		
B.1	The procedure for PM-20s should be updated to clarify: • The specific data elements to be logged by technitions. • The necessary steps for engine-only maintenance vs maintenance peformed with a load. • A reasonable target amount of time the generator should be run for during maintenance.	Implementation Date March 31, 2023 Responsible Manager **Director** Building, Utility & Fleet Services

B. Preventative Maintenance Documentation for Generators

The university has 63 backup and standby generators located on the campus, the Westside Research Park, and the Costal Science Campus. Generally, maintenance of these generators is the responsibility of the Physical Plant's "Building, Utility & Fleet Services" department.

The department appears to have generally maintained good tracking visibility of the campus fleet generators. Specifically, they maintain documentation that track key information about the generators vital for including:

- Where they are located,
- Their maintenance schedule,
- When they were last serviced,
- The number of hours the generators have run,

These generators are to be serviced according to the fleet generator service schedule. The "Planned Maintenance #20" (PM-20) procedure details the steps needed to perform this maintenance. Generally, the maintenance is done in one of two ways: either with running the generator with a load or without a load. There are 37 steps identified in the procedure that include steps like checking the oil and other fluid levels, checking for corrosion on battery terminals, putting on hearing protection before starting generator, recording various readings such as the number of hours the generator has run, etc.

The "Planned Maintenance" department under Physical Plant tracks the information recorded when the generators are serviced. The chart below shows an example of the type of information recorded as a result of the PM-20:

GS-063 GENERATOR-EMERGENCY Status Operating Asset# 166

Served by: Serves: Route: PM 20, 1030
Bldg: EH&S STOR FAC Location:
Floor: Room: Key#: Mfr#: GENERAC SWO#: SCEHSGPE HRS: 2 PERMIT: 18211

	Start CF	Stop CF	Start Hr	Stop Hr	Coolant Temp	Coolant Level OK?	Voltage Output	Voltage Output	Oil Pressure	Oil Level OK?	Frequency	Amps. Phs. A	Amps. Phs. B	Amps. Phs. C	Fuel Level %	Inspected By
Enter Readings:																
1/31/22	1009.91	1011.12	212.8	213.1	170		478	277	78		60				75	TL
12/25/21		1009.91		212.8												TL
12/2/21	1009.91	1011.12	212.8	213.1	170		478	277	78		60				75	TL

One noteworthy aspect of the example above is that it demonstrates that the PM-20 is clearly being completed frequently each year. Recording these measurements frequently is clearly beneficial to maintain visibility of the condition of the generators.

However, the logs for PM-20 maintenance are often missing a number of data elements. Without these logs being filled in completely, it is not possible to know if the technician completed all the steps within the PM-20.

The PM-20 procedures note that generators should be run for a minimum of 1.5 hours while doing transfer tasks, but in reality, I found that generators were very rarely run for this number of hours during maintenance. The median number of hours I identified in the logs was 0.3 hours per log entry during 2020 and 2021. This being said, the 1.5-hour requirement for each run may not be reasonable to begin with. According to personnel from the Cogen/Fire/Electrical & High Voltage Shop, manufacturers generally recommend fewer number of hours, but done fairly frequently. If this current standard of 1.5 hours is not reasonable, it would be beneficial to determine a more reasonable number of hours to match current practice and clarify the PM-20 procedure with the updated number of hours.

Overall, preventative maintenance records were not always fully completed in accordance with the specified steps in the preventative maintenance procedures. While it is fairly clear that generators are receiving some degree of preventative maintenance, there is some deviation in the log data from what one would expect if the PM-20 was being followed precisely. If the PM-20 is not followed precisely, there is a risk that vital preventative maintenance steps could be missed. Therefore, the procedure for PM-20s should be updated to clarify some of these present points of ambiguity.

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APPENDIX A – SUMMARY OF WORK PERFORMED AND RESULTS

Preliminary Analysis	
Work Performed	**Results**
Interviewed key personnel	Information was used to evaluate and understand the potential risk areas regarding this topic. Ultimately this was used to generate the audit steps for the project.
Reviewed various planning documents	Information was used to evaluate and understand the potential risk areas regarding this topic. Ultimately this was used to generate the audit steps for the project.

Fieldwork	
Work Performed	**Results**
Reviewed power outage planning documents.	We generally found planning for electrical outages was fairly well developed.
Discussed roles and responsibilities with key personnel. Reviewed guidance related to roles and responsibilities as it pertains to the campus power utility.	Roles and responsibilities during outages appears to be relatively well laid out and logical.
Reviewed various documentation regarding the cogeneration plant operations	The campus uses a combination of electric power provided from on campus sources (via, the campus cogeneration plant and two solar panel arrays) and utility provided power (via Pacific Gas and Electric). The on-campus generation of electrical power can be thought of as the primary source of power for the campus, with PG&E serving as a supplemental source of power during periods of higher demand or as a backup source of power in the event that on-campus generation goes offline.
Collected data on power outages from PG&E and the cogeneration plant.	There were a few instances over the past few years where an outage from PG&E seemed to occur simultaneously with that of the on-campus power generation. However, generally PG&E and on-campus power do indeed appear to operate independently of one another.
Reviewed maintenance data related to the cogeneration plant.	I was not able to find strong evidence in the material I reviewed to indicate if the maintenance of the cogeneration plant was performed well. However, we have heard testimonials that the speed in which they are

	able to respond to issues that arise is less than ideal. We have not heard specific complaints about quality of the work performed by the contractor, though that would certainly be a potential area of risk as well.
Collected data on backup and standby power generators on campus.	The department appears to have generally maintained good tracking visibility of the campus fleet generators. Specifically they maintain documentation that track key information about the generators vital for including: where they are located, their maintenance schedule, when they were last serviced, the number of hours the generators have run for, etc.
Collected and analyzed maintenance documentation related to generators.	Overall, Preventative maintenance records were often not fully completed in accordance with the specified steps in the preventative maintenance procedures

APPENDIX B – AUDITOR NOTES FROM RESEARCH COMMUNITY INTERVIEWS

We interviewed 14 individuals from the Science Community within PB Sci, Engineering, and the Office of Research. This page summarizes some of the notes the auditor took from the interviews in which multiple individuals made the same observation.

Unless citing a specific example, all the statements made on this page were repeated by at least 3 individuals. In some cases we indicate the frequency in which these statements (or substantially similar statement) came up during the interview. Due to the nature of the interview process, it is possible that (and perhaps likely) that more individuals may believe the statements to be true then we indicate, but they simply did not say the statement, or analogous statement, in question during the interview.

Comments Related to power disruptions

1. The cost of power disruption on research is very significant and takes on many different forms (Majority) but is quite hard to quantify (Many).
    a. Fiscal costs are incurred (Majority)
        i. One major fiscal costs is the premature failure of equipment (Many).
            1. A challenge with measuring the cost of equipment failure is that equipment failure often does not occur immediately after an outage, but rather occurs over time in the form of particular parts failing at a higher than expected rates. This makes the cause and effect relationship hard to determine (Some).
                a. Insurance claims are made harder due to the difficulty in creating this cause/effect relationship between outages and equipment failure (Some).
                b. Some researchers mentioned that some of their equipment simply draws too much power to be put on backup generators or uninterruptible power supply units. Furthermore, backup power generators do not kick in immediately but rather take 15-60 seconds to begin running and therefore even equipment protected by backup generators will experience a hard shutoff and extra cycles whenever power is lost (Many). Auditor Notes: Buildings which are on cogeneration power should often be able to immediately switch between PG&E and cogeneration preventing the disruption, but some research facilities, such as those in the Physical Sciences Building (PSB), are not on cogeneration power and therefore are impacted every time a PG&E outage occurs.
                c. One individual gave some examples related to "Nuclear Magnetic Resonance Spectroscopy" (NMR) Spectromotors located in the PSB. Because the PSB is not on cogeneration power and some of the ancillary

equipment to run the NMRs require too much power to run on backup generators, these very expensive instruments are totally reliant on PG&E power reliability to function properly. Unfortunately the researcher attributes a number of costly repairs to frequent PG&E power disruptions. For example within a single lab, there are several expensive repairs directly attributed to power disruptions just within the last five years:

i. A $25,000 repair in 2018 required for a broken temperature sensor which the manufacturer's engineers indicated they have not seen since the introduction of cryoprobes in the early 2000s.

ii. A $18,500 repair is currently needed to repair a temperature cooling unit which they attribute to frequent power cycles.

d. Another individual (who is on cogeneration power) gave examples of how they have noticed clear differences in the number of basic equipment items (they gave a pump as an example) that they need to replace within their own lab depending on if that equipment is behind a power supply unit or not. They have found that equipment backed up with UPS units tend to fail far less frequently, presumably because this equipment experiences less surges/disruptions in power and overall fewer cycles.

ii. Another fiscal cost results from the lost opportunity to run samples for outside organizations (Some).

iii. Researchers noted that often experiments need to be redone if they are interrupted by a power outage midway through the experiment. Because a number of supplies can be exhausted in the course of an experiment, the experiment being rerun results in wasted supplies (Many).

iv. A number of researches indicate they have spent significant financial resources to "harden" their lab against power outages. The primary method to do this is via purchases of uninterruptible power supply (UPS) units (Many).

1. There is quite a range in the amount of money spent on UPSs, but several researchers indicated they spent in the tens of thousands of dollars on the units. (Some).

2. Another way researchers have "harden" their labs is to configure the electric distribution system in their labs to include backup power outlets for critical equipment (Some).

3. In addition to the fiscal cost of hardening these labs, there is some productivity cost in that researchers need to dedicate a significant amount of time to plan how to handle backup power (Some).

4. Quite a number of researchers indicated that, in light of the frequent outages (as well as frequent power surges), it would be beneficial to have centralized support in the process of hardening their labs (Many).

    a. Some faculty were thankful for technical assistance they received when they first started at UCSC to install UPS units, backup power, etc, but they indicated that this assistance was certainly not uniformaly given to all faculty starting up labs (Some).

    b. Given that UPS units are so widely used at UCSC, several faculty members wondered if there was some way for the University to achieve some economies of scale with the process of purchasing these items (some sort of bulk purchase agreement – or at least technical assistance in choosing the right UPS units to meet their lab needs). (Some).

v. Importantly, many researchers indicate that very short outages can often be just as harmful as longer outages as many of the costs are incurred per outage and the impact often has little to do with the length of the outage (Many).

1. There are some exceptions to this, as there are cases where short disruptions do not have much of an impact but longer ones can.

    a. For example that came up in several interviews was rearding research in which freezers were needed to keep samples cold. In this case, there is generally little impact to the items in their freezers unless the outage lasts many hours and if the freezer is not on backup power (Some). One researcher explained that they would likely have essentially zero financial impact to lost samples for an outage lasting a few hours, but if that outage lasting a day it would result in catastrophic financial impact to their research as frozen samples would be ruined.

b. Lost Productivity is Incurred (Majority)

i. Often times experiments run over a long period of time. A power disruption occurring part way through an experiment will usually ruin the reliability of the results of that experiment. Therefore at a minimum the time spent preparing and running the experiment is wasted (Many).

1. There is a huge variety in how much time is actually wasted in the event of a disruption as it is dependent on the length of experiment and the length of time preparing the experiment. It was not uncommon to hear about an experiment that took several days or a week to prepare and to run (Many).

    a. Many researchers indicated that the time spent preparing an experiment is labor intensive. When a disruption occurs, several faculty reported that the entire preperation time has to be redone therefore it represents a huge productity loss. (Many). In some cases multiple undergrad/grad researchers may be involved in preparing an experiment, so the lost productivity could multiply fairly quickly (Some).

2. Importantly, similarly to the financial loss from short outages, researchers indicate that the length of the disruption often does not typically matter in regards to the lost productivity: if a disruption occurs during an experiment, the experiment is lost regardless of it is a 5 minute outage or a 5 hour outage (Some). Like in the case of the financial loss, there are exceptions where short outages have minimal outages, but longer ones can waste productivity.

ii. An additional productivity loss from an outage is due to all the troubleshooting that must occur after the outage to check to ensure equipment is running properly and samples are still viable. (Some)

1. I spoke with several faculty members who gather samples in field research to perform analysis back in their lab on campus. If an electric disruption in some way makes their samples unviable, that may result in performing additional fieldwork to replace the samples (Some).

a. One example given involved a faculty member who's graduate students needed to perform basic biology analysis on a soil samples they gathered from fieldwork. Performing this analysis was somewhat time sensitive – they needed to perform it within 24 hours or so from collecting the sample in the field. When a student was conducting this analysis from a recent fieldwork campaign, a short outage lasting a few minutes occurred. Unfortuently the file in which the results of the analysis was being collected on the computer was corrupted and all the analysis (around three hours at that point) had to be performed again. The faculty member could easily see a scenario where this could push the analysis past the 24 hour window and would then require the graduate student to perform very labor intensive fieldwork rework to regather these samples.

iii. There is a loss in productivity during outages due to the simple fact that no research can occur while the power is out. (Many).

iv. Another example given for productivity loss deals with losing work on computers when work has not been saved for some time when a power loss occurs (Many). This has become less frequent, with the greater use of labtops that have batteries, but some faculty report using desktop computers without a backup battery or old labtops which have batteries that no longer function for long. This likely does not have a very large impact on a per-individual basis, but it likely impacts a lot of people every time there is an outage. Therefore multiplied across the entire university this may have a non-trivial impact (Some).

c. Loss in mission acomplishment and prestige (Many).

i. Quite a few researchers indicated that outages have had a negative impact on their ability for them to be successful (Many).

ii. Some indicated that the outages have caused some researchers to question if they are able to do their work at this institution given the unreliability of power (Some). Poor power reliability may have contributed to some faculty departures (Some).

iii. A few researchers pointed to instances in which irreplaceable data or samples were lost due to power disruptions occurring (Some).

1. Some experiments that collect data over a period of time will not, or can not, be rerun. When power disruptions occur, some data simply is not collected and therefor one irreplaceable harm caused by outages is gaps in data collection. The impact of this on research is hard to measure, but clearly is negative. (Some)

2. One example given, (supported by several individuals), involved an outage that occurred several years ago. At the time the State Governor requested folks to reduce power consumption due to major fire risks to utility lines. A campus leader made the decision to disconnect the Physical Sciences Building from PG&E power and go on standby generators in order to reduce the overall campus PG&E load. Unfortunately researchers were not informed of this decision. Because some instruments require too much power to be on backup generators, a number of research equipment immediately went offline when the power was switched over. This went undetected by many researchers in the building for a number of hours because the main building lights and the rest of campus remained powered (and again there was no communication to the researchers). Around 4-6 hours later the backup generator failed. Due to the disconnection from PG&E power, the building was totally without power for a significant amount of time despite PG&E power never going down on campus during this time. Due to the nature of the outage not being detected immediately, some freezers containing irreplaceable samples were lost as a result of the long time without power (Some). One individual indicated that they believed a faculty member ultimately decided to retire earlier than planned as they lost many invaluable samples gathered over their career during this prolonged outage.

2. By far the most frequent criticism the research community had regarding the outages was that they believed communication was generally not adequate. (Majority). However, many of these individuals also noted that, while communication could be improved, they also believe that communication has been a bit better recently than it had been in years past (Many).

a. In regards to the specific communication elements they thought were lacking, research community members broadly identified the following areas of concern:

i. Often faculty members reported they did not know in advance when the cogeneration plant would be offline for maintenance (leaving their research at greater risk during this time if PG&E were to also go offline). (Some)

ii. Faculty members indicated that they would appreciate very timely information and some indicated they would appreciate more timely information even if the information was incomplete. For instance a number of faculty members indicated that it would be helpful for them to receive a "Cruz-Alert" style text message whenever power is lost so they can immediately take actions to protect their research if, for example, certain experiments are running. Follow-up emails with more detail about the extent and causes of the outage would be appreciated later. (Some)

iii. A number of faculty members report that they rarely get information on the ultimate determination made regarding the causes of outages. (Some)

iv. Some faculty members also indicated that they would often not have clear information on whether standby generators were working properly during outages. (Many).

   1. Auditor Note: Not knowing the status of standby generators has implications on faculty that use UPS devices. These devices are able to bridge the gap in power if standby generators run successfully during PG&E outages, but they often do not have the capacity to last over the period of a prolonged disruption.

v. Other faculty members indicated they would appreciate if they could see the status of power on campus via some sort of web portal (Some). Auditor Note: For context, the campus does have a live dashboard for solar generation accessible online.