Continuous Improvement in Investor-Owned Utility Risk Management:

Integrating Enterprise Risk Modeling and Climate Vulnerability Assessment to Enhance IOU Resilience

I. Background and Introduction

This whitepaper is submitted in advance of the planned September 13, 2023, California Public Utilities Commission (CPUC) workshop to consider the relationship between investor-owned utility (IOU) quantitative risk modeling efforts per [Rulemaking 20-07-013] and IOU climate hazard assessment efforts per [Rulemaking 18-04-019].

California's IOUs provide a critical public service via widely distributed physical infrastructure that is exposed to California's many climate-driven natural hazards. Additionally, California's IOUs assiduously manage safety and reliability risks that are inherent in operating the energy system. As climate change advances, these efforts will increasingly overlap.

The following paper provides the perspective of Pacific Gas & Electric Company on the two key questions to be discussed at the September 13th joint proceeding workshop, namely:

1. *Should analyses or results from IOU Climate Adaptation and Vulnerability Assessments (CAVAs) inform quantitative risk modeling of climate hazards using the Risk-based Decision-making Framework (RDF; D.22-12-027 Appendix B)?*

2. *How should climate hazards be reflected in Risk Assessment and Mitigation Phase (RAMP) filings?*

The answers to these questions are meaningful because they help to answer a much larger threshold question for the Commission and IOUs, which is:

3. *"How can the Commission support, and IOUs enact, necessary climate adaptation investments given the existing risk-based framework for evaluating investment proposals?"*

Considering California's recent experience with climate-driven hazards as well as the increasing severity and frequency of hazards projected by climate models, California's energy stakeholders must move swiftly to adjust the existing risk framework to allow for needed climate resilience investments while maintaining the evaluative rigor that underpins Commission approval and maintains public confidence that their valuable dollars are being spent wisely on their behalf.

PG&E's perspective is informed by our experience working to integrate enterprise risk management and physical climate risk since PG&E first attempted to do so in our 2020 Risk Assessment Mitigation Phase (RAMP) filing.

This response is organized in answer to the three questions posed above. In general, PG&E believes that IOUs should strive to integrate their operational experience and climate risk evaluation efforts to the greatest extent possible so that investment decisions are made holistically and tradeoffs between investments are apparent. Given the rapidly evolving and complex nature of managing climate risk, this is likely a multiyear maturation effort.

PG&E's responses to the questions at hand are provided at a summary level below and expanded upon in each of the corresponding sections:

1. *Should analyses or results from IOU CAVAs inform quantitative risk modeling of climate hazards using the RDF?*

   Yes, IOU risk management can benefit from aligning the analyses and results from CAVAs, acknowledging that only one IOU has produced CAVA results at this time:

   - The extent to which CAVA results may meaningfully influence the RAMP process depends on the nature of CAVA results, which are not standardized at this time. This indicates the need for general guidance rather than a heavily prescriptive integration framework.
   - Due to the nascent state of CAVA/Risk-based Decision-Making integration, in the near term, the value of CAVA results to the quantitative RAMP process is likely found in qualitatively flagging discrepancies between RAMP risk findings and longer-term CAVA risk findings, exposing the need for deeper analysis of how the risk in question may change over time outside of the RAMP period.
   - Despite meaningful differences in the structure of RAMP and CAVA, PG&E sees analogs between inputs to both analyses that indicate the potential for further integration in the future.

2. *How should climate hazards be reflected in RAMP filings?*

Recognizing the inherent challenges in integrating climate projection data with the RAMP modeling framework, PG&E proposes an initial CAVA/Risk-Based Decision-Making integrated framework based on the following elements:

- *Cumulative Risk Measures*. PG&E's 2020 RAMP treated climate hazards as Cross-Cutting Factors, which could impact either the Likelihood of Risk Event (LoRE) or Consequence of Risk Event (CoRE). PG&E believes that this treatment is sound, but at the same time resulted in weak climate signals, which were further dampened given the long-term nature of climate change, i.e., climate impacts were subject to substantial discounting. PG&E proposes utilizing a cumulative view of climate risk within RAMP to ensure the impacts of climate change are more clearly represented.
- *Scenario-Based Approach to Hazard Quantification*. The RDF is probabilistic; however, modeling climate hazards using probability distributions and stochastic processes is challenging. PG&E proposes using the climate scenarios established in CAVA to quantify Climate Hazards (Cross Cutting Factors; CCF)
- *Confidence Ranges*. The Cumulative Measures above should not be point estimates; ranges for Risk values should be developed based on, for example, 10^{th}-50^{th}-90^{th} percentile Hazard scenarios.

- *Scenario-based approach to Modeling Cascading Events.* The CAVA rulemaking requires consideration of cascading events (when a climate-driven risk hazard occurs concurrently with or as a result of another climate hazard event). However, the RDF, at its essence, relies on calculating the mathematical expectation of a probability distribution. The likelihood and consequence of *concurrent* events (e.g., the simultaneous occurrence of a catastrophic wildfire, a dam failure, seismic damage to infrastructure) is not well handled in this framework. PG&E proposes that cascading events be specifically defined by scenarios and that Risk Events (i.e., bowties) be created to incorporate them into the RDF.
- *Uncertainty Analyses*. Elements of the Transparency Proposal that was piloted in D.21-11-009 can be used to quantify the uncertainty and sensitivity of risk values to the underlying climate Hazard assumptions.

3. *How can the Commission support, and IOUs enact, necessary climate adaptation investments given the existing risk-based framework for evaluating investment proposals?*

   As previously mentioned, PG&E's proposal represents an initial and feasible, integration of the CAVA analysis into the RDF. By no means is it the only way nor has the proposal been rigorously tested. *For these reasons, PG&E ultimately recommends that the Commission adopt a flexible, iterative approach to integration, consisting of the following*:
   - The Commission should establish a pilot phase for the CAVA/Risk-Based Decision-Making Integration Framework proposal included in this paper.
   - At the end of the pilot, a gap assessment should be conducted to identify areas of improvement or decide on the viability of the approach.
   - Based on the gap/feasibility assessment, the Commission should decide which parts, if any, of the integrated approach can be adopted, and which should be further refined through subsequent phases.
   - In the meantime, the IOUs must be afforded the flexibility to continue their current climate modeling efforts and make the case for climate-based investment in the manner most appropriate to their circumstances.

II. Full Comments

1. *Should analyses or results from IOU CAVAs inform quantitative risk modeling of climate hazards using the RDF?*

In general, PG&E holds that climate change data should be integrated into utility activity wherever appropriate and possible so that climate-informed decision-making is standard business practice. For this reason, PG&E agrees that analyses and results from IOU CAVAs should inform quantitative risk modeling of climate hazard using the RDF that forms RAMP.

However, the extent which CAVA results may meaningfully influence the RAMP modeling process and modeling depends on the nature of CAVA results which are not standardized and have only been produced by one IOU at this time. As PG&E has developed its CAVA, due May 2024, the primary output is a climate-risk rating of PG&E's asset families relative to expected hazards for target year 2050. These ratings indicate which asset families are relatively more vulnerable to the climate hazards in scope; they indicate where more detailed analysis is required, but they do not offer an asset-by-asset assessment of probability or impact of future failure events. These relative climate risk ratings, while based on quantitative analysis, are ultimately qualitative, and do not apply to the drivers and consequences of RAMP risk bowtie models directly at this time.

Figure 1: A PG&E's CPUC-compliant CAVA Methodology

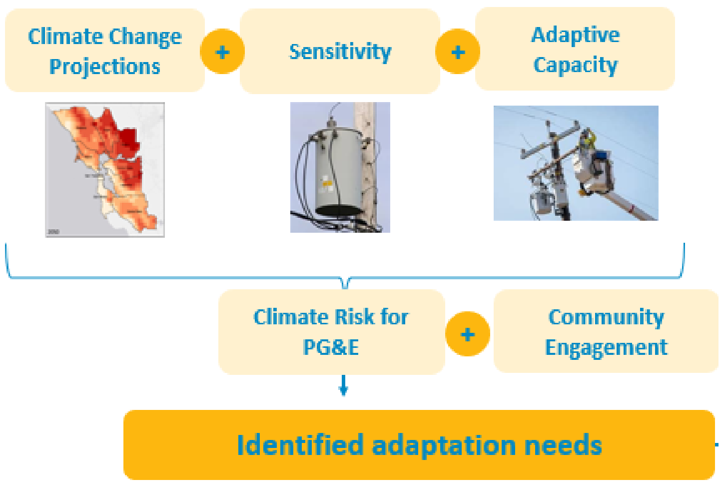
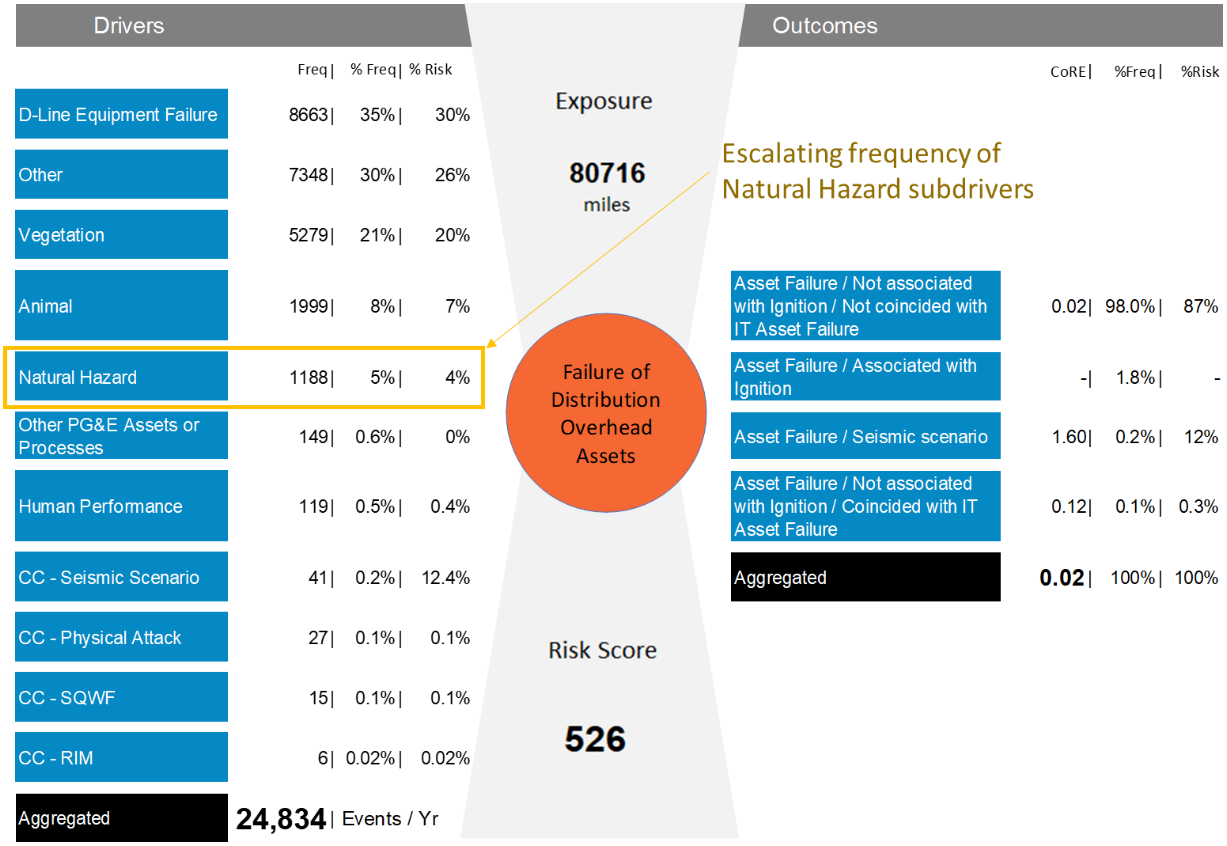


Figure 2: A representative RAMP bowtie model. Note the relatively minor contribution of natural hazard events to the risk event.



Given CAVA outputs initially will not provide the types of inputs needed for being fully incorporated into quantitative RAMP risk models, in the near-term the value of CAVA relative to the RAMP process is likely found in qualitatively highlighting discrepancies between RAMP risk findings and CAVA findings. If an asset family is found to have a high climate risk rating from CAVA (with target year of 2050) but the corresponding RAMP model indicates that near-term risk is low, that is a clear indication that further analysis is required to better understand the source of discrepancy and how the risk is changing in order to manage it effectively. PG&E is piloting this comparative approach in our upcoming RAMP filing by including relevant CAVA findings in the corresponding RAMP risk chapters and flagging said discrepancies.

However, the statements above should not be interpreted to say that PG&E does not support a quantitative integration of RAMP with CAVA, but merely to illustrate some of the challenges associated with doing so.

CAVA and RDF Analogues

Stepping back, analogues do exist between the two approaches as displayed in the following table.

CAVA	**Comments**	**Risk-based Decision-Making Framework**	**Comments**
Climate Change Projections (Climate Hazards)	Involve hazard identification and quantification	Cross-Cutting Factors (CCFs; PG&E Implementation)	Only *identified* CCFs can be scored; in this regard CAVA serves a complementary role by characterizing climate hazards of significance.
Sensitivity	Not to be confused with Sensitivity Analysis. This term refers to whether and to what extent an asset will be impaired if exposed to a climate hazard, i.e., vulnerability.	Risk Bowties and elements (drivers, consequences)	Asset vulnerabilities ultimately are drivers for Risk Events; some of which might not be currently identified in IOU's Risk Registers.
Adaptive Capacity	An organization's existing tools and strategies for resisting, absorbing, and recovering from disruptive events.	Existing Controls/planned mitigations	
Community Engagement	Input from customer communities regarding energy system needs in the face of climate change	Consequence modeling; Mitigation development	Community engagement can assist in quantifying Risk consequences and mitigation prioritization
Climate Risk Output	Qualitative rating (High, Medium, Low)	Risk value measured in risk-adjusted $	
Identified Adaptation Needs	For example, a hypothetical accelerated transformer replacement program	Proposed mitigations	

There are some aspects of the CAVA approach that are not explicitly treated in the RDF, most prominently Cascading Events. Also, current RAMP reporting requirements, wherein Risk values are reported for the GRC period in question, do not lend themselves well to expressing the impact (risk intensification) from Climate Change over long periods of time. Nevertheless, PG&E believes that the

RDF can be supplemented by additional results and analysis to portray the impacts of Climate Change more accurately.

Based on the above, PG&E concludes that the two approaches are compatible, or can be made compatible, to some degree. The exact extent has yet to be determined and the proposal below should be seen as a first, exploratory step to answering this question.

2. How should climate hazards be reflected in RAMP filings?

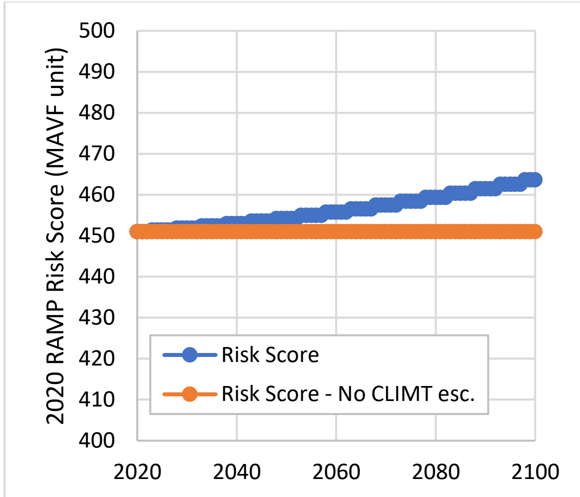
As discussed in Section 1, efforts to align CAVA results and RAMP inputs may not be the most effective way to elevate climate change risk within the RAMP process. However, ensuring that RAMP models are climate-informed, using the same data that informs CAVA analysis, is an important process that deserves further attention.

As the primary purpose of RAMP is the quantification of enterprise risks, there are elements of the RAMP risk modeling framework that pose challenges to effectively integrating physical climate risk. Two of them are described below:

1. **Driver attributions based on historical data** – As discussed in Section 1, physical climate risk manifests as more frequent and severe natural hazard events, which in turn drive the occurrence of more risk events. However, according to PG&E's historical data, natural hazard events have accounted for a small fraction of risk event occurrences. As a result, even successful integration of climate data into a risk bowtie by escalating a low frequency risk driver may have little impact on the ultimate risk score in question. A near term solution, as noted in Section 1, is to qualitatively compare CAVA and RAMP findings. More specifically, it may be useful to compare undiscounted RAMP risk modeling results, modeled out to the year 2050 to CAVA findings, paying particular attention to whether asset failure frequencies in the risk modeling align with the level of vulnerability identified by CAVA.

Generally, as we move into the paradigm where the past is no longer a useful proxy for the future, we have decreasing confidence that simply adjusting/escalating historical event rates due to natural hazards reflect an accurate picture of future risk.

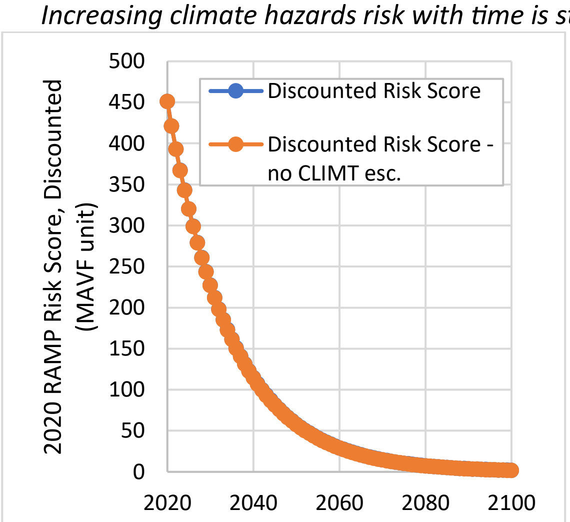
Figure 3: A representative risk score without and including escalation reflecting expected climate change.

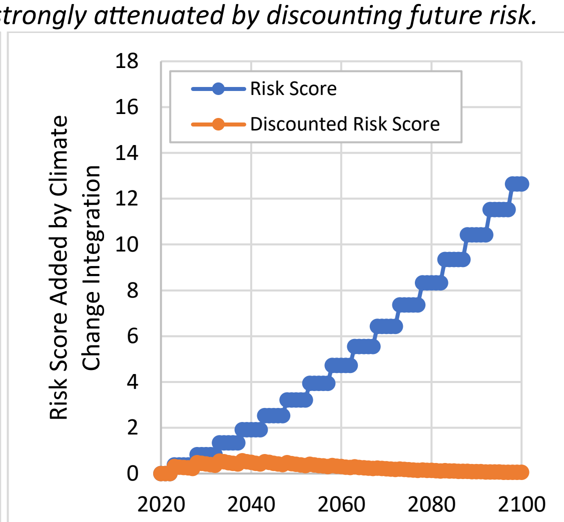


2. **Discounting of Out-Year Risks** – While the issue of discount rates has been specified for a latter phase of this proceeding, the discounting of out-year risks must be mentioned here as a current hurdle to using RAMP as the primary driver of prudent and proactive resilience investment.

Figure 5: (Left) Demonstration of the impact of discounting on the climate signal in RAMP. Note that the brown and blue lines are essentially equivalent.

Figure 6: (Right) Demonstration of divergence in climate-integrated risk score with discount applied. Increasing climate hazards risk with time is strongly attenuated by discounting future risk.





Despite the challenges discussed above, PG&E firmly supports the further integration of climate change into the RAMP framework.

In PG&E's 2020 RAMP, PG&E has quantitatively incorporated climate data into two RAMP risks: Failure of Distribution Overhead Assets and Wildfire. These risks were selected for their relatively high RAMP risk scores, indicating that these were priority risks even before adjustments related to climate change, and because the climate data available through Cal-Adapt.org supported integration from a technical perspective. At a high level, these bowties were integrated by applying relevant climate data, for example, increasing average temperatures, to escalate the frequency of risk drivers or the extent of consequences.

It is important to note that there are some risks to which climate change does not apply or its impact is expected to be minor, and therefore the effort of RAMP model climate data integration is not warranted. These include risk events that do not have a natural hazard driver, for example Cyber Security Incident, as well as some risk events that may intuitively have a natural hazard driver component but are insensitive to climate impacts.

Initial Ideas for Advancing Climate-Informed RAMP

With this context in mind, PG&E proposes an initial CAVA/Risk-Based Decision-Making integrated framework. This proposal is best illustrated by a simplified spreadsheet example.

RAMP

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Long Term Interest Rate	4.25%												
Discount Factor		88%	84%	81%	77%	74%	71%	68%	65%	63%	60%	58%	55%
Risk		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
WildFire		21,429	20,538	19,683	18,864	18,657	17,881	17,381	16,893	16,415	16,273	15,596	14,947
Large Uncontrolled Water Release		61	59	57	55	53	51	50	48	47	45	43	41
Loss of Containment - Gas Transmission		255	244	236	228	219	210	202	195	188	180	175	167
Distribution Overhead Failure		471	451	432	414	402	385	371	358	345	331	323	309
...													

Climate Change Supplement

Climate Hazard(s)	Risk	Cumulative Impact due to Hazard (in Risk Units)	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Increased Temps	WildFire	30,257	643	616	590	566	560	536	521	507	492	488	936	897
Flood Risk	Large Uncontrolled Water Release	24	-	0	1	1	1	1	1	1	1	1	1	1
Flood Risk, subsidence	Loss of Containment - Gas Transmission	68	-	-	2	3	3	3	3	3	2	2	4	4
Increased Temps	Distribution Overhead Failure	241	8	7	7	6	11	10	9	8	8	7	13	12
Increased Temps	New Risk from CAVA scenarios - Circuit Overloading	2,865	-	-	-	37	37	37	37	37	37	37	74	74
Increased Temps	New Risk from CAVA scenarios - Cascading Event X	2,958	-	-	-	-	-	22	22	22	22	22	96	96
	...													

Overall Impact of Climate Change 36,414 (Risk Units)

Legend

- Baseline Risk Value (score) currently reported in PG&E RAMP
- Cumulative Impact (across all years) on Risk Due to Climate Hazard Intensification
- Annual impact (discounted $) on Risk due to Climate Hazard Intensification
- Sum of all the Cumulative Impacts

The top section labeled "RAMP" represents the risk results required by RAMP, namely calculating annual Risk values (baseline, post-mitigation, etc.). The section labeled "Climate Change Supplement" represents additional results that portray the impact of Climate Change. Most importantly, the impact of Climate Hazards on Risks (e.g., the Climate Hazard "Increased Temps" on Wildfire Risk) should be determined for each year. In the example above, it is assumed that the frequency of ignitions due to Temperature Intensification is 3% annually for the first decade (2027-2036), 6% for the next decade and so on. PG&E's risk modelling has a linear relationship between driver frequency and risk values, i.e., a 3% increase in ignitions would lead to a 3% increase in risk values (for 2027, this leads to a value of 643).

On an annual basis, this number might be small enough to mask the real impact of climate change, but if the annual discounted values for each year (over a suitable investment horizon, in this case, assumed to be 40 years, consistent with D.20-08-046's long-term time frame of between 30-50 years) are summed, this provides a better signal for the impact of climate change. For example, the impact of the Climate Hazard "Increased Temps" on Wildfire is 30,257 Risk Units. Reporting the Cumulative Impact is also more appropriate than single annual values because Climate Change's effects are cumulative and happen over a long period of time.

Following on, Climate Change is represented by the Climate Hazards (Increased Temperatures, Sea Level Rise, Flooding, etc.) identified in the CAVA (which are themselves candidates for Cross-Cutting Factors in the RDF). Hence the sum of Cumulative Impacts from all the Climate Hazards constitutes the Climate Change Impact within the RAMP framework.

This example also highlights many important topics that a mature climate-informed RAMP framework should consider, and that PG&E's proposal attempts to account for.

1. The RDF, as implemented by PG&E, accommodates CCFs in general, but does not specifically *identify* what the Climate Hazards/CCFs are. The CAVA provides identification and prioritization of climate hazards to be quantified and included in the RAMP risk modeling performed using RDF.

2. Quantification is "by Risk", more specifically, event-based Risk per the RDF. Hence if an Event is not identified and defined, its risk would not be quantifiable. This puts an emphasis on upstream processes like horizon scanning and identifying new, potential event Risks from the CAVA. In the example, an illustrative Risk called "New Risk from CAVA scenarios – Circuit Overloading" was defined and hence the Climate Change Impacts on it were quantified.

3. Cascading Events are handled by defining them as new Risks. The RDF considers Likelihoods and Consequences one Risk at a time. Hence the framework values two (or more) risks the same whether they happen simultaneously or not. However, as recent events (for example, the 2021 Texas winter storm) have demonstrated, the most extreme and tragic outcomes happen not through a set of isolated events but are caused by cascading or correlated events which are more likely to occur than commonly anticipated due to the complex, inter-related nature of physical systems. To account for these potential situations, one needs to identify and assess, to the extent possible, "mega"-Risks arising from a series of related Risk events with an underlying common cross-cutting factor, like climate change. The proposal envisions that the CAVA can be used as a starting point to further identify nascent cascading

Risks for quantification in the RDF, because it explores the exposure of a set of important utility assets to common hazards.

4. Quantifying new Risks, whether from vulnerability analysis or for Cascading Events, ultimately involves estimating likelihoods and consequences for events that have not appeared in the historical record. While various estimation approaches can be employed, there will still be a high degree of uncertainty involved. The uncertainty should be quantified as much as reasonably possible. In this regard, PG&E believes that the Transparency Proposal piloted in D.21-11-009 can be utilized to serve this function.

5. Finally, it is important to realize that the Climate Hazards/CCFs themselves are probabilistic in nature. For e.g., one cannot say with certainty how temperatures will increase over a 40-year period and its impact on different assets and systems. A proper mathematical approach would be to determine the "probability distribution"/stochastic process for the Climate Hazard, and to find the expected value for the Climate Change Impact (as defined above) over this distribution. This would likely involve generating Monte-Carlo trials for each Climate Hazard/Cross Cutting Factor and then determining the Climate Change Impact for each trial and calculating the average.

   However, modeling Climate Hazards probabilistically is a challenging and time-consuming endeavor. A much more viable and productive first step would be to calculate the Climate Change Impact over different scenarios to get a range of values (for e.g., 10^{th}-50^{th}-90^{th} percentile scenarios). This also has the advantage of making the analysis accessible to a wider audience because scenarios can be specified in a more transparent manner as opposed to relying on complex statistical analysis.

   Climate Change Impacts from different scenarios can also be probability-weighted to get an estimate of the Expected Climate Change Impact (from using a fully stochastic approach). In the example above, it is important to recognize that the section called "Climate Change Supplement" only represents the results from one scenario. The results should be calculated across multiple scenarios that should be defined and provided by CAVA.

3. *How can the Commission support, and IOUs enact, necessary climate adaptation investments given the existing risk-based framework for evaluating investment proposals?*

Given the urgency of the climate crisis, the Commission and IOUs must act swiftly to identify guidelines within the RAMP/General Rate Case (GRC) process that allow for well-justified adaptation investments in parallel with further integrating climate change into RAMP risk modeling.[1] It is important to continue to advance quantitative climate integration within the RAMP framework, and also it is not possible to wait for the development of a perfected, unified risk model to accelerate energy system climate adaptation.

[1] PG&E notes that this is true for all if its asset families including those that rely on sources of funding other than the CPUC General Rate Case.

Given the support Californians will need in the face of increasingly severe and frequent climate hazards, the time to act is now. This imperative is only strengthened by consistent estimates from leading bodies that the return on climate adaption investments is between two and ten dollars for each dollar spent today.[2]

Regarding advancing a climate-informed RAMP framework, PG&E proposed the following:

- The Commission should establish a pilot phase for the CAVA/Risk-Based Decision-Making Integration Framework proposal included in this paper.
- At the end of the pilot, a gap assessment should be conducted to identify areas of improvement or decide whether the approach is viable.
- Based on the gap/feasibility assessment the Commission should decide which parts, if any, of the integrated approach can be adopted, and which should be further refined through subsequent phases.

PG&E is not currently able to offer a comprehensive proposal for urgent, “no-regrets”, resilience investments. Climate risk assessment is a complex and evolving discipline as is climate-informed investment decision-making. However, we offer the following suggestions to advance utility resilience as climate-informed quantitative risk assessment continues to mature.

- **RAMP, CAVA, and Follow-On Analysis** – Via their CAVA analyses, IOUs may identify assets or asset families at greater relative risk of negative climate change impacts. Depending on the nature of the CAVA analysis, the results may indicate specific, “no-regrets” investments that can be submitted and evaluated through the GRC process.

  Alternatively, as in PG&E’s case, CAVA analysis may serve as the first step in prioritizing further analysis by indicating which assets families are subject to relatively elevated climate risk. As discussed in Section 1, it may be useful to compare RAMP findings and CAVA findings, paying particular attention to discrepancies between near-term and longer-term results.

  PG&E relied on CAVA to inform which asset category to select as well as which hazards to assess for a climate hazard quantification Study currently being conducted in partnership with an outside consultant. The Study is designed to determine site-specific probabilities of asset failures at electric substations stemming from future extreme heat, flooding, and wind conditions, as well as associated costs.[3] The end goal of this effort is to develop asset-specific cost-benefit ratios for climate adaptation measures for each substation, informed by the climate-driven natural hazard impacts the substation is likely to experience in the future.

  Efforts like the Study to both increase the granularity of climate hazard analysis as well as produce outputs in dollars will likely play a prominent role in identifying and prioritizing climate resilience investments. This kind of analysis will be particularly important for investments that may not have a favorable benefit-cost ratio during a given RAMP window, but that are highly

[2] Global Commission on Adaptation. Adapt Now. (2019).
[3] See Appendix B for more detail on the Study. This work is still in progress and as such PG&E cannot commit to the inclusion of findings or related material in the 2024 RAMP filing at this time.

justified by projected future conditions. In the long term, a full mature, climate-integrated RAMP framework may diminish the need for these kinds of additional studies to justify investment; in the meantime, PG&E is working to rigorously characterize priority climate risks using currently available analysis.

- **"What is a 'Climate Resilience' Investment?" –** PG&E raises this question because a precise definition of what constitutes a climate resilience investment is important for determining when a proposed investment is appropriate. PG&E cautions against an overly proscriptive definition; climate resilience investments come in many forms, from PG&E's 10K Undergrounding initiative to accelerating the replacement of transformers with climate-resilient upgrades to expanded funding for Emergency Planning and Response. A useful distinction between a resilience investment and other types of investments might have to do with the return period on investment. PG&E expects that insights from further integrating climate change data into RAMP may help better answer this question.

  Additionally, we would like to highlight the increasing importance of investments made in partnership with communities that are organizing around their own climate resilience. Resilience is a shared goal, and the climate-driven hazards that impact our ability to deliver energy also impact our customers at the same time. To that end, the Commission and IOUs must work to ensure that whatever methodology is developed encourages and accelerates these types of resilience partnerships. Allowing for these partnerships is even more important given the amount of state and federal money becoming available to communities for climate resilience.

- **For Further Consideration: Climate Resilience versus Other Critical Investments -** PG&E acknowledges that none of the suggestions above address the problem of prioritizing climate resilience investments relative to investments driven by RAMP or other strategic or regulatory considerations (for example, the need to invest heavily in expanded electric grid capacity to support California's decarbonization efforts). The IOUs understand that affordability is paramount even as climate change is expected to pose new costs on safely and reliably maintaining the energy grid. Managing these competing dynamics effectively is a key strategic priority.

To conclude Section 3, PG&E reiterates that there is still much to learn about climate-informed utility investment planning, but also that stakeholders must work together to develop a workable process for evaluating and authorizing well-justified proactive climate adaptation investments as soon as possible.

III. Conclusion

PG&E deeply appreciates the opportunity to submit this whitepaper in advance of the joint proceeding workshop. These comments are an opportunity to share the hard-won experience we have gained in assessing and integrating the impacts of climate change into how we do business over the last few years.

Undoubtedly there is much more to learn and to do on the path toward mature climate-informed investment decision-making, but Commission and IOU efforts to advance operational risk assessment, climate vulnerability assessment, and the overall rigor of utility investment planning in recent years represent meaningful progress and leave this process well positioned to advance further.

The onus is on the IOUs to perform high quality analysis and use the best available data to make the case for necessary resilience investments. PG&E and our sister utilities are committed to doing that in a way that allows the Commission to fulfill its role as the protector of the public trust and arbiter of prudent utility investment while also supporting the climate resilient energy system the people of California deserve.

Appendix A: Pacific Gas & Electric's Response to the Workshop #3 Planning Questions

On August 23, the Commission's Safety Policy Division issued eleven Planning Questions in advance of the September 13 workshop on Climate Change. Although PG&E had already developed its whitepaper on the topic of the integration of the Climate Adaptation Vulnerability Assessment and the Risk Assessment and Mitigation Phase report, it provides a brief response to each of the questions below to further help facilitate discussion at the workshop.

1. *Should the Commission modify the RDF to ensure that climate hazards or risks are properly accounted for within the risk models in the IOU's RAMP filings? If so, what language in the RDF, including potential definitions, should be modified?*

   The Commission may need to modify the RDF to ensure that climate hazards or risks are properly accounted for within the risk's models in the IOU's RAMP filings. However, at this time, it is not entirely clear what the extent of modifications, if any, are required. PG&E's pilot proposal herein, should be adopted as a step that will assist in answering this question.

2. *What is a process utilities can undertake to identify whether or not future climate hazard conditions will have a meaningful impact on risk scores and warrant additional research and analysis to inform risk models? Should the Commission direct utilities to undertake such a process? On what timeline?*

   In its proposal, PG&E outlined an approach whereby the scenario analysis performed for CAVA are used as the basis for identifying new potential risks and cascading events. Discrepancies between RAMP and CAVA findings for previously-identified risks may also indicate the need for further research. Should this component of the proposed pilot prove to be useful, the Commission can incorporate this additional step as part of a requirement to integrate CAVA and RAMP filings.

3. *Do climate hazards pose any additional risks that may not yet be included in Enterprise Risk Registries? If yes, what risks?*

   It is possible that climate hazards pose additional risks that may not yet be included in Enterprise Risk Registries. PG&E believes that the vulnerability analysis performed in the CAVA is the first step to identifying new risks, as vulnerabilities describe conditions for asset failure, a major driver in many risks' bowties. Furthermore, since the vulnerabilities being studied in CAVA are all related to climate, it highlights the potential for cascading events, where a risk event leads to other risk events eventually resulting in catastrophic consequences.

4. *Should and, if so, how should climate data be incorporated into risk models and IOU RAMP filings? What criteria should be considered for determining if including climate data in risk models is needed?*

   PG&E described a framework in its proposed pilot wherein climate data can be incorporated into risk models and IOU RAMP filings. Different climate scenarios can be used to determine the ranges of Risk Scores and the Impact of Climate Change. Please see the section *"Initial Ideas for Advancing Climate-Informed RAMP"* for more information.

5. *Should inputs into the CAVAs (climate data or projections) or CAVA results (e.g., assets identified as vulnerable or potential adaptation options), or both, be used as inputs into risk models found in IOU RAMP filings?*

   PG&E believes that CAVA scenarios can be used to determine ranges for Risk Scores, and the calculated Climate Change Impact. Furthermore, the Vulnerability Analysis can be the starting point for identifying new potential Risks and cascading events. Adaptive capacity would form the basis of determining existing controls and planned mitigation and adaptation needs can be part of proposed mitigations.

6. *Should and, if so, how should climate data, models or projections, including inputs into the CAVA or CAVA results, be used to affect the calculation of Likelihood of Risk Event or Consequence of Risk Event in IOU RAMP filings?*

   Generally speaking, climate data, models and projections, including inputs into the CAVA or CAVA results should be used to affect the calculation of LoRE and CoRE. In its 2020 RAMP (A.20-06-13; Ch. 20), PG&E treated Climate Change as a Cross-Cutting Factor (CCF), which in general, were modeled to either impact LoRE or CoRE or both. For example, a CCF may be modeled as increasing the frequency of Risk Events. Alternatively, it can be modeled as magnifying consequences (e.g., with Wildfire Risk, the correlation of ignitions during Red Flag Warning days was strengthened resulting in more ignitions during those days). PG&E believes that the CCF approaches in its 2020 RAMP are still conceptually valid, but the challenge is how to identify and quantify the changes, e.g., how to determine which Risk drivers are affected by Climate Change, and what multiplier to use for the associated driver frequencies, etc. In this respect, PG&E believes that the scenario results from CAVA can be a helpful source of information in both identifying affected risk components (LoRE or CoRE) and serving as the basis for quantification of multipliers, etc.

7. *What is the relationship between near-term, RAMP-driven investments and long-term adaptation benefits? What existing methodologies exist for quantifying the "climate adaptation value" of a RAMP-driven investment?*

   In concept, long-term adaptation benefits would be captured in the Cost-Benefit Ratio calculation because Row No 25 of the RDF (D.22-12-027 Appendix B) states that the Benefits of any mitigation "should reflect the *full* set of Benefits that are the results of the incurred costs." Hence in the RDF the difference between near-term RAMP driver investments and long-term adaptation benefits is the time period when the benefits are obtained. In practice, it is hard to quantify the adaptation benefits because of its long-term nature. This is due to the considerable uncertainty around whether the impact of climate change has been captured correctly over long periods, and whether new climate-derived Risks have been identified. Discounting will further mask the benefits. Row No 26 of the RDF also presents other reasons why Cost-Benefit Ratios should not be used solely for evaluating mitigations.

   Under PG&E's proposal, the Climate Change Impact measures the cumulative impact (over the CAVA scenario period) of climate on new and existing Risks (e.g., whether climate trends lead to an intensification of Risks). While any mitigation (including long-term adaptations) can have both long and short-term (i.e., GRC period) benefits, long-term adaptation benefits are those that primarily mitigate the cumulative long-term Impact of Climate Change measure. RAMP-driven investments are those that primarily focus on existing Risks and are likely to be part of the IOU's adaptive capacity in the long-term timeframe. Both kinds of measures would have Cost-Benefit Ratios but as with all mitigations, would be subject to the conditions in Row No 26 of the RDF.

8. *Which long-term climate-related investments also serve to mitigate near-term risk, if any? Should and, if so, how should the near-term risk reduction benefit of a climate-related investment be quantified for inclusion in IOU RAMP filings?*

   As mentioned above, the Cost-Benefit Ratio is a potential measure of long-term climate-related investments. Another alternative is to undertake scenario analysis to determine which investments effectively mitigate the consequences of the identified scenarios. As more work needs to be done on integrating the CAVA with the RDF/RAMP, it is important that IOUs be accorded the flexibility in the meantime to present alternatives to quantifying climate change impacts and the benefits of long-term climate-related investments.

9. *What methodologies and approaches to using different climate data sets can allow utilities to evaluate a range of potential future weather patterns, including the evaluation of lower probability, high-impact conditions that could have implications for risk events described in RAMP filings?*

   Please see the section *"Initial Ideas for Advancing Climate-Informed RAMP"* for a detailed discussion of how climate data sets (scenarios) can be used to determine ranges for Risks values.

10. *Are there other steps the utilities and/or the Commission should take to ensure appropriate modeling of climate change and communication of associated uncertainties in IOU RAMP and general rate case filings?*
    PG&E views the integration of climate data into RAMP, CAVA analysis, and this effort to further integrate these two views of risk as strong steps toward more mature, climate-informed enterprise risk management. Given the potentially significant developments pending with regard to all of these efforts, including initial CAVA filings from three of the four California IOUs, PG&E views the current agenda as appropriately ambitious as scoped.

11. *As knowledge and information regarding climate change science and modelling improves in coming years, how should the Commission support utilities' use of the best techniques and data to inform climate change modeling and related mitigation proposals?*

    The Commission can support utilities' with regard to the use of rapidly evolving climate science by structuring guidance to accommodate said advancements. For example, guidance in D. 20-08-046 specifies that IOUs should rely on the most recent California Climate Change Assessment as a primary data source. This is more helpful than specific mandate to use California's Fourth Climate Change Assessment Data, as said guidance would need to be revised as new Assessments are generated. The Commission may also wish to remove or broaden requirements regarding which Representative Concentration Pathway (RCP) or Shared Social Pathway (SSP) to utilize for analysis, as using multiple RCPs/SSPs can help provide a range for expected conditions. Also, the RCP/SSP that most accurately tracks global social and energy trends may change over time as the world continues to decarbonize.

    IOUs also require the flexibility to experiment with new data sources and climate modeling techniques that become available. PG&E understands that the burden of proof and/or need for transparency will be elevated for proprietary and experimental analysis; however, preventing IOUs from participating in the rapidly developing climate modeling and risk assessment community of practice would unnecessarily constrain progress.

Appendix B: Follow-on Climate Hazard Quantification

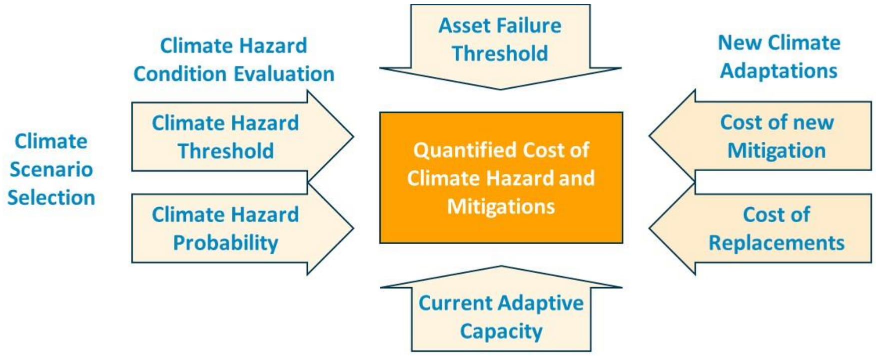
PG&E is evaluating alternative methods to quantify how climate change can impact the frequency of a risk event or asset failure. This effort is intended to advance the justification for climate resilience investments in parallel with the further development of a fully climate-informed RAMP methodology. The company is undertaking a Pilot climate hazard quantification study with Electric Substations Asset Management and an outside consultant to determine site-specific costs and probabilities of asset failures from three climate hazards, extreme heat, flooding, and wind. PG&E used the preliminary results from the company's CAVA to inform what asset category to assess in this pilot and determine the three climate hazard conditions to consider.

This approach includes analysis of downscaled climate data projections on the three climate hazards at each electric substation. Through consultation with subject matter experts and Substation Asset Management team, critical failure thresholds were identified for each hazard and major equipment types located at substation facilities. Once identified, a probability was determined for these failure thresholds based on the magnitude of the conditions identified. Each hazard required input and collaboration between climate experts and asset management and engineering SMEs to identify failure thresholds for each major asset type.

Failure events needed to consider the question if the conditions would lead to the need for a full replacement of if additional asset repairs would be the likely outcome of these event. Further consideration included the nature of a failure event for each of the three climate hazards (wind, extreme heat, and flooding). Extreme heat typically has a chronic impact on the asset health, and it is typically the accumulation of heat related stress that results in asset impairments over longer periods of time. This is a different failure model than the type of a failure event caused by flooding, which can be categorized more as an acute asset failure. Additionally, the degree of inundation associated with flooding events needs to be directly considered given the differences in the amount of time a substation would be flooded and the time it would take to return to service.

Following the quantification of the probability of climate conditions that can cause a failure event that would lead to either repairs or full replacement. The next step is to consider the costs of these events and the cost of new climate adaptations and or the impact of current mitigations programs that would reduce the probability of failures. **Figure** below shows a simplified approach for the quantification of climate hazard conditions.

Figure C1. Graphic of Process for the Quantification of Climate Hazards and Climate Adaptations



The final product of this work has not yet been identified and PG&E makes no commitment that this pilot climate risk quantification study will inform the company's 2024 RAMP filing and has yet to identify its influence on any proposals for mitigation funding for these assets.

The aim of this type of analysis of climate hazard conditions is to develop a potential estimate of probabilistic financial risk that is associated with different Global Climate Model (GCM) scenarios, the represented climate hazard conditions, and forecasts of expected costs of failures and repair/replacement costs. The end goal is to develop asset specific cost benefits ratios (CBRs) of different climate adaptations to protect electric substations against projected climate hazard conditions based on more localized projections of climate hazard impacts.

This climate risk modelling effort is a pilot project designed to inform PG&E's future direction in integrating climate data in the company's risk modelling process. Several important considerations for this type of more detailed level of analysis for the Commission to consider include:

- This analysis requires significant time and internal resources to develop the necessary inputs to the risk quantification.
- There is a difference between point (such as an electric substation) and line (such as natural gas transmission lines) assets that can make this type of approach more difficult to implement for line assets or asset categories with high numbers of deployed infrastructure.
- Information on asset health and design standards is required to ensure failure thresholds are accurate and provide meaningful analysis.
- Approaches and analysis for each climate hazard needs and the failure metrics need to be customized to that hazard and the relevant thresholds.
- There can often be an indirect link between climate conditions and failure events.
- In some cases, there may not be historic data on failure events from weather or climate conditions, particularly for emerging threat from Sea Level Rise.
- A direct partnership with engineering and design experts and climate experts is needed to understand and quantify climate hazard impacts given the relationship between both facility failure thresholds and to what standard potential climate adaptations should be designed to.