California Energy Commission

Task 11: Integration Workshop Summary

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Prepared for the California Energy Commission

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on behalf of the Pyregence Consortium

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INTRODUCTION AND SUMMARY

Through a California Energy Commission EPIC grant and match funding (contract number EPC-18-026), Spatial Informatics Group (SIG) assembled the Pyregence Consortium (Pyregence, or Consortium). The Consortium's core objective in this project is to advance wildfire science and improve wildfire risk management in the state by incorporating the dynamics of tree mortality, extreme weather, and climate change projections into next generation near-term and long-term wildfire models.

To achieve this aim, Pyregence Consortium members are organized into four workgroups. Workgroup #1 and Workgroup #2 focus on advancing the core science of wildfire weather (led by Dr. Janice Coen), and fuels and fire behavior (led by Dr. Scott Stephens). Workgroup #3 and Workgroup #4 focus on advancing wildfire simulation and risk assessment tools, including near-term wildfire forecasts (led by Dr. Chris Lautenberger) and long-term projections (led by Dr. LeRoy Westerling).

Critical to the success of this project is the establishment of relationships with potential users of the science, data and tools the Consortium develops. These relationships provide an opportunity for the Pyregence team to gain a better understanding of (a) current and ongoing wildfire risk management activities and processes, (b) the strengths and gaps in existing tools in use by different organizations, and (c) users' needs for improvements in wildfire science, wildfire risk models, and operational tools. These relationships also build user awareness of what the Consortium has to offer and experience in working with our products.

Project deliverables include documentation and summaries of user engagements including, but not limited to, a series of user engagement workshops and written summary reports. This Integration Workshop Summary (Task 11 under EPC-18-026) reflects activities in Phase II of our user engagement process, building from the Phase I User Engagement Summary (Task 8 under EPC-18-026) delivered on June 26, 2020. This report provides an overview of Phase II user engagement activities and key information learned to improve benefits to users as they integrate Pyregence data and tools into their risk management activities.

Highlights of the Phase II user engagement process include:

- Educational webinars on extreme wildfire and microscale weather patterns *(Workgroup #1)*
- Demonstration webinars of the near-term fire forecasting tool *(Workgroup #3)*
- Questionnaires on scenario design for the long-term wildfire risk projections *(Workgroup #4).*
- One-on-one brainstorming sessions on the features and functions for a long-term wildfire risk projections user interface and data curation needs *(Workgroup #4).*
- Ongoing one-on-one dialogue on opportunities to collaborate and integrate Pyregence science, data and tools *(all workgroups).*

Insights gained from user engagement principally indicated:

- The PyreCast near-term wildfire forecast tool is yielding benefits: The tool is in-use by a variety of users and the user engagement process has helped to focus tool development efforts on high-value data and associated visualization, computational efficiency, and tool feature improvements.
- Long-term wildfire risk scenario considerations: Various associated scenarios related to modeling long-term wildfire risk were in an exploratory phase as part of phase 2 engagement - most users were only able to provide generalized feedback on scenario dimensions related to future global

emissions, vegetation management, and urban growth. However, the feedback was sufficient to guide the team's understanding of critical projection time periods for planning and approach to present scenarios based on "bookends" that capture a range of possible future outcomes.

- Weather Station Optimization model: The utility (regulatory and electric utilities) and private sectors have expressed high interest in applying the MaxEnt model developed by Workgroup 1 to better identify gaps in weather station networks. For the private sector, a company has approached the project team to commercialize its application to utilities outside of California. PG&E worked directly with the project team to refine on-the-ground constraint criteria and have applied the model into their workflow for planning and positioning new weather monitoring stations. California Office of Energy Infrastructure Safety has similarly coordinated with the project team as part of their compliance review of utilities.

- Broad potential for use cases and benefits: Users have highlighted and expressed interest in a broad range of use cases beyond utility risk management in the electricity service industry: spanning academia, the public sector, and the private sector; and including (but not limited to) firefighting and emergency planning, local and state resilience planning, regional electricity reliability planning and operations, insurance and real estate markets, and land and forest management.

- Consistency with Cal-Adapt architecture: Electric utility users, in particular, represent a wide range of technical capabilities and needs but tend to fall into two categories in terms of what type of product they are looking for: one is limited in resources and capacity for in-house data handling and benefits more from visualization and guided exploration of the data (similar to Cal-Adapt visualization tools); the other has more of an appetite for raw data availability and big data processing (like what Cal-Adapt 'Analytics Engine' offers). This input has guided the basic architecture of Pyregence tools (as built or as envisioned) and work products.

- Data management considerations: Data volumes—both in the public arena and in users' work flows—are growing rapidly, driving needs to (a) house data and provide easy and centralized access, (b) provide a variety of input data options and enable comparisons to existing data that users are familiar with, and (c) provide guidance on how to subset data and curate scenarios that might be of most relevance to a user. Generally, users have expressed the need for an entity to assume the long-term management and maintenance of data and tools developed as part of the Pyregence project.

- Forecast tool integration challenges and opportunities: From an electricity service perspective (utility, regulator, or customer), integration challenges and commercialization opportunities of a public-facing wildfire risk assessment tool (near-term and long-term) are defined by barriers to incorporation of metrics on electric asset health, utility financial impacts, and end-use customer impacts.

USER ENGAGEMENT ACTIVITIES

The June 2020 Phase I User Engagement Summary outlined the following user engagement approach and 6-step communication process:

1. Prepare a user engagement plan and review relevant documents;
2. Identify the key user;
3. Initiate contact;
4. Provide a questionnaire;
5. Follow-up with user;
6. Summarize feedback (e.g., as documented in the Phase I User Engagement Summary and in this Integration Workshop Summary)

In Phase II, the project team followed this engagement approach largely to collect feedback on scenario design for the long-term wildfire risk projections. The team also conducted educational webinars on extreme wildfire and microscale weather patterns research results, and demonstration webinars on the weather station optimization model and near-term fire forecasting tool. Furthermore, on an ongoing basis each workgroup engaged in one-on-one dialogue with users, individualized to each interested organization, with the aim to collect additional feedback on data and tool development needs, keep parties updated on project progress and schedule, and explore new use cases and collaboration opportunities. **Appendix A** includes a list of key organizations engaged in Phase II. The sections below provide more detail on more significant user engagement efforts.

SCENARIO DEVELOPMENT QUESTIONNAIRES AND INTERVIEWS FOR THE LONG-TERM WILDFIRE PROJECTION MODEL

Prepared and implemented by Workgroup #4

March 2021–February 2023

Over the course of two years, Workgroup #4 conducted several iterations of outreach to elicit feedback from potential users of the long-term wildfire projection model on scenarios that would be most useful in their strategic planning processes. Key dimensions of the long-term scenarios included: (a) vegetation management, (b) climate models and global emissions, and (c) land and urban development. Scenario development is also guided by prioritization of long-term modeling effort, such as gauging users' consideration of the relative importance of mid-century versus end-of-century outlooks and relative importance of capturing different types of extreme events.

Outreach was in the form of informational memos and several written questionnaires, email communications, one-on-one interviews, two meetings with the project's Technical Advisory Committee plus key stakeholders in 2021 to broadly discuss scenario feedback, and one focus group meeting in early 2023 specifically to confirm urban growth scenarios. Examples of specific questions asked are included in **Appendix B**.

PYRECAST FIRE FORECASTING TOOL DEMONSTRATION WEBINAR

Hosted by Pyregence and presented by Dr. Chris Lautenberger

June 18, 2021

In this webinar Shane Romsos, the project manager, introduces the overall project context and objectives and Dr. Lautenberger introduces the PyreCast web-based tool in development by Workgroup #3; its usage and capabilities; the tool's fuels, weather, risk, and active fires visualizations. Dr. Lautenberger also

discusses some technical details to orient the audience with the data sources and models they know, how to integrate PyreCast data into other tools and visualizations, and planned PyreCast enhancements. For the webinar recording see https://pyregence.org/media/. Sectors and organizations engaged in the PyreCast webinars are listed in **Appendix C**.

EXTREME WILDFIRE AND MICROSCALE WEATHER PATTERNS WEBINAR
Hosted by Pyregence and presented by Dr. Janice Coen
August 11, 2021

In this webinar Dr. Janice Coen describes how her investigation of regional and microscale weather patterns reveals the extreme weather types, weather indicators, air flows, and weather/fire dynamics behind some of California's most destructive wildfire events. For the webinar recording see https://pyregence.org/media/.

FUELSCAPE WEBINAR
Hosted by Pyregence and presented by Joe Scott
January 24, 2022

In this webinar Joe Scott from Pyrologix provides an overview of the 2021 data products produced for the project and the near-term wildfire forecast models. Data products included Fuelscape and modeled fire behavior/risk-related outputs from the large-fire simulator model (Fsim) and a deterministic process for estimating flame-length probabilities (FLEP-Gen).

INVESTOR-OWNED UTILITY INTERVIEWS AND BRAINSTORMING SESSIONS ON LONG-TERM WILDFIRE PROJECTION MODEL SCENARIOS AND DECISION SUPPORT TOOLS
Led by Mariko Geronimo Aydin, Dr. LeRoy Westerling, and Shane Romsos
January 2022–January 2023

Workgroup #4 conducted outreach to each of the investor-owned utilities to elicit feedback on (a) long-term wildfire projection scenario design described above, plus (b) the features and functions of a long-term decision support tool that would best match their needs and priorities. One objective was to design and implement scenarios that are as helpful as possible to stakeholders' 10–50-year wildfire mitigation planning decisions. Another objective was to synergize with and help lay the foundation for other related planning efforts underway or in the future, such as the state's 5th Climate Change Assessment. Depending on each utility's appetite, meetings ranged in depth and complexity of subject matter discussion, from high-level discussions of essential features of a decision support tool, to an in-depth session with SDG&E using a structured brainstorming method that both encourages diversity of thought and identifies areas of consensus called the Nominal Group Technique. Key meeting dates and utility representatives engaged are summarized in **Appendix D**.

PYRECAST FIRE FORECASTING TOOL DEMONSTRATION WEBINAR
Hosted by Pyregence and presented by Dr. Chris Lautenberger
June 22, 2022

In this webinar Dr. Lautenberger provides a demonstration of the PyreCast web-based tool in development by Workgroup #3, including an introduction to the tool's fuels, weather, risk, and active fires visualizations; options for alternative data layers and computational models; and the types of insights that can be gained with different use cases for the tool. Dr. Lautenberger also discusses tool limitations and areas for future development, such as representation of suppression impacts and the need for fire-

weather coupling to forecast plume-driven fires. For the webinar recording see https://pyregence.org/media/. Sectors and organizations engaged in the PyreCast webinars are listed in **Appendix C**.

CALIFORNIA PUBLIC UTILITY COMMISSION MEETINGS
Meeting hosted by CPUC staff (Cheryl Cox, Kristen Rounds, Adam Banasiak) and Workgroup 4 (LeRoy Westerling, Mariko Geronimo Aydin, Ashley Conrad-Saydah, and Shane Romsos)
February 8, 2023, and March 30, 2023

Two meetings were coordinated to gain a deeper understanding of Pyregence long-term wildfire risk outputs and to discuss approaches used to select available CMIP6 GCMs and to identify grid vulnerabilities and interpretation of uncertainties across/within GCMs. Meetings and information exchange supported CPUC staff in exploring climate and wildfire projections data availability and interpretation relevant to their Climate Adaptation and Vulnerability Assessment requirements for utilities.

WILDLAND FIRE BEHAVIOR AND FACTORS CONTRIBUTING TO RISK IN WESTERN U.S. EVENTS WEBINAR
Hosted by National Oceanic and Atmospheric Administration (NOAA) and presented by Dr. Janice Coen
March 30, 2022

In this webinar Dr. Coen describes the Workgroup #1 Coupled Atmosphere Wildland Fire-Environment (CAWFE) model case studies, yielded insights in explaining extreme plume-driven landscape-scale wildland fire events, the relative importance of underlying drivers (such as drought and fuel accumulation, and how similar extreme events can be better assessed in real-time. For more information see https://csl.noaa.gov/seminars/2022/Coen.html.

PYRECAST FIRE FORECASTING TOOL DEMONSTRATION WEBINAR
Hosted by Pyregence and presented by Dr. Chris Lautenberger
August 18, 2023

In this webinar Dr. Lautenberger provides a demonstration of the PyreCast web-based tool in development by Workgroup #3, including an introduction to the tool's fuels, weather, risk, and active fires visualizations; options for alternative data layers and computational models; and the types of insights that can be gained with different use cases for the tool. Dr. Lautenberger introduces new data and features—such as live satellite data (GOES-16 data), structures data for assessing risk to structures, a wildfire camera tool, 3-dimensional data exploration, new weather forecast layers, and smoke forecast—and upcoming areas for development in preparation for the 2024 fire season. For the webinar recording see https://pyregence.org/media/. Sectors and organizations engaged in the PyreCast webinars are listed in **Appendix C**.

KEY FINDINGS

This section summarizes the key information learned to improve benefits to users as they integrate Pyregence data, models, and tools into their risk management activities. Users provided information that guides development of current work products, plus suggestions for future research and further tool development activities that would build upon this project.

User engagement activities in Phase II focused mostly on ongoing model and tool development in Workgroup #3 and Workgroup #4, while Workgroup #1 and Workgroup #2 conducted their core analysis

and research. For completeness, a summary of Workgroup #1 and Workgroup #2 activities are also included in the following sections.

Extreme Fire Weather (Workgroup #1)

The goals of this workgroup are to develop a methodology for identifying the optimal location and configurations of weather stations, and to advance the scientific record and understanding of the relationship between weather extrema and damaging wildfires.

In Phase I this workgroup collected feedback from electric utilities, and State and Federal organizations on what they view as major gaps in weather station placements, configurations, and datasets.

In Phase II this workgroup focused on (a) conducting the weather station 'blind spot' analysis, (b) conducting research and analysis on extreme fire weather. Additionally, and in response to user feedback to Workgroup #3 (discussed more below), Workgroup #1 is collaborating with Workgroup #3 to integrate a fire/weather-coupled model (CAWFE) to better forecast plume-driven wildfire spread in the PyreCast near-term wildfire forecast tool (a task proving to be difficult based on code used for CAWFE).

Work completed related to modeling weather 'blind spots' in California has led to several follow-up conversations with interested users of the research. PG&E provided constructive input on data inputs (e.g., distance to drivable roads and vegetation cover) to improve the applicability of the optimization model. Additionally, PG&E worked with the team to re-analyze their service territory to reflect information on newly installed weather stations within their service territory. All indications are that PG&E has integrated this work into their weather station planning process because they included results produced by WG1 into a 2023 Wildfire Mitigation Plan (WMP) submission to California Office of Energy Infrastructure Safety.[1]

As a follow-up to PG&E's WMP submission, Workgroup 1 worked with the California Office of Energy Infrastructure Safety (Cal-OEIS) to share the task report and answered several questions regarding modeling methods used and the level of interaction that occurred with different IOUs across the state. Additionally, Workgroup 1 conducted a re-analysis of IOU weather station data in response to Cal-OEIS requests to evaluate new weather stations that were not in the original analysis.

Other engagements have extended included working with a company called AEM (Advanced Environmental Monitoring) - a company that offers a range of weather station solutions and situational awareness technologies. Specifically, AEM has shown interest in use of the Pyregence weather station optimization model for their utility clients outside of California. To date, AEM has introduced Workgroup 1 to utilities (Xcel Energy) in Colorado. In response, Workgroup 1 has developed and shared a prospectus with AEM on how the Pyregence team can provide solutions for Xcel Energy's weather station optimization modeling needs.

Fire Behavior (Workgroup #2)

The goals of the workgroup are to advance the scientific record and understanding of fuels burn behavior and heat release rates, and to develop and deploy an improved fuel measurement and mapping system for forest fuels. In Phase I this workgroup collected feedback from electric utilities and Federal and Tribal

[1] See pages 1052 - 1054, *In:* PG&E 2023-2025 Wildfire Mitigation Plan R3

organizations on what they view as major gaps in vegetation and fire fuels data, and on how those data are represented in fuels and fire spread models.

In Phase II this workgroup focused on fuels data collection and mapping, and on building the large-scale burn chamber needed to conduct research on fuels burn behavior and heat release rates. Since the inception of the Pyregence project, research collaboration with the United States Geological Survey (USGS, Adrian Das) on measuring and mapping fuels at Sequoia King Canyon National Park has occurred, with expressed interest in continuing research collaboration beyond the Pyregence project.

With respect to Workgroup 2 project products, PG&E (Tyson McCarthy) has expressed interest in gaining access to tree mortality maps (produced by Salo Sciences and provided to PG&E) and the tree mortality projection data layers (that are still under development by UC Berkeley and SIG of WG2). PG&E indicated this work could be used to better target fuels reduction planning efforts.

Once all data products are completed by Workgroup 2, additional engagement with the project's TAC is expected.

PyreCast Near-Term Forecast (Workgroup #3)

The focus of this workgroup is to develop the next generation of forecast models for predicting near-term fire weather, fire spread and fire risk.

On an ongoing basis, this team continues to add new features and functions in response to user feedback. User feedback through annual PyreCast webinars and through one-on-one engagements with state agencies, federal agencies, and selected utilities helped the team to build and fine-tune the model over several iterations, yielding major model updates and improvements prior to each fire season.

In 2021, user engagements focused on orienting users with the tool and identifying opportunities to streamline and enhance the basic user experience in navigating through the tool. Users asked many clarifying questions, including questions on interpretation of the PyreCast risk metrics, interpretation of map colors, input data sources and levels of granularity, the cadence of various data updates, and data access. These questions helped the team to identify improvements in naming conventions, annotations, design, and map layers. Users emphasized the need to better forecast plume-driven fires. Some already found useful integrations of the PyreCast data, including integrations by Zonehaven—a business developing an application (using PyreCast) to inform evacuations of affected communities.

Each fire season, the WG3 team assesses the model's performance, and external users informally experiment with integrating PyreCast tools into their wildfire situation assessment work flows. This user activity helps to gauge the model's strengths and needs for further development. Advancements relative to status quo models in the incorporation of the most up-to-date data layers and real-time situational information were clearly valuable in those user experiences, as evidenced by their questions and comments. In 2022, user questions on the cadence of data updates and model runs, plus any lags with updating information on active fires, underscored the importance of frequent forecast refresh in managing a real-time situation and as they use the tool to monitor active fires. Additional user suggestions and/or support for further model improvements included:

- Ability to add user data to maps.
- Better representation of nighttime vapor pressure deficit driving fires.
- Corrections for false spotting from satellite data (MODIS) when they pick up heat from smoke.

- Some validation of ex ante forecast to actual outcomes.
- Better forecasts of plume-driven via fire/atmosphere coupling.
- Additional data layers (e.g., GOES17 satellite data).

In 2023, users continued to ask questions about the cadence of data updates and model runs, underscoring the importance of this to a broad range of users. Users expressed support for various data and modeling expansions and refinements, including improvements to the model's representation of spotting, large plume-driven fires, fire suppression effects, smoke transport, urban fire spread, and rekindling.

Several potential integrations of the PyreCast platform have occurred across different sectors over the course of the project. The California Office of Emergency Services – Wildfire and Threat Intelligence Integration Center has included a link to PyreCast platform on their external threat indices webpage. Liberty Utilities and South Tahoe Public Utility District have used PyreCast data services for situational awareness during the Tamarack (2020) and Caldor Fires (2021). The CEC Energy Assessment Division and CAISO have been testing the capabilities of the PyreCast platform as part of their situational awareness programs and have provided input on the platform itself. Additionally, some Fire Behavior Analysts (FBAN) assigned to fire incidents are using the Pyrecast platform in concert with other tools that are traditionally used to track the status of on-going fires.

User participation in the PyreCast webinars has been consistently enthusiastic and the level of engagement and types of questions in these meetings indicate they are using the PyreCast tool. Approximately 90 organizations have participated in the PyreCast webinars, listed in **Appendix C**. In parallel, traffic on the PyreCast platform continues to grow. The cumulative number of users of PyreCast platform increased from approximately 6,000 in 2022 to 8,900 in August 2023 based on Google analytics website tracking data.

Long-Term Wildfire Scenario Analysis (Workgroup #4)

The goal of this workgroup is to develop the next generation of coupled statistical fire-climate-vegetation models to project long-term wildfire risk in the state.

Over the course of two years the Workgroup #4 team conducted several iterations of outreach to elicit feedback from potential users of the long-term wildfire projection model on scenarios that would be most useful in their strategic planning processes. Through the engagement process the team found that most users were not yet positioned to provide substantive feedback or guidance on any scenario dimension, driven by unfamiliarity with the latest global climate projections (CMIP6); unfamiliarity with the details of long-term landscape, carbon, and wildfire models; and/or planning processes that had not yet made decisions on key uncertainties or planning levers of interest. It should be noted that at the time of this outreach effort the global climate projections had not yet been downscaled to the California landscape and thus not yet explored by the team nor users.

As a result, the team's final scenario selection is designed to support users' exploratory work, aiming to:

- Acknowledge and consider the planning uncertainties expressed by users.
- Represent bookends in the range of inputs and assumptions to yield information on a wide range of future fire risk outcomes.
- Limit the number of final model runs (each representing a combination of scenarios on layers of inputs) to yield a feasible and flexible work flow.

In tandem with outreach on scenario design, in early 2022 Workgroup #4 also elicited feedback from the investor-owned utilities on key features and functions of a long-term decision support tool that would best match their needs and priorities. Considering the Workgroup #4 scope of work the following products were identified as most useful to the utilities:

- For all scenarios, availability of raw input and output data (vegetation outputs, burn areas, fire size, burn probabilities, number of fires, fire severity), accompanied by:
    - An easy-to-write script or script template to download raw data files assuming an API is not immediately available.
    - Thorough documentation, including a data dictionary, methodology and assumptions, limitations and caveats, drivers of key changes over time, and other helpful guidance.
    - Data and analytics pushed into the Cal-Adapt platform users are already familiar with.
    - Curation of, or guidance on, scenario selection (depending on how many scenarios are produced).
- Narrative and demonstrative on how the coupled models affect each other.
- A set of key visual summaries (static maps), including:
    - Inputs, now vs. mid-century
        - Weather/environmental extremes (heat, dryness, wind, fire threat metric);
        - Vegetation now vs. mid-century.
        - Land use and population growth now vs. mid-century.
    - Outputs, now vs. mid-century
        - Burn probabilities.
        - Extreme fire probabilities.
        - A few data overlays, such as:
            - Transportation network
            - Utility (current) infrastructure
            - Disadvantaged and vulnerable communities
            - Also available in raw data for download

Additional useful work products include:

- An Application Programming Interface (API) for ease of integration with user workflows.
- Threshold analysis that flag areas or changes of concern, threats to infrastructure.
- Metrics on the probabilities of individual vs. combined extremes over time.
- Very detailed POI and egress data within service areas and how they may change over time.
- Additional web map and web summaries, through Cal-Adapt.
- More detailed and dynamically defined output metrics (e.g., curated fire indices from climate data), perhaps through Cal-Adapt Analytics Engine.
- A way to overlay or incorporate user-defined vulnerabilities (such as designated disadvantaged communities).
- Calculation of landslide risk (i.e., cascading impacts association with fires, perhaps as a function of burn area or probability outputs and landscape characteristics).
- Additional analysis of extremes affecting wildfire risk, including drought, vegetation (e.g., type conversion), wind gusts; metrics on probability of individual vs. combined extremes over time.
- Parameters for calculating financial and safety consequences; additional exploration of environmental consequences.
- All input and output data compared to some historical normal.
- All input and output data at 95th and 99th percentile conditions.

- People locations (not just where they live), smoke transport, indicators of health impact, impacts on macroeconomic dynamics such as migrations.
- Comparative analysis of CCCA4 projections and scenarios vs. what happened.
- In-depth analysis of vegetation management strategies and how regional resource needs shift.

Other Research and Business-Related Collaboration Efforts

Hosted by various members of the Pyregence project.

Webinars and a range of knowledge transfer activities associated with the project (for example participation in professional conferences) spawned several spin-off research collaborations across the Pyregence team. The following highlights some of the more significant research collaborations

- *UC Berkeley (Gollner Lab)*—collaborating on next-generation WUI/Urban spread model.
- *Mitre*—Transcoding PyreCast fire models into Python language for AI–Based fire suppression modeling.
- *UCSD WIFIRE "FireMap"*—providing FireMap program API access for ELMFIRE and GridFire wildfire models amongst other research to enhance WIFIRE program capabilities.
- *UC Irvine (Randerson, Gouldin Labs)*—PyreCast model performance evaluation, production of fuel data.
- *First Street Foundation*—ELMFIRE model used development of Fire Factor application.
- *Lawrence Livermore National Laboratory*—using Pyrecast models to support the Department of Energy's 'North America Energy Resilience Model' program and is additionally finalizing a contract to fund the extension of forecast capabilities throughout western states.
- *USFS*—working to expand model backend to extend forecast capabilities for Alaska and Hawaii
- *Fortress Fire*—PyreCast providing access to wildfire behavior models to support assessments of wildfire ignition risks and monitoring of potential threats.
- *USDA NIFA SBIR Phase 1*—Grant received to develop uncertainty framework for wildfire spread models. Related support resulted in a draft commercialization plan.
- *NASA*—Collaborating to further access to open-source fire science and to leverage NASA fire detection satellites and sensors.
- Participants on > 4 grant climate research applications with other universities (previously funding through California research programs).

CONCLUSION

Engaging with potential users and stakeholders has been a valuable exercise for the project team as well as for those who were receptive to the engagement and collaboration, including IOUs, State and Federal land and emergency management agencies, and research collaborators. The effort discussed herein was an opportunity to further relationships with key organizations to raise awareness of the project's scope of work and continue a dialogue for continued input and feedback cycles regarding product development, wildfire science as the moves toward conclusion. Maintaining relationships following the project with potential users and research collaborators through sustained engagement (now that relationships have been established) is paramount to the long-term benefit of the EPIC program and ultimately to ratepayers. The knowledge that was shared and gained through user engagement activities provided the project team with a deeper understanding of the various existing wildfire programs, models and tools currently being used, including where information is deficient and data gaps exist. Overall, users of data and tools developed (or under development) confirms demand for open-source wildfire models and reveals promising benefits of the ongoing work under the Pyregence Consortium.

APPENDIX A. Key Organizations Engaged

Organization	Organization Category[1]	Organization Subcategory	Pyregence Workgroups	Key Contact(s)
Bear Valley Electric Service	IOU	Electric Power	WG1, WG3, WG4	Paul Marconi
CAISO/RC West	Other	Electric Power	WG3	Tim Beach, Amber Motley, Jessica Taheri, Justin Bohlen
California Air Resources Board (CARB)	SA	Regulatory	WG1, WG2, WG3, WG4	Adam Moreno (TAC Member)
California Department of Conservation	SA	Planning	WG4	Nathaniel Roth
California Energy Commission - Energy Analysis Division	SA	Planning	WG3, WG4	David Erne, Joseph Merrill
California Energy Commission – Energy Research and Development Division	SA	Planning	WG1, WG2, WG3, WG4	Susan Wilhelm, David Stoms, Alex Horangic
California Governor's Office of Planning and Research	SA	Planning	WG4	Elea Becker, Ben McMahan, Neil Matouka
California Office of Emergency Services	SA	Public Safety	WG3	Carlos Camarena, Robert Scott
California Office of Energy Infrastructure Safety (OEIS)	SA	Regulatory	WG1	Jeff Fuentes [CalFire], Alan Solomon, Andie Biggs
California Public Utilities Commission (CPUC)	SA	Regulatory	WG4	Kristin Rounds Adam Banasiak
California Wildfire & Forest Resilience Task Force	SA	Planning	WG2, WG3, and WG4	Patrick Wright, John Battles
Colorado Utilities	IOU	Electric Power	WG1, WG3	Jason Mauch (Xcel Energy)
Liberty Utilities	IOU	Electric Power	WG1, WG3, WG4	Eliot Jones
Pacific Gas and Electric	IOU	Electric Power	WG1, WG2, WG3, WG4	Eric Kuhle, Tyson McCarthy, Kevin Johnson, Brenna Mahoney, Nathan Bengtsson, Jimmy O'Hare

Organization	Organization Category[1]	Organization Subcategory	Pyregence Workgroups	Key Contact(s)
PacifiCorp	IOU	Electric Power	WG1, WG2, WG3, WG4	Heide Caswell (TAC Member)
San Diego Gas and Electric	IOU	Electric Power	WG1, WG2, WG3, WG4	Brian D'Agostino (TAC Member)
Southern California Edison	IOU	Electric Power	WG1, WG2, WG3, WG4	Robert LeMoine (TAC Member) Stephen Torres
The Nature Conservancy	Non-Profit	Environmental	WG4	Joe Fargione, Kristen Shive, Dick Cameron
USFS	FA	Land Management	WG1, WG2, WG3	Randy Striplin (TAC Member), Patrick Doyle, Stacy Drury

[1] IOU = Investor-Owned Utility; SA = State Agency; FA = Federal Agency

APPENDIX B. Questionnaires on Long-term Wildfire Risk Scenario Design

Each section below describes questionnaires distributed to potential users of the PyreClimate long-term wildfire risk projections under development by Workgroup #4. These questionnaires were supported by meetings with the project's Technical Advisory Committee and other smaller focus groups. To facilitate more feedback, the study team also posed and discussed these questions via one-on-one company meetings.

Vegetation Management Scenarios #2 (March 2021 request for information and draft memo on July 21, 2021)

Please comment on the following proposed vegetation management scenarios:

- *High ambition treatment scenario: assumptions and treatment schedule*
- *Business-as-usual (low ambition) treatment scenario*
- *Table comparing scenario results for acres treated per year by management zone (wildland-urban interface, state-managed, federally managed, utility areas, protected areas, other ownership areas).*

Long-Term Climate and Global Emissions Scenarios (final memo on March 3, 2022)

We seek your advice on scenario selection in order to:

- *Better understand what scenario characteristics are most relevant in your strategic planning, recognizing that climate and global emissions are interrelated. For example, is the global emissions scenario (RCP) most relevant to your work, or the temperature trajectory regardless of how it is reached?*
- *Align with recent/prior efforts in order to facilitate cross-study comparisons and understanding of our modeling results. We would like to align our work with climate scenarios you routinely reference or use as benchmarks. For example, RCP4.5 as a low CO2 emissions scenario and RCP8.5 as a high scenario would be consistent with Cal-Adapt, California Public Utility Commission (CPUC) decisions, and other prior modeling efforts we review.*
- *Align with your most current thinking on the most relevant climate and emission scenarios.*
- *Prioritize realistic temporal ranges or endpoints that would be most helpful to your strategic planning efforts. Through mid-century we can model a broader range of scenarios, but between mid-century and end of century we would like to limit to a small number (no more than two) of climate/emissions scenarios given our budget and scope of work limitations.*

Please comment on the following proposed emissions scenarios:

- *At least two CO2 emissions scenarios through mid-century (from among SSP2-4.5, SSP3-7.0, and SSP5-8.5), but with an expansive range of climate models that explore variability in precipitation extremes through mid-century. The project team prefers evaluating SSP3-4.5 and SSP5-8.5 through mid-century in order to capture the lower and upper range in likely emission scenarios.*
- *A high and low emissions scenario through the end of the century (from among SSP2-4.5, SSP3- 7.0, SSP5-8.5), but with potentially fewer climate models.*

Additional questions:

- *Mid-century versus end-of-century outlook. The team is discussing how much effort to allocate for modeling the lattermost years of this century (2065–2100). In particular, we would suggest emphasizing long term trade-offs between low and high global emissions for the end of century scenarios.*
    - *What outlook years are most important to you (e.g., 2045 for meeting clean energy goals)?*
- *Extreme events.*

    - *Other than climate changes in general, how important is it to capture extreme events in your long-term models?*
    - *Specifically, what types of extreme events or combinations of events are you interested in?*
    - *Over what time horizons are needed and meaningful for decision making?*
- *Trade-offs in work effort. Extreme events significantly influence vegetation conditions and the extent and distribution of fires. Examples of such linkages include the severe 2012-2016 drought resulting in widespread tree mortality or a combination of extreme heat and drought resulting in the 2020 and 2021 fire seasons. Generally, climate model outputs do not capture the frequency or magnitude of extreme events that we have recently experienced. We could consider the feasibility of using resampled climate data in lieu of an additional RCP because that approach would allow us to investigate ecosystem response and area burned in response to increasingly frequent extreme events.*
    - *What should the minimum set of scenarios through the end-of-century look like?*
    - *How much additional detail should we incorporate through mid-century with fully coupled fire and vegetation models?*
    - *Is there a preference to generate outputs that better reflect variability in extreme events or is there a preference to stick to selected RCPs and the range of precipitation variability available in the existing climate model runs?*

<u>Vegetation Management Scenarios #3 (included in March 3, 2022 emissions scenarios memo)</u>

Please comment on the following proposed vegetation management scenarios:

- *High Ambition Management Scenario - This scenario models forest treatments to meet a goal of one million acres treated per year, a goal identified in a 2018 Executive Order and emphasized in the 2021 California Wildfire and Forest Resilience Action Plan; the plan prioritizes reducing fuels (i.e., through vegetation management) in areas classified by CAL FIRE as 'high' and 'extremely high' fire hazard risk zones.*
- *Business-As-Usual (BAU; Low Ambition) Management Scenario - This scenario represents an attempt to sustain the vegetation management/treatment approach from the previous decade (2010-2019). As such, the total average annual treatment rate across the state is approximately 440,000 acres per year, or 55 percent less activity than the high ambition scenario.*

Additional questions:

- *Streamlined scenarios after 2064. The team may streamline the vegetation management and urban development scenarios after 2064. For example, maintain a low sprawl trajectory (concentrated around existing communities) for urban development footprint after 2064.*
    - *Should we assume a vegetation treatment "maintenance mode" in terms of extent, timing and space - where fuels are maintained at a level conducive to reduced fire risk?*
    - *What would be most useful to you: BAU vs. high ambition treatment rates? Low vs. high sprawl urban development?*
- *Spatial prioritization of vegetation management efforts. We previously proposed prioritizing reducing wildfire risk through vegetation management at the wildland-urban interface (WUI) and in areas designated with high wildfire threat. Under this prioritization scheme, WUI areas with high fire threat classification would be prioritized for fuels reduction treatment first. As those acres are completed, areas beyond the WUI that are classified as high fire threat would be addressed next and so on.*
    - *Do you have thoughts on how we could refine our prioritization/allocation of vegetation management efforts to better relieve disadvantaged communities or otherwise mitigate wildfire related risks to communities?*

Land and Urban Development Scenarios #1 (draft memo on September 20, 2022)

Please comment on the following aspects of the land and urban development scenarios:

- *The magnitude of total new urbanization*
- *Allocation of that development to metropolitan areas versus wildland-urban interface (WUI) areas in our "concentrated" and "sprawling" development scenarios*

Additional questions:

- *Do you have a preference on what historical years are sampled to derive transition targets in our "sprawling" versus "concentrated" urban development scenarios?*
- *Do you have any strong views on the odds (or approximate odds) of urbanization in the WUI versus Core Metropolitan Areas in our two urban development scenarios?*

Additional questions to stakeholders (in one-on-one meetings throughout the engagement process)

Please comment on the following aspects of the land and urban development scenarios:

- *What are the key individual drivers of an extreme event you monitor or look for, and at what thresholds?*
- *Please describe a specific or type of future extreme situation you are most concerned about. What key characteristics or combinations of drivers contribute to the severity the situation?*
- *Imagine you had all of the information you needed on a web map and tool to help you explore long-term climate and wildfire projections. What "must have" features would you look for to help you explore future extreme situations and threats?*

APPENDIX C. Sectors & Organizations Registered for Pyregence Webinars

Sector
Academic
Electric Utility
Federal Government
Fire Department
Fire Industry
Insurance
International Fire Organization
International Government
International Non-Profit
Local Government
Media
Native American Tribes
Non-Profit Conservancy
Non-Profit Organization
Private Consultancy
Public
Special District
State Government
Telecommunications
Venture Capital/Angel Investor
Water Utility

Organization	Organization
Academic Data Science Alliance	CWRU, USA
Advanced Environmental Monitoring (AEM)	Digital Mapping Solutions
Agency for Integrated Fire Management, Portugal (AGIF)	Dogwood Springs Forestry
American Association of Insurance Services	Drone Seed
Anew Climate	East Bay regional park district
Applied Technology and Science (ATS)	EcoCiencia
ARUP	Feather River College
AT&T	FEPC/ANEPC/GAUF (Portugal) Civil Protection Special Force
Berkshire Hathaway Specialty Insurance	First Street Foundation
BlackRock, Inc.	Florida Forest Service
Bureau of Land Management	Fortress Fire
CalFIRE	Frontline Wildfire Defense
Cal Poly – San Luis Obispo	Geospatial Consultancy Services
California Air Resources Board	Gouvernement du Québec
California Department of State Parks and Recreation	Idaho Power Co
California Energy Commission	Idaho Power Company
California Forestry Association (CalForests)	Imperial Irrigation District
California Office of Emergency Service	Insignia Environmental
California Office of Planning and Research	IPMA (Portuguese Institute for Sea and Atmosphere)
California Tahoe Conservancy	Kodama Systems
Canadian Forest Service	Lebanon Reforestation Initiative
Central Sierra Environmental Resource Center	Lincoln University
Cheshire (CT) Fire Department	Marin Municipal Water District
Chugachmiut (Tribal Service Organization for the Chumach Region)	M-bar Technologies and Consulting, LLC
City of Irvine	Montecito Fire Protection District
Clark University	NASA
Cloudfire	National Authority for Emergency and Civil Protection (ANEPC, Portugal); Autoridade Nacional de Emergência e Proteção Civil
Code Red Consultants	National Center for Atmospheric Research
Collins Pine Company	National Park Service
Colorado Division of Fire Prevention and Control	Natural Communities Coalition
Colorado State University	NEOS, Ltd
Columbia University	Northwest Interagency Coordination Center
Conservation Biology Institute	Northwestern University

Organization	Organization
Contra Costa Mosquito and Vector Control District (CCMVCD)	NV Bureau of Land Management
Copper State Wildfire Management	NV Energy
Coroba Corporation	NV5 Geospatial
Our Kettle, Inc.	UC Berkeley
Pacific Power	UC Davis
PacifiCorp	Universidad Tecnica Federico Santa Maria
Panorama Environmental	University at Buffalo
Pasadena Glen Fire Safe Council	University College Cork (Ireland)
Pau Costa Foundation	University of British Columbia
PG&E	University of California Cooperative Extension
Plumas Corporation	University of California, Berkeley
Portland General Electric	University of California, Davis
Powers Forestry	University of California, Los Angeles
Primary Apps LLC	University of California, Merced
PrometheUs ICG	University of Idaho
Province of British Columbia – Ministry of Forests	University of Lisbon (Portugal)
Pyrologix	University of Oklahoma
Reax Engineering	University of the Frontier (Chile)
Redzone	University of Washington
Resource Conservation District of Santa Monica Mountains	Universidad Nacional Mayor de San Marcos
Retired Firefighter	Upper Mokelumne River Watershed Authority
Retired USFS, self-employed consultant	USDA California Climate Hub
San Diego State University	USDA Forest Service
Santa Barbara County Fire Safe Council	USGS
Santa Monica Mountains Resource Conservation District	Utah State University
SCS Global Services	VegaMX, Inc
Seminole Tribe of Florida	Verdant Associates
Sierra Forest Legacy	Vibrant Planet
Sierra Nevada Conservancy	Vigilante Wildland Fire Consulting
Sierra Pacific Industries	Wataniba
Sonoma Technology	Watershed Center
Spatial Informatics Group	Whitebark Institute
Stanford University (Jasper Ridge Biological Preserve)	Wildfire Today
State of Florida	Xcel Energy
SWCA Environmental Consultants	Yakama Nation
Tahoe Resource Conservation District	Zonehaven

Organization	Organization
TetraTech	The Nature Conservancy
The Fire Restoration Group	Northern Arizona University

APPENDIX D. Utility Interviews on Long-term Wildfire Data and Planning Support Tools Needs

User Organization	Key Meeting Dates	Contacts
San Diego Gas & Electric (SDG&E)	Feb 22, 2022	Brian D'Agostino Maxwell M Beller Mark Mexta Phi Nguyen Joaquin Peral Ashley Llacuna
Bear Valley Electric Service (BVES)	Feb 28, 2022	Paul Marconi
Liberty Utilities	Feb 28, 2022	Eliot Jones Jordan Parrillo Rick Dalton
Southern California Edison (SCE)	Mar 4, 2022	Dawn Anaiscourt Stephen Torres Alexander Pusch Alexandria Chwierut Erica Bowman
San Diego Gas & Electric (SDG&E)	May 19, 2022	Brian D'Agostino Maxwell M Beller Mark Mexta Phi Nguyen Joaquin Peral Ashley Llacuna
Pacific Gas and Electric (PG&E)	Jan 25, 2023	Eric Kuhle Brenna Mahoney Nathan Bengtsson Jimmy O'Hare
PacifiCorp and NV Energy	*	*

*PacifiCorp and NV Energy were contacted as part of this effort, but no response was received.