NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Wildfire Mitigation Reference Guide

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Introduction

Electricity is a vital component of the fabric of modern society. The Electric Reliability Organization (ERO) Enterprise, which consists of the North American Electric Reliability Corporation[1] (NERC) and the six Regional Entities,[2] serves to strengthen that fabric for the benefit of nearly 400 million citizens of North America. The ERO Enterprise pursues its mission of assuring the effective and efficient reduction of risks to the reliability, resilience, and security of the bulk power system (BPS) by working with users, owners, and operators of BPS assets, government partners, and other stakeholders and industry participants.

The Reliability Issues Steering Committee describes and prioritizes risks to the reliable operation of the BPS in a biannual report[3] to the NERC Board of Trustees that includes recommendations regarding the approach the ERO Enterprise and industry should take to enhance reliability and manage those risks. Wildfires pose risks because they can disrupt the reliable generation and delivery (transmission and distribution) of electricity to customers. Electric utilities in high fire-threat areas should have plans or strategies to address and mitigate the threat of electrical infrastructure or equipment causing ignitions that could lead to wildfires and/or being impacted or damaged by wildfires.

Preface

Wildfires[4] are generally defined as unplanned, uncontrolled fires fueled by an area of combustible vegetation and, like all fires, require three fundamental elements to exist: fuel, oxygen, and heat. The fuel supply across North America has increased over the past few decades due to political policies around fire suppression and forest management, the introduction of non-native grasses, and dryer climates and droughts that left forests damaged by insects and disease. The oxygen often comes in the form of high winds that can spread the fires quickly. The sparks that initiate the fires are primarily generated from human activities and weather, but about 10% of wildfire ignitions[5] are sparked by faults on electrical infrastructure or electric equipment failure. In recent years, wildfires have emerged as a significant risk to public safety and to the BPS assets that serve the Western Interconnection of North America.

WECC[6] promotes BPS reliability and security in the Western Interconnection. WECC extends from Canada to Mexico and includes the provinces of Alberta and British Columbia, the northern portion of Baja California, Mexico, and all or portions of the 14 western states between. These western states and the two

[1] North American Electric Reliability Corporation
[2] Regional Entities
[3] 2019 ERO Reliability Risk Priorities Report
[4] National Geographic - Wildfires
[5] 2019 California Redbook
[6] WECC

Canadian provinces have experienced numerous catastrophic wildfires in the recent past, and the fires are getting larger and more intense. In 2020, California experienced five of its largest (acreage burned) fires in recorded history. Wildfire seasons are getting longer and the fires are increasing in frequency and severity. Since 2017, California has experienced thirteen of its most destructive (structures destroyed) fires and eight of its most deadly.[7]

Wildfire Mitigation Plans

Wildfires initiated by electric utility infrastructure prompted the state of California to enact legislation[8] in 2018 that required each electrical corporation, local publicly owned electric utility, and electrical cooperative to do two things: construct, maintain, and operate its electrical lines and equipment in a manner that will minimize the risk of catastrophic wildfire posed by those electrical lines and equipment and prepare and submit wildfire mitigation plans[9] (WMPs) on an annual basis for review and approval by the California Public Utility Commission (CPUC). The WMPs required by the CPUC contain up to 20 mandated elements that create a comprehensive strategy and defense against wildfire initiation by the utility's electrical lines and equipment.

In general, WMPs describe how the utilities' electric systems are designed, constructed, operated, inspected, and maintained to promote wildfire safety, prevention, mitigation, and recovery. The CPUC requires utilities under its purview to organize the information into the following categories:

1. Risk Assessment and Mapping
2. Situational Awareness and Forecasting
3. Grid Design and System Hardening
4. Asset Management and Inspections
5. Vegetation Management and Inspections
6. Grid Operations and Protocols
7. Data Governance
8. Resource Allocation Methodology
9. Emergency Planning and Preparedness
10. Stakeholder Cooperation and Community Engagement

One of the most effective and highly scrutinized mitigation measures is the public safety power shutoff (PSPS). Allowed under California law, a PSPS is the proactive de-energization of power lines that are forecasted to be in the path of critical fire weather conditions. For utilities that strive to provide reliable electric energy to customers 100% of the time, intentionally turning off the power is a last resort, but removing these vulnerable lines from service eliminates the risk of ignition. Although effective in protecting customers, first responders, and property, PSPS events are extremely disruptive to customers' lives.

[7] California Fire Statistics
[8] California Senate Bill 901
[9] Wildfire Mitigation Plans

Consequently, electric utilities have undertaken risk-based initiatives to limit the scope, duration, and frequency of PSPS events to minimize their impacts. Descriptions of these initiatives, such as system hardening, installing additional sectionalizers, installing weather stations and high definition cameras, installing microgrids, and using data to predict the highest fire threat areas and the fire's potential spread are included in the WMPs.

WMPs detail the electric utility's initiatives and activities for reducing the risks of its lines and equipment igniting wildfires in the high fire risk areas of its service territory. The risks associated with the equipment vary depending upon several factors: age and condition, population density (ingress and egress), surrounding climate, terrain and vegetation, voltage class and type of construction, and policies and regulations around land/forest management. New technologies and increasing data capture have enabled companies to perform risk analysis at the asset level, allowing them to prioritize activities and develop initiatives for specific lines and equipment. This granularity provides for more effective and efficient mitigations. While each utility's risks are unique, general metrics have been developed for various aspects of the plan that enable the utility and the CPUC to assess the outcomes and measure the performance of the individual initiatives. Identifying successes and deficiencies within the plan ensures that the iterative process of plan development is one of continuous improvement. For example, the CPUC developed its 2021 guidelines[10] for wildfire mitigation plans after the CPUC's Wildfire Safety Division completed its annual review of the utility plans, including evaluating best practices and lessons learned from 2020 wildfire mitigation plans.

Conclusion

Although catastrophic wildfires have predominantly been a western experience, the threat of wildfires is a growing concern for other areas of North America. Ever-changing more extreme weather and the abundance of dry fuels provide two of the three necessary elements for wildfires. Due to the presence of electric current, electrical infrastructure and equipment have the potential to provide the ignition spark. While completely eliminating the risk of being the source is not possible, it is incumbent on electric utilities to proactively minimize that risk. To accomplish this, electric utilities across North America located in heightened fire-threat areas could develop and implement wildfire mitigation plans.

NERC and WECC developed this document with the goal of creating more awareness across all Interconnections of the knowledge and experience gained by western utilities on wildfire preparedness and mitigation. Research and development efforts by the Department of Energy (DOE) National Laboratories in partnership with electric utilities and other stakeholders on many facets of wildfire mitigation, situational awareness, and pre- and post-fire analyses are also highlighted in the document.

[10] WMP Guidelines

References

The links provided below will connect the reader to information and tools helpful for developing a comprehensive wildfire mitigation plan. *Note: These references are not a comprehensive listing.*

Wildfire Mitigation Plans

North American Utilities: United States

- Pacific Gas and Electric
- Southern California Edison
- San Diego Gas & Electric
- Liberty Utilities
- Bear Valley
- Horizon West
- Trans Bay Cable
- Sacramento Municipal Utility District
- Los Angeles Department of Water and Power
- Anza Electric Cooperative
- PacifiCorp
- Bonneville Power Administration

North American Utilities: Canada

- BC Hydro Wildfire Safety
- Altalink Wildfire Safety Booklet

Bushfire Mitigation Plans and Fire Safety

Australia

- Jemena
- Powercor
- AusNet Services
- Transgrid
- AGL Hydro
- Powerlink - Queensland | Australia
- Western Power - Western Australia

Organizations

The websites below link to organizations involved in various aspects of wildfire prevention and mitigation, management and recovery, and research and development.

State of California

- California Public Utilities Commission (CPUC)
- Wildfire Safety Division
- California Department of Forestry and Fire Protection (CAL FIRE)

Federal Agencies

- United States Forest Service
- United States Department of Agriculture
- National Wildfire Coordinating Group
- United States Fire Administration
- National Interagency Fire Center
- Forests and Rangelands
- U.S. Department of the Interior (Bureau of Land Management)
- U.S. Department of Energy (Grid Modernization Lab Consortium)
- U.S. National Parks Service
- National Weather Service

Canadian Federal Agencies

- Canadian Electricity Association (CEA)
- Natural Resources Canada
- Canadian Interagency Forest Fire Centre (CIFFC)

Associations, Forums, and Councils

Note: EEI, NATF, APPA, NRECA, CEATI, and EPRI are “Members Only”; however, each has a public-facing webpage that can be searched using the keyword “wildfire.” For example, EPRI has public reports referenced in this document:

- Electricity Subsector Coordinating Council (ESCC)
- Edison Electric Institute (EEI)
- North American Transmission Forum (NATF)
- American Public Power Association (APPA)
- National Rural Electric Cooperative Association (NRECA)
- Electric Power Research Institute (EPRI)

- CEATI International
- Society for the Protection of Forests Against Fire (SOPFEU)
- Wildland Fire Leadership Council
- International Association of Wildland Fire (IAWF)

Websites

- Wildfire Today
- Wildfire Risk to Communities
- LANDFIRE
- Portugal wildfires

Publications

- Utility Wildfire Mitigation Guide 2020
- 2019–2020 Bushfires Quick Guide
- Wildfire Risk Reduction Methods
- Distribution Protection Options to Reduce Damage and Improve Public Safety
- Wildfire and the Oregon Electricity System

Webinars and Conferences

- WECC Wildfire Webinar Series - Wildfires in the West
- WECC Wildfire Webinar Series - Best Practices and Lessons Learned
- WECC Wildfire Webinar Series - Compliance Open Webinar
- West Coast Utility Commissions - Wildfire Dialogue

Research and Development

- Electric Power Research Institute (EPRI)
- Texas A&M University

Department of Energy (DOE) National Laboratories

In November 2019, the Office of Electricity sent a request for information on projects regarding wildfire capabilities to 13 DOE laboratories and received responses from the following:

- Argonne National Laboratory
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Oak Ridge National Laboratory

- Pacific Northwest National Laboratory
- Sandia National Laboratory
- SLAC National Accelerator Laboratory

The responses identify capabilities with the potential of being used immediately or being adapted for use within a few months. This list was updated in August 2020 to capture progress and include newly added capabilities that meet the aforementioned requirements. The point of contact at the DOE for this information is Stewart Cedres.[11]

Area of Research: Sensing and Detection

Distribution Arcing Fault Signature Library (ORNL)

This project between Oak Ridge National Laboratory (ORNL), Lawrence Livermore National Laboratory, and Pacific Gas & Electric Company will install a high-fidelity sensor cluster on an electric distribution feeder (substation outlet) to capture grid signatures that can be used as early indicators of arcing to identify and mitigate fire risk. In order to capture real signatures, the sensor cluster will be installed in an operational utility service area. The novelty of the project is in both the high-fidelity sensor technology and analytical methodology on a custom purpose platform.

Monitoring Structural Health of High Voltage Transmission Lines (ORNL)

ORNL has developed a "smart patch" technology, which incorporates piezoelectric transducers and electromechanical impedance analysis to monitor the structural health of compression connectors used in high-voltage transmission lines that tend to fail as a result of thermal aging and thermal fatigue.

Real-time Aerial Sensors for Extreme Environments (ORNL)

ORNL is working with the United States forestry services on the development of real-time airborne and ground asbestos sensors for application during forest fire operations. There are concerns pertaining to EPA superfund sites and the implications of wildfires pertaining to the release of toxins in the air. Demonstration of unmanned-aerial-systems-based measurement of grid components (pole mounted transformers, intelliruptors) with live visual, thermal, and sensor reading feeds was completed with the utility control center at the Electric Power Board of Chattanooga.[12]

Multi-modal Autonomous Vehicle NETworks (ORNL)

ORNL created Multi-modal Autonomous Vehicle NETworks (MAVNET) to provide reliable and robust command, control, communication, and computing (C4) for unmanned vehicles. MAVNet is particularly well-suited for beyond visual line of sight C2, swarm operations, and a secure implementation of the Internet of Drones. Through the development of advanced sensors along with the integration of MAVNet, a situational awareness platform can be created to assist in developing solutions. This includes the potential of pulling real-time thermal and earth observation video/images from both UAS and manned aircraft to

[11] Stewart Cedres
[12] Link is to an early survey of best practices for the use of small unmanned aerial systems (UAS) by electric utilities: https://info.ornl.gov/sites/publications/Files/Pub73072.pdf

identify fire locations and evaluate post-fire damage along with integration into visualization platforms like Eagle-I.

ORNL links of unmanned aerial systems technology for search and rescue in the Smokies:

- ORNL Drones help Smokies search and rescue[13]
- ORNL drones find lifesaving lessons in Smokies[14]

Distributed Wildfire Detection (ANL)

The Argonne Waggle platform supports customized sensor arrays, edge computing, and image analysis code that can be programmed to detect specific types of objects, movements, or phenomena (e.g., a flash of lightning). Argonne has deployed Waggle systems for wildfire prediction for the power grid and has developed field capabilities for detection of wildfires and wildfire conditions, including real-time control of cameras. The field test for this project is WIFIRE[15], a network of towers in Southern California operated by the University of California-San Diego (UCSD) and is in use by wildfire emergency responders. ANL has been working with the UCSD San Diego Supercomputer Center to develop computer vision/deep learning algorithms to use the camera network to spot fires.[16]

Area of Research: Situational Awareness

EAGLE-I (ORNL)

EAGLE-I is a next-generation situational awareness tool for advanced energy-sector monitoring and analysis in the United States. The operational system is hosted and managed by the ORNL for DOE's Infrastructure Security and Energy Restoration division. Built-in capabilities include energy-sector data collection, integration, and monitoring; modeling and analysis; and immediate, strategic dissemination of vital information. The tool integrates real-time data on electricity, natural gas, and petroleum in an interactive web platform, enhancing the nation's energy infrastructure awareness and allowing for organized, coordinated, and rapid emergency response and recovery efforts.

Note: ORNL has every building mapped for the CONUS (supporting FEMA) for wildfire risk assessment. ORNL also have capabilities for smoke and haze detection from very high-resolution satellite imagery as well as damage assessment.[17]

ForWarn (ORNL)

ForWarn provides near-real-time tracking of vegetation changes across landscapes in the United States. This system produces maps every 8 days that enable detection of vegetation disturbances. Useful for both monitoring disturbance events as well as year-to-year variability, derived products can also be used to develop insights into seasonal and inter-annual dynamics. An opportunity could be to change the detection that could be overlaid with electrical grid to determine risk and possible vulnerabilities.[18]

[13] https://www.youtube.com/watch?v=eVIrygh9tnQ
[14] https://www.wbir.com/article/news/local/ornl-drones-find-lifesaving-lessons-in-smokies/51-25209a52-a069-4573-a7e0-11ea30c695c4
[15] WIFIRE
[16] https://www.anl.gov/mcs/waggle-an-open-platform-for-intelligent-attentive-sensors
[17] https://eagle-i.doe.gov/login
[18] https://forwarn.forestthreats.org

PlanetSense (ORNL)

PlanetSense is a platform for geospatial intelligence that is built to harness the existing power of archived data along with the dynamics of real-time streams, seamlessly integrated with sophisticated data mining algorithms and analytics tools for generating operational intelligence on the fly. The platform has four main components: GeoData Cloud, a data architecture for storing and managing disparate datasets; a mechanism to harvest real-time streaming data; a data analytics framework; and a presentation and visualization through web interface and RESTful services. Using two case studies, we underpin the necessity of our platform in modeling ambient population and building occupancy at scale. PlanetSense capability (National Geospatial-Intelligence Agency) allows us to collect Open Source data, including images to provide real-time situational awareness of the changing scenarios.

Note: ORNL demonstrated this capability during the Gatlinburg fire in 2016.[19]

Water Extreme Lookup Library (PNNL)

The Water Extreme Lookup Library provides a truly unique data source in which previously run simulations can be used to support both the rapid-response situational awareness and provide the data to support planned studies. This library includes dam failure simulations available and developed methods to include riverine flood simulations.

Note: The Water Extreme Lookup Library is operational but it would take 1–3 months to incorporate more fire information into the repository.

Proximity Analysis Tool (PNNL)

The Proximity Analysis Tool uses geospatial clustering methods to determine important critical infrastructure assets or clusters of these assets. This clustering approach can help determine if a group of components can be identified that will lead to severe degradation in performance of infrastructure systems if damaged or destroyed.

Note: This tool is expected to be operational in 6–12 months; it is currently a prototype.

High Power/Low Power Arc and Ground Fault Detection/Mitigation (SNL)

Work on arc-fault and ground fault detection and mitigation for photovoltaic dc systems that could potentially be ported over to ac systems. The Sandia Photovoltaic Arc and Ground Fault Detection and Mitigation program ran from 2010–2015 and made a number of significant contributions to the field of photovoltaic system safety and reliability. During the course of the program, Sandia worked with over a dozen solar and original equipment manufacturers and investigated series and parallel arc-fault detection methods; improvements to the draft arc-fault circuit interrupter certification standard, UL 1699B; arc plasma physics models and burn characteristics; array electrical behavior during ground faults (including those constituting the detection "blind spot"); and recommendations for novel and traditional ground fault detectors.

[19] https://planetsense.ornl.gov/webps/

Multi-Source Multi-Time-Scale Wildfire Data Warehouse and Visualization Platform (ANL)

Argonne's situational analysis and wildfire risk analysis draws on data pipelines and a data warehouse that pull three types of data: climate and environmental factors (e.g., fuel buildup), weather conditions, and power delivery operations. The dataset includes publicly available data sources (e.g., NOAA) and Argonne's data on wildfire indices and transmission line temperature and sag, for example. The platform synthesizes these key datasets used in wildfire modeling and mitigation into a single visualization tool that is updated in real-time. This allows decision-makers to easily see the real-time changes in data that affect the ignition and propagation of wildfires, highlighting the geographical location of power system components and wildfire-related metrics (e.g., wildfire indices, temperature, humidity, wind speed).

Risk and Crisis Communication–National Public Affairs Academy (ANL)

Communicating with the public clearly and effectively beforehand about wildfire risk and then providing timely and accurate information during a wildfire emergency are both critical to mitigating its effects. The National Public Affairs Academy at Argonne National Laboratory offers more than two dozen training courses and workshops that address a wide range of communication and emergency public information topics from media relations and risk and crisis communication to social media technology and digital communication and participating in an area Joint Information System/Center with partner agencies. All National Public Affairs Academy courses are fully customizable and can be specifically adapted to address wildfire hazards, helping utility operators to communicate more effectively with their stakeholders.[20] [21]

Area of Research: Modeling and Analytical Tools

Dynamic Contingency Analysis Tool for Extreme Wildfire Event Planning (PNNL)

Partnered with Electric Reliability Council of Texas, Siemens, General Electric, Bonneville Power Administration, and EPRI, PNNL developed a hybrid dynamic and steady-state approach to mimic the cascading failure process that includes both fast dynamic and slower events. Integrated dynamic models with protection schemes models.

Note: PNNL is working with General Electric to integrate into PSLF toolsets used in WECC.[22] [23]

Sustainable Forest Biomass for Fire Mitigation (PNNL)

PNNL developed decision support tools that support optimization of fire mitigation activities by linking systems of spatial, forest, fuel/fire/economic and hydrological models to characterize wildfire potential.

Note: This is not an electric equipment fire mitigation technology, but it is a tool that can be used to identify critical zones where wildfire could propagate.

Multi-Sensor Data Exploitation for Wildfire Damage Assessment (PNNL)

PNNL has developed algorithms that exploit best-available satellite and airborne sensor data to perform automated characterization of high-risk vegetation (ignition/fuel/risk); vegetation management priorities

[20] Argonne Fusion Cell public affairs research and training facility: https://pastfusion.egs.anl.gov/
[21] NPAA 2020 Course Catalog: https://pastfusion.egs.anl.gov/wp-content/uploads/2020/04/CATALOG_0220-Final.pdf
[22] https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26197.pdf
[23] https://www.youtube.com/watch?v=IhsVNTBPozI

for critical infrastructure; active hot-spots/fire lines (thermal sensing); burned area/impacted infrastructure.

Standard Unified Modeling, Mapping, and Integration Toolkit (SNL)

The Standard Unified Modeling, Mapping, and Integration Toolkit (SUMMIT) is a modeling & simulation framework for decision support. The California Fire and Rescue Training Authority deployed SUMMIT to help agencies exercise their responses to emergency scenarios, including wildfires, chlorine releases from railcars, and radiological dispersal devices. Equally important, SUMMIT can link multiple models in a single template to more fully simulate complex scenarios. SUMMIT allows the models and data to work together seamlessly, generating results that can be visualized in many different formats and exported for other uses. As a further benefit, the templates can be used repeatedly and customized with new input data, increasing planning efficiency.

FASTMap (SNL)

FASTMap is a web-based mapping tool that displays any infrastructure data on a map, can include overlays of areas of interest or risk, and can perform analysis on other infrastructure, population, economic activity in the vicinity of a scenario or actual disruption. While FASTMap can depict any infrastructure and areas of interest or concern, it has capabilities that can be leveraged specifically in strategy for reduction of electric power fire hazards, and actual emergency response or response planning. FASTMap can maintain and visually depict the status of transmission or distribution lines, identification of areas of high flammability hazard, evacuation zones, inspection and survey progress, and status classifications.

Note: FASTMap is a web and tablet based mapping application that browses national infrastructure and emergency resources data that generates maps and reports of assets at risk within any area of disruption or any analysis area. FASTMap can depict any geospatial datasets (currently National Geospatial-Intelligence Agency's HSIP Gold infrastructure data) and provides immediate data access through a fully symbolized, publication-quality interactive mapping interface available to browsers and mobile tablets.

LANDFIRE (SNL)

Develop a forest risk analysis by applying LANDFIRE and Monitoring Trends in Burn Severity indicators and other contemporary earth science data and process models to forest wildfire risk management decisions, and conduct a value of information impact assessment of the application of satellite and other contemporary earth observation data to forest risk management decisions.

Physics-Informed Machine Learning Emulators of Wildfire Spread (LBNL)

This technology accelerates the simulation of wildfire spread scenarios by 2–3 orders of magnitude compared to standard fire physics models, while incorporating dynamic conditions on the ground such as wind fields, humidity, elevation maps, vegetation maps etc. By simulating many more scenarios of wildfire spread with ignition points along utility equipment, the technology better characterize the risk dynamic wildfire risk profiles at high spatial resolution (~250m to 30m), temporal resolution (daily or better), and over large areas. A wildfire model has been developed that takes real-time updated meteorological data (wind, temperature, relative humidity, etc.), local topography, and vegetation as inputs and predicts the probability of large wildfire growth. The model is high-resolution (1km) covering all of California and is aimed at assessing evolving wildfire risk. LBNL has validated the model against historical fire data (2002–

2019) and has shown that it is predictive of fire size, burned area extent, and overall burn probability. This work has been published in scientific journals and LBNL is actively exploring potential commercial use cases in energy and insurance sectors.

Note: LBNL is also actively developing an additional model layer aimed at predicting ignition probability that takes into account a number of geospatial features including proximity to roads and power lines, but this component is still under development. Preliminary discussions are underway with grid operators to evaluate the model.[24] [25]

XAI Models of Wildfire Risk and Risk Management (LBNL)

This technology enables the modeling of wildfire risk by using available satellite imaging data, including hyperspectral and synthetic LIDAR, to model wildfire risk as a function of local vegetation patterns. Further, the resulting models are amenable to constrained optimization, modeling wildfire risk as an emergent ecosystem service, and providing ecological engineering solutions to vegetation management. These solutions include modeling ecosystem dynamics to enable passive (planting-based) solutions to wildfire risk mitigation.

Note: XAI is ready for testing on fire data.

Predictability of Fire Behavior and Effects in the Wildland Urban Interface in California (LBNL)

This model uses Geostationary Operational Environmental Satellite Network imagery and machine learning for early detection, monitoring, and realistic predictions of fire behavior and effects in the wildland urban interface. It is ready to use but might need to be calibrated depending on the ecosystem characteristics and topography. The model can evaluate how fire spreads, how the extent and/or severity are directly relevant for the grid exposure, and how model outcomes on vegetation mortality and community change help predict future fire risk around specific grid infrastructure. The rapid detection and real-time prediction collaborators are LBNL-ETA, CALFIRE, the US Forest Service, and UC Berkeley. This work will address the following question: what are the critical mechanistic interactions of climate, vegetation, and topographic variables driving the spatial and temporal predictability of fire behavior (spread rate and intensity) and fire effects in the wildland urban interface (WUI) in California? This mechanistic understanding will be derived from wildfire behavior and effects data and complex bio-geophysical data in a machine learning framework. Remote sensing and machine learning can be adapted in 6–10 months.[26] [27]

Climate Modeling for California Planning (LBNL)

LBNL is developing two new projects in close coordination with electric utilities for the CA Energy Commission to develop the next generation of regional climate projections, analytics, and a data platform for supporting electricity sector climate resilience planning. These two activities consist of *Development of*

[24] https://e3sm.org/wp-content/uploads/2020/05/200514_Q_Zhu_reduced.pdf
[25] https://acme-climate.atlassian.net/wiki/spaces/ECM/pages/1929707601/2020-10+Meeting+Oral+Presentations?preview=/1929707601/1945471073/E3SM%20PI%20meeting%20QING%20ZHU.pdf
[26] https://ylfeng.users.earthengine.app/view/fireca
[27] https://caralyngorman.users.earthengine.app/view/camp-fire-sliding-map-3-9-19

Climate Projections for California and Identification of Priority Projections and *A Co-Produced Climate Data and Analytics Platform to Support California's Electricity Resilience Investments*.

Note: Work is in collaboration with the following utilities: PG&E, SDG&E, SCE, and PacifiCorp.[28]

Attention-Based Long-Short-Term-Memory Model (LBNL)

This is a recurrent neural network framework with an attention mechanism that is designed to predict wildfire activity with relatively long leading time in wildland urban interface. The model is ready to be used but may require calibration. This model can also be used to evaluate how fire spreads and to predict risk around the grid infrastructure. For more information can be found here:

- Wildfire modeling with E3SM and machine learning techniques[29]
- Trial by Fire FATES-SPITFIRE[30]
- Importance of size structure and fuels for fire: FATES-SPITFIRE[31]
- The NGEET FATES model[32]

Data-Driven Wildfire Risk Model and Optimal Grid De-energization Strategies (LBNL)

The ongoing project funded by the University of California, office of president aims to investigate the changes in fire-weather regimes in California, determine wildfire risks associated with extreme weather conditions (e.g., high winds) and electric power line ignitions using unique datasets of climate observations and weather/fire simulations, and develop optimal de-energization (power shut-off) strategies given the wildfire risks as inputs and evaluate the reliability and economics implications of various fire-related planning and operation policies. The development is based on real-world distribution and transmission circuits. The derived risk model and de-energization rules will be incorporated into an integrated decision-making framework, which will be ready for use in 6–10 months. The team is having exploratory conversations with PG&E and SCE on data sharing and integration of this work with the utility practices.

Note: Forthcoming web site will provide data and preliminary results for public.[33]

[28] https://docs.google.com/presentation/d/1JNlfQPHr95rwrQe0h7BAaMH9H-5i8yY3i9_MI_fU7gs/edit#slide=id.p1
[29] https://e3sm.org/wp-content/uploads/2020/05/200514_Q_Zhu_reduced.pdf
[30] www.cesm.ucar.edu/events/workshops/ws.2017/presentations/bgcwg/shuman.pdf
[31] http://www.cesm.ucar.edu/events/workshops/ws.2018/presentations/bgcwg/shuman.pdf
[32] The model is at this website: https://github.com/NGEET/fates
[33] http://smartcity.lbl.gov/wildfire

Grid Resilience and Intelligence Platform (GRIP) – (SLAC)

SLAC is working in collaboration with LBNL, Southern California Edison, the Presence Product Group, Packetized Energy, and NRECA to develop and deploy a suite of novel software tools to anticipate, absorb, and recover from extreme events. The wildfire portion of the tool is being coordinated with SCE. GRIP's goal is to respond to electric grid events by demonstrating machine learning and artificial intelligence from different data sources to anticipate grid events, validating controls for distributed energy resources for absorbing grid events, and reducing recovery time by managing distributed energy resources in the case of limited communications. The project builds on previous efforts to collect massive amounts of data and uses it to fine-tune grid operations, including other Grid Modernization Lab Consortium projects on distributed controls and cyber security.

NOTE: GRIP is a suite of different capabilities and some are ready for deployment and commercialization within 6–10 months.

Argonne Wildfire Threat Model: Risk Assessment for Interdependent Power and Telecommunications Systems (ANL)

ANL has assembled a database of major historical fire events with GIS features for animated depictions of daily burn progression over the entire temporal occurrence of the empirical event. Through the Argonne probabilistic Wildfire Threat Model, the empirical daily fire behavior can be modified in both direction and intensity to fit a scenario that would allow for the assessment of performance of strongly coupled power and telecommunications systems in the context of a specified wildfire event. Performance assessment includes identification of multiple at-risk electric and telecom assets and the quantification of the possible cascading failures and outages that could occur both in terms of geospatial extent and depth of impact (MW loss and number of customers affected). Argonne's EPfast and TELCO fast tools are used to assess electric and telecommunications system performance and to quantify impacts, and the Wildfire Threat Model is used to define scenarios and fire behavior. Wildfire fragility curves for transmission lines, power plants, microwave towers, cells towers, and fiber optics cables are used to determine damage levels of the assets as the fire progresses and fire intensity increases. Integration of the tools into a coupled system would require additional effort.[34] [35]

Wildfire Risk Modeling (ANL)

Argonne has developed a thermal overloading risk quantification model based on a semi-analytical probabilistic approach. The model can assess system uncertainty in, for example, renewable energy resources or loads. The model is used to compute the probability of a line current violation and can be integrated into other decision-making processes as a chance-constraint relaxation. Moreover, wildfire risk analysis based on wide-area modeling of power line temperature evolution and monitoring of line sag is incorporated into the existing modeling framework.

In the next six months, Argonne will extend the capability by integrating additional risk quantification into the framework. The objective is to provide comprehensive risk analysis of wildfire while considering multiple impact factors related to ignition and spread of wildfires.

[34] For more information, go to this website: https://www.anl.gov/dis/infrastructure-science
[35] Argonne Wildfire Probabilistic Threat Model: https://www.anl.gov/sites/www/files/2020-11/Argonne_Wildfire_Probabilistic_Threat_Model.pdf

Operations and Planning for Wildfire Risk Mitigation (ANL)

Argonne has developed a wildfire mitigation decision support tool for both operations (e.g., optimal Public Safety Power Shutoff programs) and planning (e.g., risk-informed expansion planning). The capability includes a transmission expansion planning framework that uses historical fire potential data to place new electric power infrastructure for wildfire mitigation, and a daily dispatch tool used to reduce the probability of a wildfire ignited by electric power infrastructure through transmission switching and power flow reductions. In the next six months, Argonne will expand the capability to include an Argonne Operational Wildfire Mitigation Tool, a daily dispatch tool used to reduce the probability of a wildfire ignited by electric power infrastructure through targeted de-energizing and power flow reduction while minimizing load shed.

Note: The Argonne Operational Wildfire Mitigation Tool referenced above is being developed to aid the PSPS (Public Safety Power Shutoff) program in California to more intelligently identify the electric power infrastructure most likely to ignite fires, and use stochastic optimization methods to determine the optimal operational scheme to reduce fire risk while limiting load shedding.

Geospatial Analysis Tool Kit for Regional Climate Datasets (ANL)

ANL has developed a GIS analysis tool named Geospatial Analysis Tool Kit for Regional Climate Datasets (GATOR) to provide easy access to a large database of regional scale climate projections to a variety of users. Data layers include temperature, precipitation, soil conditions and other relevant weather/climate parameters obtained from a high-resolution regional scale climate model dataset developed at ANL. The lab has also developed a wildfire risk indicator database for current and future climate conditions for the mid and end of the century. This database and the tools for calculating the fire risk indicators can be combined into a GATOR-FIRE for long-term planning by industry. GATOR-FIRE for long-term planning will be available for industry use in 6 months. Adapting GATOR-FIRE for short-term fire forecasting is a second activity. Argonne leads the community Python ARM Radar Toolkit (Py-ART), which is used by hundreds of institutions to gain insight from weather radar. Py-ART has been used to study wildfires using both research radars and open data from operational radar networks. GATOR-FIRE will be adapted to use weather forecast data (0–5-day forecasts from the NOAA High-Resolution Rapid Refresh (HRRR) model). By integrating radar data with HRRR forecasts in the GATOR-FIRE GIS platform, the lab will stand up a tool for identifying and studying the propagation of wildfires (in 6–12 months) that will use the radar data. GATOR-FIRE will provide near-term risk assessments with forecasting, analysis, and real-time monitoring capabilities.[36]

National Preparedness Analytics Center (ANL)

ANL's National Preparedness Analytics Center (NPAC) is a national leader in the provision of science-informed technical assistance for all-hazards evacuation and shelter-in-place planning, including for wildfire events. As an example, NPAC is funded by the Federal Emergency Management Agency to examine human behavior in protective action decision-making related to hazard-driven evacuations or shelter-in-place decisions (including individual and organization decisions); partner with local governments and infrastructure owners and operators to develop consequence-informed and time-bounded protective action plans, tools, and guidance; support operational decision-making related to hazard-based

[36] For more information, go to this website: https://www.evs.anl.gov/research-areas/environmental-systems/

evacuations; and conduct training sessions, workshops, and symposia that bring industry and government together to plan for disasters (e.g., wildfires) that could cause evacuation or shelter-in-place operations to occur.[37]

Area of Research: Post Fire Analysis

Rapid Inundation Flood Tool (PNNL)

The Rapid Inundation Flood Tool provides rapid predictive flood analytics for infrastructure situational awareness. This tool can easily simulate post-fire flooding events to determine the impact of heavy rainfall. Following a major fire, the flood risk greatly increases because of less vegetation to slow runoff down and the soil can become hydrophobic, meaning that the soil will repel water. PNNL employs two approaches to provide this situational awareness: the near real-time modeling and simulation and the development of a simulation archive, the Water Extreme Lookup Library.[38] [39]

Area of Research: Fire Testing Capabilities

Thermal Test Complex (SNL)

The Thermal Test Complex comprises multiple test cells, ovens, and a laser lab for controlled fire experiments. Tests range in size from small-scale experiments that use lasers to large-scale tests that burn custom-made structures and models. Team members change variables such as temperatures, wind speed, and materials to see how the test objects fare under abnormal and extreme conditions.[40]

Testing of Wildland Ignitions from High-Flux Sources (SNL)

Sandia has recently been involved with a multi-million dollar multi-year test campaign that used concentrated solar power to evaluate the fire behavior of materials in response to high heat flux. A moderate portion of this test campaign has involved materials and configurations highly relevant to wildland fire ignition. SNL has particular expertise in ignition from high flux scenarios as may be relevant to the problem at hand. Prior to this experimental work, SNL has significant legacy experience in pyrolysis, transport, and reaction behaviors relevant to wildland fires and high flux scenarios including several journal papers and many conference and institutional reports. Further data exists in the Official Use Only form that could be communicated as necessary.[41]

[37] For more information, see the following website: https://www.anl.gov/dis
[38] https://www.pnnl.gov/news/release.aspx?id=4466
[39] https://www.pnnl.gov/news-media/high-tech-damage-assessment-speeds-disaster-recovery
[40] http://tours.sandia.gov/TTC/ttc_info.html
[41] https://www.youtube.com/watch?v=P4So-SwuqA0