CalEEMod

California Emissions Estimator Model

Appendix E
Support Documentation for Climate Change Analyses

Prepared for:
California Air Pollution Control Officers Association (CAPCOA)

Prepared by:
ICF
in collaboration with
Sacramento Metropolitan Air Quality Management District, Fehr & Peers, STI, and Ramboll

April 2022
CalEEMod Version 2022.1

Table of Contents

1 Overview

The California Emissions Estimator Model (CalEEMod) displays data for extreme heat, precipitation, sea level rise, and wildfire through an application programming interface (API) with Cal-Adapt. Based on the Cal-Adapt data and user inputs, the model provides a method to quantify and score the vulnerability of a project or asset to projected climate change. The vulnerability assessment includes the four Cal-Adapt hazards, as well as flooding, air quality degradation, decrease in snowpack, and drought. This appendix provides the methodology for the vulnerability assessment performed by the **Climate Risk** module. The appendix describes the types of emission reduction measures included in the **Measures** module. Because information from the **Climate** map screen underpins much of the analysis in the **Climate Risk** module and **Measures** module, additional context for the map screen is also provided.

The method for scoring climate risks is largely based on the guidance presented in Chapter 4, Assessing Climate Exposures and Measures to Reduce Vulnerabilities, of CAPCOA's *Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity: Designed for Local Governments, Communities, and Project Developers* (Handbook). Relevant information and guidance from the Handbook have been directly incorporated into this appendix.

2 Climate Map Screen

The **Climate** map screen displays extreme heat, precipitation, sea level rise, and wildfire risks that are relevant to the project area. The climate projections are from Cal-Adapt under Representative Concentration Pathway (RCP) 8.5 for the mid-century timeframe. The RCP 8.5 assumes greenhouse gas (GHG) emissions will continue to rise strongly through the year 2050 and then plateau around 2100; this pathway reflects a scenario in which society does not significantly reduce its GHG emissions and closely resembles the current trajectory in global GHG concentrations. The following variables are used to define the climate risk for each hazard.

- *Extreme heat:* Projected number of annual extreme heat days for the 6 kilometer (km) by 6 km, or 3.7 miles (mi) by 3.7 mi, grid cell in which a project is located. The projection is based on the 98th historical percentile of daily maximum/minimum temperatures from observed historical data (32 climate model ensemble from Cal-Adapt, 2040–2059 average under RCP 8.5).
- *Precipitation:* Projected number of annual days with precipitation above 20 millimeters (mm) for the 6 km by 6 km grid cell in which a project is located (32 climate model ensemble from Cal-Adapt, 2040–2059 average under RCP 8.5). The threshold of 20 mm is equivalent to about 0.75 inch of rain, which would be light to moderate rainfall if received over a full day or heavy rain if received over a period of 2 to 4 hours.
- *Sea level rise:* Projected sea level rise inundation depth reported in meters (m) for the 50 meter (m) by 50 m, or 164 feet (ft) by 164 ft, grid cell in which a project is located. The projections are from Radke et al. (2017), as reported in Cal-Adapt (2040–2059 average under RCP 8.5), and consider different increments of sea level rise coupled with extreme storm events. The user may click the dropdown menu to select from four model simulations to view the range in potential inundation depth for the grid cell. Note that the sea level rise geospatial layer must be selected for the dropdown menu to activate. Click the circle button to select the

layer. The four simulations make different assumptions about expected rainfall and temperature, defined as follows.

  - Warmer/drier (HadGEM2-ES).
  - Cooler/wetter (CNRM-CM5).
  - Average conditions (CanESM2).
  - Range of different rainfall and temperature possibilities (MIROC5).

- *Wildfire:* Projected annual area burned reported in hectares (ha) for the 6 km by 6 km grid cell in which a project is located (1 ha is equivalent to about 2.5 acres). The projections are from the University of California, Davis, as reported in Cal-Adapt (2040-2059 average under RCP 8.5), and consider historical data of climate, vegetation, population density, and large (>400 ha or 988 acres) fire history. The user may click the dropdown menu to select from four model simulations to view the range in potential wildfire probabilities for the grid cell, as defined above for the sea level rise hazard. Note that the wildfire geospatial layer must be selected for the dropdown menu to activate.

3 Climate Risk Module

The **Climate Risk** Module is comprised of seven screens that guide the user through calculating the climate risks of their project to the eight different hazards. Each of these screens is discussed below.

3.1 Introduction Screen

The **Introduction** screen offers a high-level outline of the process the user will go through to assess climate hazards and develop a vulnerability score. No calculations are performed on this screen. The user should select the climate hazards they wish to analyze further. Climate hazards most applicable to the project analysis based on the project location will be preselected.

3.2 Determine Exposure Score Screen

The methodology behind climate exposure score screening consists of two components: Cal-Adapt data to develop an initial exposure score and guiding questions to refine the initial score into the user's final exposure score.

The exposure scores represent the change in the eight climate hazards that the site is projected to experience. These scores are quantile-based (1 to 5) and draw from site-specific climate projections relative to all projection values in the California climate region of interest. These regions, which come from California's *Fourth Climate Change Assessment* (OPR, CEC, and CNRA 2018), include the following.

- Central Coast
- Inland Desert
- Los Angeles
- North Coast
- Sacramento Valley
- San Diego

- San Francisco Bay Area
- San Joaquin Valley
- Sierra Nevada

For example, future climate projections show that the Los Angeles region will experience higher change in number of extreme heat days than the Sierra Nevada region. Therefore, an extreme heat score of "5" in Los Angeles may (for example) represent 20 additional days of extreme heat, while the same score in the Sierra Nevada may represent 10 additional days of extreme heat. The purpose of these region-specific scores is to emphasize the importance of change in climate hazard. Communities and systems are already adapted to the climate they are in but may experience more serious impacts under significant change.

The climate projections used are based on a 2050 time horizon (assuming a 20-year climatology from 2040 to 2059) under RCP 8.5. Projection values are the ensemble mean of the four priority California statistically downscaled Global Climate Models (HadGEM2-ES, CNRM-CM5, CanESM2, and MIROC5). These projections use a single time horizon and RCP to address computational and storage constraints. The 2050 time horizon and RCP 8.5 are commonly used to assess exposure within a typical planning horizon.

The four Cal-Adapt hazards and their indicators are as follows.

- **Extreme heat** (also referred to as temperature and extreme heat): Change in number of extreme heat days per year based on the 98th percentile temperature. This addresses location relative exposure and is a common variable definition used by Cal-Adapt and in exposure assessments. Note that 98th percentile temperature may be a much hotter temperature in the Central Valley than in the North Coast; thus, even a small projected number of extreme heat days may lead to impacts for vulnerable communities.
- **Extreme precipitation**: Change in number of extreme precipitation days per year based on the 95th percentile temperature. This addresses location relative exposure and is a common variable definition used by Cal-Adapt and in exposure assessments.
- **Wildfire**: Change in wildfire probability using the Westerling (2018) dataset.
- **Sea level rise**: Change in coastal flooding depth as a result of sea level rise and a coastal storm event using the Radke et al. (2017) dataset.

The other four hazards–flooding, drought, air quality degradation, and snowpack reductions–do not have adequate datasets available through Cal-Adapt, so these were not analyzed quantitatively. (While Cal-Adapt does have a snowpack indicator, existing datasets do not address exposure to basin-wide water supply reductions.) Instead, a series of guiding questions help the user determine their exposure score to these hazards.

Tables E-1 through E-5 summarize the guiding questions and outline the parameters applied by the model to score the hazards of flooding, temperature and extreme heat, wildfire, drought, and air quality degradation based on user responses. Exposure scores for sea level rise and extreme precipitation are determined exclusively from Cal-Adapt. No additional questions are asked for the user. The exposure score for decreased snowpack is determined after the user responds.

Table E-1. Exposure Questions and Scoring Parameters for Flooding

Question	User Response	Scoring Action
Is the project located in a 100-year FEMA floodplain?	Yes	Score of 5. No further questions asked.
	No	User advanced to the next question.
Is the project located in a 500-year FEMA floodplain?	Yes	Score of 4. User advanced to the next question.
	No	User advanced to the next question.
Has the project area experienced flooding in the past?	Yes	Score of 5. No further questions asked.
	No	User advanced to the next question.
Is the project area projected to experience an expansion in flood risk areas, increased flood depths, or increased extreme precipitation events?	Yes	User asked to score their exposure using the slider.
	No	

Table E-2. Exposure Questions and Scoring Parameters for Temperature and Extreme Heat

Question	User Response	Scoring Action [a]
Is the project located in an urban heat island (UHI)? (Is the project located in dense urban or suburban environment?)	Yes	+1 is added to the initial Cal-Adapt score. User advanced to the next question.
	No	No change in initial Cal-Adapt score. User advanced to the next question.
Is the project area projected to have higher projected temperature and extreme heat values compared to the region as a whole?	Yes	+1 is added to the initial Cal-Adapt score.
	No	No change in initial Cal-Adapt score.

[a] Scores are added up to a maximum score of 5.

Table E-3. Exposure Questions and Scoring Parameters for Wildfire

Question	User Response	Scoring Action [a]
Is the project located in the wildland-urban interface (WUI) (as defined by CAL FIRE hazard and/or county WUI maps) (the WUI is a zone of transition between wilderness and land developed by human activity)?	Yes	Score of 5. No further questions asked.
	No	No change in initial Cal-Adapt score. User advanced to the next question.
Has the project site experienced wildfire in the past?	Yes	Score of 5. No further questions asked.
	No	No change in initial Cal-Adapt score. User advanced to the next question.

Question	User Response	Scoring Action [a]
Is the project in or near an area that experiences high wind events?	Yes	+1 is added to the initial Cal-Adapt score. User advanced to the next question.
	No	No change in initial Cal-Adapt score. User advanced to the next question.
Is the area around the project composed of vegetation that could serve as significant wildfire fuel?	Yes	+1 is added to the initial Cal-Adapt score. User advanced to the next question.
	No	No change in initial Cal-Adapt score. User advanced to the next question.
Is the project area projected to have higher wildfire risk compared to the region as a whole?	Yes	+1 is added to the initial Cal-Adapt score.
	No	No change in initial Cal-Adapt score.

[a] Scores are added up to a maximum score of 5.

Table E-4. Exposure Questions and Scoring Parameters for Drought

Question	User Response	Scoring Action [a]
Is the project area projected to experience an increase in the frequency or severity of drought in the future?	Yes	Score of 5. User advanced to the next question.
	No	Score of 1. User advanced to the next question.
Is or has the project area ever been identified in a state drought emergency declaration?	Yes	Score of 5. User advanced to the next question.
	No	Score of 1. User advanced to the next question.
Has or does the project area's local government impose water conservation requirements beyond the statewide requirements?	Yes	Score of 4. User advanced to the next question.
	No	Score of 1. User advanced to the next question.
Has the project site area experienced curtailments in water deliveries from imported water sources in the past?	Yes	Score of 4.
	No	Score of 1.

[a] Once all questions are answered, CalEEMod averages scores as (Q1 * 0.40) + (Q2* 0.40) + (Q3 * 0.10) + (Q4 * 0.10). The result is rounded to the nearest whole number.

Table E-5. Exposure Questions and Scoring Parameters for Air Quality Degradation

Question	User Response	Scoring Action
Is the project area within a nonattainment area for federal or state ambient air quality standard?	Yes	Score of 5. User advanced to the next question.
	No	User advanced to the next question.
Is the user's project located within 0.25 mile of a major freeway?	Yes	Score of 5. User advanced to the next question.
	No	User advanced to the next question.
Is the user's project located within 0.25 mile of a major industrial zone or logistics center?	Yes	Score of 5. User advanced to the next question.
	No	User advanced to the next question.
Is this project located in the wildland-urban interface?	Yes	Score of 2 (or +2 to existing score). User advanced to the next question.
	No	User advanced to the next question.
Is the project area projected to experience a decrease in future air quality due to climate change (e.g., due to increased smoke from wildfires)?	Yes	Score of 1 (or +1 to existing score).
	No	Score of 1.

The exposure score for decreased snowpack is determined after the user responds to all guiding questions according to the following logic.

- If the user answers yes to **all** questions, a score of 5 is given.
- If the user answers yes to either question 1 or question 2 **and** yes to question 3, a score of 5 is given.
- If the user answers no to either question 1 or question 2 **and** no to question 3, a score of 3 is given.
- If the user answers no to question 1 **and** Q2 but yes to question 3, a score of 2 is given.
- If the user answers no to **all** questions, a score of 1 is given.

The user may refine any of the exposure scores determined for the climate hazards by adjusting the slider. When refining the exposure score, it may be useful to refer to climate projection tools to consider climate hazard exposure in the specific area where the project will be located. The user is also encouraged to consult any local climate vulnerability assessments, local hazard mitigation plans, or other climate planning documents for their region or project area. The following resources provide additional guidance on understanding climate exposures, as well as exposure maps, that can be used to further refine the exposure score. In some cases, selecting a refined exposure score may require the user to make certain assumptions or judgements.

- Cal-Adapt: This is the official statewide climate hazard mapping tool. Use this tool to assess exposure to temperature, precipitation, and wildfire-related hazards by location.[1]

[1] Available: https://cal-adapt.org/.

- Our Coast, Our Future: A web visualization tool based on data from the US Geological Survey's Costal Storm Modeling System (CoSMoS). Use this tool to assess exposure to sea level rise and coastal flooding hazards.[2]
- Adaptation Planning Guide (APG): The California Governor's Office of Emergency Services (Cal OES) provides detailed guidance for conducting vulnerability studies that can help the user expand on the baseline assessment here.[3]
- Integrated Climate Adaptation and Resiliency Program (ICARP) Adaptation Clearinghouse: OPR's official database of adaptation case studies and technical reports. The user can search the ICARP database to look for detailed vulnerability assessments covering the project site.[4]
- Caltrans 2019 Climate Change Vulnerability Assessments: The California Department of Transportation (Caltrans) has conducted climate change vulnerability assessments for each of its 12 regions. While the focus is on resilience of the state highway system, the climate hazard analysis and recommendations can be generalized to other land uses and projects. Each region also has an interactive map that provides localized climate impact projections.[5]

3.3 Determine Sensitivity Score Screen

This screen guides the user through determining the sensitivity score. The sensitivity score reflects the extent to which a project would be adversely affected by exposure to a climate hazard. There are multiple aspects of sensitivity to consider.

- **Physical**: How sensitive the project may be to physical damage from climate hazards. For example, wildfire can impair the structural integrity of buildings through incineration and exposure to extreme temperatures. Historical data on events for the project site and similar projects can provide insights for how sensitive the project may be to physical effects from different hazards.
- **Operational**: How sensitive the project may be to disruptions of regular operations from climate hazards. For example, flooding along roads may disrupt public transportation operations. Wildfire smoke events may disrupt operations of recreational or commercial land uses. Historical data on events for the project site, similar projects, and critical interconnections (e.g., local energy utilities, transportation networks) will be helpful in understanding potential operational disruptions.
- **Safety**: How sensitive populations associated with a project may be to different climate hazards. For example, apartments in urban areas may become hot and not cool down easily during extreme heat events due to urban heat island effects, endangering the health of residents. Some projects may serve populations that are more vulnerable to climate hazards, such as hospitals or nursing homes.

The screen presents a series of guiding questions to assess how project specifics and site historical data can help provide insights to the sensitivities of a project to climate hazards. Some of the questions, such as those on populations served by the project or project elements vulnerable to physical impacts, are specific to the project type and the user's knowledge of the

[2] Available: https://coast.noaa.gov/digitalcoast/tools/ocof.html.

[3] Available: https://www.caloes.ca.gov/HazardMitigationSite/Documents/CA-Adaptation-Planning-Guide-FINAL-June-2020-Accessible.pdf.

[4] Available: https://resilientca.org/.

[5] Available: https://dot.ca.gov/programs/transportation-planning/2019-climate-change-vulnerability-assessments.

project. Other questions may require the user to access existing reports for the project area. For example, historical data on hazard impacts for the project area and similar projects may be found in local hazard mitigation plans or through engaging local community planners and decision makers.

CalEEMod calculates the final sensitivity score for each hazard by averaging the scores across all questions. The user may refine any of the sensitivity scores determined for the climate hazards by adjusting the slider.

3.4 Determine Adaptive Capacity Score Screen

The adaptive capacity of a project refers to its ability to manage and reduce vulnerabilities from projected climate hazards. For example, a housing development with heating, ventilation, and air conditioning (HVAC) throughout the building will provide residents with cooling and air filtration against projected increases in heat waves and smoke from wildfire events. Identifying the adaptive capacity of a proposed project will help the user understand the degree to which vulnerabilities may be addressed before taking adaptation actions.

The screen presents a series of guiding questions to assess the adaptive capacity of the project. Like sensitivity, CalEEMod calculates the final adaptive capacity score for each hazard by averaging the scores across all questions. The user may refine any of the sensitivity scores determined for the climate hazards by adjusting the slider.

3.5 Develop Potential Impacts Score Screen

This screen presents the potential impacts score for the climate risk analysis. CalEEMod averages the exposure and sensitivity scores for each climate hazard to develop potential impacts scores. If the result is a decimal score (e.g., 2.5), CalEEMod rounds up or down to the nearest whole number (e.g., 2.5 is rounded to a score of 3; 2.1 is rounded to a score of 2). Because the potential impacts scores are based on the previously calculated exposure and sensitive scores, the values cannot be modified on this screen.

3.6 Develop Overall Vulnerability Score Screen

This screen presents the overall vulnerability score for the climate risk analysis. CalEEMod combines the potential impacts and adaptative capacity assessments for each climate hazard to develop overall vulnerability scores. Figure E-1 illustrates how CalEEMod converts the results of the two assessments into a single score. Specifically, the intersection between potential impacts score (1 to 5) in the first column and the adaptive capacity rating (low to high) in the bottom row is the resulting vulnerability score for the climate hazard. Because the vulnerability scores are based on the previously calculated scores, the values cannot be modified on this screen.

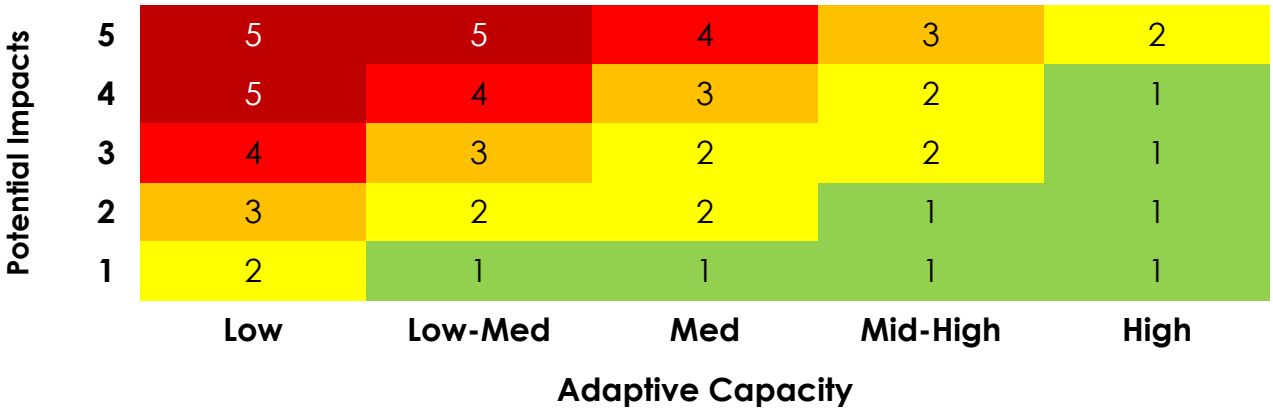

Figure E-1. CalEEMod Vulnerability Score Matrix

3.7 Select Highest Scoring Vulnerabilities

This screen shows overall vulnerability scores for all climate hazards and selects the hazards that have a vulnerability score of 3 or above. The user can click on additional hazards to include them when selecting risk reduction measures or uncheck preselected hazards based on their risk tolerance and/or other considerations (e.g., policy objectives).

4 Climate Risk Reduction Module

The **Climate Risk Reduction Measures** screen provides 99 measures for a user to select from to reduce their project's vulnerability. To help a user identify the measures that are most applicable to their project, the **Climate** map screen will generate a list of measures based on user input of their project's specific scale and land use subtype(s) on the **Start a New Project** splash screen. Land use subtypes are assigned for all measures based on reasonable judgment. For example, a measure to improve building efficiency would not be applicable to outdoor land use subtypes, like parks. See Tables G-45 and G-46 for the applicable land use subtypes and project scales by measure, respectively. Measures not applicable to the project based on the user identified land use subtype(s) and project scale are shown in gray on the **Climate Risk Reduction Measures** screen. Measures that were preselected on the **Climate** and **Health and Equity** map screens are automatically checked.

4.1 Selecting and Scoring Measures

Each measure could have one or more of the following risk reduction benefits: reduces exposure, reduces sensitivity, and increases adaptive capacity. Some measures may not reduce an element of climate risk (zero value), whereas others may provide a range of potential reduction depending on implementation (e.g., 2 to 4). When a range is provided, a user should select the appropriate reduction benefit score for the project using the dropdown menu. The following sections provide guiding questions to consider when scoring the benefit and further define risk reduction benefits.

4.1.1 Reduces Exposure

The primary driver of exposure is location. A project's proximity to areas susceptible to a hazard will affect the extent to which the project will be subjected to a climate hazard. For example, a project located in a flood zone or in the WUI will be exposed to flooding and wildfire, respectively. While location primarily drives exposure, the user can use adaptation actions to lessen the degree

to which a project is exposed to a hazard. The degree to which an adaptation measure lessens the amount of exposure determines its exposure reduction. The following guiding questions can help the user determine the extent to which a measure lowers exposure to a specific hazard.

- How does the measure remove exposure (e.g., relocating a project)?
- How much does the measure change the project design to reduce future exposure (e.g., raising a building to reduce flood exposure)?
- Does the measure change post-construction operations and management to reduce future exposure (e.g., wildfire fuel removal or management)?

4.1.2 Reduces Sensitivity

To lower sensitivity, a measure must reduce the degree to which a project is affected by exposure to a hazard. The following guiding questions can support the user in determining the extent to which a measure decreases harm to a project.

- How much does the measure mitigate the hazards' effect on fragile or critical components of the project (e.g., cooling systems for equipment sensitive to overheating)?
- Does the measure lower the hazard's effect on individuals, particularly members of vulnerable populations (e.g., greater access for underserved populations to parks)?
- Does the measure lower the impact to an operational component affected by the climate hazard (e.g., conduct regular cleaning and maintenance of storm drains along key roadways)?

4.1.3 Increases Adaptive Capacity

Adaptation measures can also increase a project's adaptive capacity. A measure provides adaptive capacity benefits if it improves the project's capacity to take advantage of opportunities or mitigate the hazard's consequences. These guiding questions support the user in considering how a measure bolsters adaptive capacity.

- Does the measure add climate resilient components to the project (e.g., drainage system, cool roof)?
- Does the measure incorporate policies or standards that account for climate change (e.g., adopt or update heat emergency plan)?
- How does the measure improve the project's management of climate hazards (e.g., incorporating projected changes in precipitation and flooding into planned wastewater systems)?
- Does the measure reduce how project users are exposed to the hazard (e.g., using a notification system to provide evacuation information)?

4.2 Calculating Measure Effects on Vulnerability Scores

Based on the user provided scores, CalEEMod estimates the extent to which the user selected climate risk reduction measure(s) reduce exposure and sensitivity and increases adaptive capacity for each climate hazard. No measure, with the exception or relocating a project, can completely remove the threat from a particular climate hazard with a defined geographic footprint (e.g., floodplain). Measures mitigate, rather than remove, potential impacts from a hazard. Likewise, no measure can increase adaptive capacity to the extent to which overall vulnerability

is eliminated. Rather, measures can only strengthen a project's overall adaptive capacity score. For these reasons, measure scores are not additive, and a user's exposure, sensitivity, and adaptive capacity score will not go below 0 or surpass 5. CalEEMod recalculates these scores according to the following method.

1. Subtracts the maximum user-identified points across all measures for reduced exposure from the initial exposure score.
2. Subtracts the maximum user-identified points across all measures for reduced sensitivity from the initial sensitivity score.
3. Adds the maximum user-identified points across all measures for increased adaptive capacity to the initial adaptive capacity score.

CalEEMod then recalculates the potential impacts score and the overall vulnerability score.

5 References

Office of Planning and Research (OPR), California Energy Commission (CEC), and California Natural Resources Agency (CNRA). 2018. *California's Fourth Climate Change Assessment.* Available: https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf. Accessed: December 2021.

Radke, J. D., G. S. Biging, M. Schmidt-Poolman, H. Foster, E. Roe, Y. Ju, O. Hoes, T. Beach, A. Alruheil, L. Meier, W. Hsu, R. Neuhausler, W. Fourt (University of California, Berkeley). 2017. *Assessment of Bay Area Natural Gas Pipeline Vulnerability to Climate Change.* California Energy Commission. Available: https://cal-adapt.org/media/files/CEC-500-2017-008.pdf. Accessed: December 2021.

Westerling, A. L. (University of California, Merced). 2018. *Wildfire Simulations for California's Forth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events with a Warming Climate*. California Energy Commission. Available: https://www.energy.ca.gov/sites/default/files/2019-11/Projections_CCCA4-CEC-2018-014_ADA.pdf. Accessed: December 2021.