PG&E Wildfire Risk Modeling Workshop Report

In response to the September 29, 2021 guidelines issued by the Office of Infrastructure Safety (Energy Safety) for the recently established Wildfire risk-modeling working group, PG&E provided a summary of current wildfire risk modeling efforts as part of the October 5, 2021 workshop. Given the limited time available at the workshop, Energy Supply requested that the utilities augment their respective presentations with a more detailed report on specified topics. As the purpose of the Report is to "provide Energy Safety and Stakeholders with detailed documentation on each utility's modeling practices", PG&E is utilizing a tabular format in this report to facilitate establishing a baseline comparison and understanding of the modeling methods and practices.

These detailed responses address each topic for the Wildfire Distribution Risk Model v2 (WDRM v2), (formerly referred to as the 2021 Wildfire Distribution Model) that is discussed in PG&E's 2021 Wildfire Mitigation Plan (WMP) as well as the WDRM v3 that will be included in PG&E's 2022 WMP. PG&E is moving to a version nomenclature instead of the year.

The detailed documentation for the WDRM v2 was previously provided in the 2021 Wildfire Distribution Risk Model Overview document which was include as Attachment 2021 WMP_Revision_PGE-02_Atch02 in PG&E's 2021 WMP Response to Revision Notice on June 3, 2021. For consistency and convenience this document is referenced in the tables below and is included as an attachment to this Report.

For the WDRM v3, preliminary responses and descriptions are provided in the tables below. A more detailed overview document of the WDRM v3 will be provided as part of PG&E's 2022 WMP.

September 29, 2021 Energy Safety Guidelines and PG&E Responses:

In its guidelines, Energy Safety provided the following summary of the purpose for this Report:

> At the October 5, 2021, Risk Modeling Workshop, the utilities must present a summary of their current efforts on each of the points below. Given the limited amount of time for presentations, utilities may not be able to present each of the points in detail. To augment the presentations, the utilities must submit a report that provides a detailed description of each of the points below by October 13, 2021. The purpose of the report is to provide Energy Safety and Stakeholders with detailed documentation of each utility's current modeling practices.

Below, we provide information responsive to each of the categories identified by Energy Safety.

In the tables below, PG&E provides the requested information for the WDRM v2 and the WDRM v3. Much of the information for WDRM v2 is provided in detail in the 2021 Wildfire Distribution Risk Model Overview, which is attached to this Report. For the WDRM v2, detailed information, we have included a reference to the applicable section in the 2021 Wildfire Distribution Risk Model Overview.

Section 1: Data used broken down by model, including:

- Scale and geographical context
- Topography
- Quality of historical outage, fault, and ignition data
- Usage of outage and fault events to augment ignition data
- Integration of potential ignitions avoided due to PSPS events (to account for bias in ignition data post during PSPS events)
- Asset data (including asset age, health, inspection results, type, etc.)
- Impacts of system hardening and other initiative efforts
- Climate conditions (including historical wind conditions, relative humidity, temperature, etc.)
- Vegetation (including type, density, height, etc.)
- Fuel characteristics (including load, size, continuity, vertical arrangement, moisture, etc.)
- Impacts of Routine and Enhanced vegetation management activities (including tree-trimming, tree-removal, inspections, etc.)
- Frequency of updates to datasets and inputs, including any associated triggers to determine the need for updates
- Accuracy and quality checks for data and inputs

PG&E Data for the WDRM v2 and WDRM v3

Model Data Use						
	WDRM v2 Model		WDRM v3 Model			
Usage	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
Scale and geographical context	100m x 100m pixels across the HFTD Tier 2&3. Sec 11.1	100m x 100m pixels across the HFTD Tier 2&3. Sec 20.1	100m x 100m pixels across the overhead (OH) distribution system	100m x 100m pixels across the OH distribution system	100m x 100m pixels across the OH distribution system	100m x 100m pixels across the OH distribution system

Model Data Use						
	WDRM v2 Model		WDRM v3 Model			
Usage	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
Topography	USGS Topographic Position Index, Sec 28.4	USGS Topographic Position Index, Sec 28.4	Consistent with (v2) model	Consistent with (v2) model	Consistent with (v2) model	Consistent with (v2) model
Quality of historical outage, fault, and ignition data	2015 – 2019 CPUC Reportable Ignitions, Sec 2, 5.1.1(2), 11.4, 16	2015 – 2019 CPUC Reportable Ignitions, Sec 2, 5.1.1(2), 20.3.3.4, 21.1	2015 – 2020 outages, Public Safety Power Shutoff (PSPS) damages and all recorded ignitions	2015 – 2020 outages, PSPS damages and all recorded ignitions	2015 – 2020 outages, PSPS damages and all recorded ignitions	2015 – 2020 outages, PSPS damages and all recorded ignitions
Usage of outage and fault events to augment ignition data	Trained on CPUC Reportable Ignitions, Sec 2, 5.1.1(2), 11.4	Trained on CPUC Reportable Ignitions, Sec 2, 5.1.1(2), 5.1.2.1, 24	Risk formula moved to probability of outage x probability of ignition x wildfire consequence	Risk formula moved to probability of outage x probability of ignition x wildfire consequence	Risk formula moved to probability of outage x probability of ignition x wildfire consequence	Risk formula moved to probability of outage x probability of ignition x wildfire consequence
Integration of potential ignitions avoided due to PSPS events (to account for bias in ignition data post during PSPS events)	PSPS damages not included.	PSPS damages not included.	PSPS damages included in outage data.	PSPS damages included in outage data.	PSPS damages included in outage data.	PSPS damages included in outage data.
Asset data (including asset age, health, inspection results, type, etc.)	n/a	Conductor age, type and size, Sec 20.3, 20.4, 28.4	n/a	Asset age, conductor type and size	Asset age, type, treatments, inspection data, soils	Asset age, type, loading history

Model Data Use						
	WDRM v2 Model		WDRM v3 Model			
Usage	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
Impacts of system hardening and other initiative efforts	Reflected in updated asset characteristic, Sec 24	Reflected in updated asset characteristic, Sec 6.1, 24	Estimated probability and risk reduction due to mitigations	Estimated probability and risk reduction due to mitigations	Estimated probability and risk reduction due to mitigations	Estimated probability and risk reduction due to mitigations
Climate conditions (including historical wind conditions, relative humidity, temperature, etc.)	Precipitation, specific humidity, Average Temperature, Vapor Pressure, Gusty Summer Day Pct., Windy Summer Day, Wind Ave., Max. Wind, Sec 11.4, 11.5.1, 28.4	Precipitation, specific humidity, Average Temperature, Vapor Pressure, Gusty Summer Day Pct., Windy Summer Day, Wind Ave., Max. Wind, Sec 11.4, 11.5.1, 28.4	Average Wind, Precipitation Max., Gusty Wind Pct., Windy Summer Pct., Vapor Pressure, Humidity	Average Wind, Precipitation Max., Gusty Wind Pct., Windy Summer Pct., Vapor Pressure, Humidity	Average Wind, Precipitation Max., Gusty Wind Pct., Windy Summer Pct., Vapor Pressure, Humidity	Average Wind, Precipitation Max., Gusty Wind Pct., Windy Summer Pct., Vapor Pressure, Humidity
Vegetation (including type, density, height, etc.)	Tree height Ave., Tree height Max., Sec 11.4, 11.5.1, 28.4	Tree height Ave., Tree height Max., Sec 20.3, 20.4, 28.4	LiDAR for High Fire Threat District (HFTD) and Satellite data for non-HFTD (height and distance from line, species data.	LiDAR for HFTD and Satellite data for non-HFTD (height and distance from line, species data.	LiDAR for HFTD and Satellite data for non-HFTD (height and distance from line, species data.	LiDAR for HFTD and Satellite data for non-HFTD (height and distance from line, species data.

Model Data Use						
	WDRM v2 Model		WDRM v3 Model			
Usage	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
Fuel characteristics (including load, size, continuity, vertical arrangement, moisture, etc.)	100-hour fuels Ave., 1000-hour fuels Ave., Sec 11.4, 11.5.1, 28.4	100-hour fuels Ave., 1000-hour fuels Ave., Sec 20.3, 20.4, 28.4	10-hour fuels Ave., 100-hour fuels Ave., 1000-hour fuels Ave., with additional year of data	10-hour fuels Ave., 100-hour fuels Ave., 1000-hour fuels Ave., with additional year of data	10-hour fuels Ave., 100-hour fuels Ave., 1000-hour fuels Ave., with additional year of data	10-hour fuels Ave., 100-hour fuels Ave., 1000-hour fuels Ave., with additional year of data
Impacts of Routine and Enhanced vegetation management activities (including tree-trimming, tree-removal, inspections, etc.)	Reflected in updated tree data and status, Sec 11.3	Reflected in updated tree data and status, Sec 11.3	Estimated probability and risk reduction due to Enhanced Vegetation Management (EVM) on branch and trunk failures	Estimated probability and risk reduction due to EVM on branch and trunk failures	Estimated probability and risk reduction due to EVM on branch and trunk failures	Estimated probability and risk reduction due to EVM on branch and trunk failures
Frequency of updates to datasets and inputs, including any associated triggers to determine the need for updates	Annual planning model, Sec 2, 5.3 pg. 24, 26 & 29	Annual planning model, Sec 2	Annual model production with transition plan for workplans	Annual model production with transition plan for workplans	Annual model production with transition plan for workplans	Annual model production with transition plan for workplans
Accuracy and quality checks for data and inputs	Manual checks and review by SMEs, Sec 5.5	Manual checks and review by SMEs, Sec 5.5	Established curated data sets in Palantir Foundry platform. Composite	Established curated data sets in Palantir Foundry platform. Composite	Established curated data sets in Palantir Foundry platform. Composite	Established curated data sets in Palantir Foundry platform. Composite

Model Data Use						
	WDRM v2 Model		WDRM v3 Model			
Usage	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
			model code in AWS with test code.	model code in AWS with test code.	model code in AWS with test code.	model code in AWS with test code.

Section 2: Model descriptions for ignition, consequence, and PSPS models, including:

- Algorithms used and machine learning capabilities
- Impact of climate change
- Ingress and egress
- Modeling components, linkages, and interdependencies
- Weight of each data components and inputs
- Automatization implemented
- Frequency of updates to modeling, including the basis for updates

PG&E Model Descriptions for the WDRM v2 and WDRM v3

Model Descriptions						
	WDRM v2 Model		WDRM v3 Model			
Description	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
Algorithms used and machine learning capabilities	Max Ent, Sec 2, 4.2, 9, 11.1, 11.4, 12.2, 24, 28.1	MaxEnt, Sec 2, 4.2, 18, 20, 20.3.2, 21.2, 24, 28.1	MaxEnt	MaxEnt	Random Forest Classifier	Random Forest Classifier
Impact of climate change	Current climate conditions	Current climate conditions	Model employs data sets that	Model employs data sets that	Model employs data sets that	Model employs data sets that

Model Descriptions						
	WDRM v2 Model		WDRM v3 Model			
Description	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
	modeled. Sec 34, 36, 41	modeled. Sec 34, 36, 41	characterize current climate conditions only	characterize current climate conditions only	characterize current climate conditions only	characterize current climate conditions only
Ingress and egress	Not in WDRM v2.	Not in WDRM v2.	Not in WDRM v3. Continue to work with UCLA Risk Institute on Egress model development.	Not in WDRM v3. Continue to work with UCLA Risk Institute on Egress model development.	Not in WDRM v3. Continue to work with UCLA Risk Institute on Egress model development.	Not in WDRM v3. Continue to work with UCLA Risk Institute on Egress model development.
Modeling components, linkages, and interdependencies	Similar data sets to PSPS models. Algorithms and temporal scales differ based on use case.	Similar data sets to PSPS models. Algorithms and temporal scales differ based on use case.	Alignment of Probability of Ignition (POI) model between PSPS and WDRM on cause categories and P(outage) & P(ignition) steps.	Alignment of POI model between PSPS and WDRM on cause categories and P(outage) & P(ignition) steps.	Alignment of POI model between PSPS and WDRM on cause categories and P(outage) & P(ignition) steps.	Alignment of POI model between PSPS and WDRM on cause categories and P(outage) & P(ignition) steps.
Weight of each data components and inputs	Data components not weighted but input covariates have varied	Data components not weighted but input covariates have varied	Pending finalization of WDRM v3	Pending finalization of WDRM v3	Pending finalization of WDRM v3	Pending finalization of WDRM v3

Model Descriptions						
	WDRM v2 Model		WDRM v3 Model			
Description	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
	level of permutation importance, Sec 11.5	level of permutation importance Sec 20.3.4, 20.4				
Automatization implemented	Manual code, input data and training data sets	Manual code, input data and training data sets	Repeatable and transparent data and code. Palantir Foundry as key enabler with composite code framework in AWS	Repeatable and transparent data and code. Palantir Foundry as key enabler with composite code framework in AWS	Repeatable and transparent data and code. Palantir Foundry as key enabler with composite code framework in AWS	Repeatable and transparent data and code. Palantir Foundry as key enabler with composite code framework in AWS
Frequency of updates to modeling, including the basis for updates	Annual model update, Sec 2, 5.3 pg. 24, 26 & 29	Annual model update, Sec 2	Annual model update and transition plan for workplans	Annual model update and transition plan for workplans	Annual model update and transition plan for workplans	Annual model update and transition plan for workplans

Section 3: How model outputs are analyzed and utilized for each model, including:

- Confidences for each modeling component, including how such confidences were determined
- Range of uncertainty for model outputs, including how those ranges are determined and how uncertainty is minimized
- Systems used to verify the model outputs, including verifier (subject matter experts, third-party) and description of implementing lessons learned

- How uncertainty affects the interpretations of model outputs
- Determination of highest risk areas based on model outputs
- Use of subject matter expertise for inputs and further verification

PG&E Analysis and Utilization of Models for the WDRM v2 and WDRM v3

Model Outputs						
	WDRM v2 Model		WDRM v3 Model			
Output	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
Confidences for each modeling component, including how such confidences were determined	Receiver Operating Characteristic (ROC) /Area Under the Curve (AUC), Sec. 11, App. 3 (Sec 26 -32)	Receiver Operating Characteristic (ROC) /Area Under the Curve (AUC), Sec. 20, App. 3 (Sec 26 -32)	Receiver Operating Characteristic (ROC) /Area Under the Curve (AUC) similar to WDRM v2	Receiver Operating Characteristic (ROC) /Area Under the Curve (AUC) similar to WDRM v2	Receiver Operating Characteristic (ROC) /Area Under the Curve (AUC) similar to WDRM v2	Receiver Operating Characteristic (ROC) /Area Under the Curve (AUC) similar to WDRM v2
Range of uncertainty for model outputs, including how those ranges are determined and how uncertainty is minimized	Evaluation of ROC/AUC, Precision, and Recall values, Sec. 11.5 - 15	Evaluation of ROC/AUC, Precision, and Recall values, Sec. 20.4 - 23	Similar to WDRM v2	Similar to WDRM v2	Similar to WDRM v2	Similar to WDRM v2
Systems used to verify the model outputs, including verifier (subject matter experts, third-party) and description of implementing lessons learned	Internal – SME reviews, Wildfire Governance Steering Committee, External – E3 Validation, Sec 8, 14, 17	Internal – SME reviews, Wildfire Governance Steering Committee, External – E3 Validation, Sec. 8, 23, 25	Internal – SME reviews, Challenge team, and Wildfire Governance Steering Committee. External – E3 validation	Internal – SME reviews, Challenge team, and Wildfire Governance Steering Committee. External – E3 validation	Internal – SME reviews, Challenge team, and Wildfire Governance Steering Committee. External – E3 validation	Internal – SME reviews, Challenge team, and Wildfire Governance Steering Committee. External – E3 validation

Model Outputs						
	WDRM v2 Model		WDRM v3 Model			
Output	**Vegetation**	**Conductor**	**Vegetation**	**Conductor**	**Support Structure**	**Transformer**
How uncertainty affects the interpretations of model outputs	Detailed tree and tree species data incorporate in post model steps to develop workplan, Sec. 11.5 - 15	Outage location based on interruptive device and not incident resulting in noisier pixel level results. Circuit and circuit segment level results best for workplan development. Site specific details used post model to develop SH project scope. Sec. 20.4 - 23	Inclusion of LiDAR and species data will require less post model interpretation steps between model output and workplan.	Outage location is still based on interruptive device and not incident resulting noisier pixel level results. Circuit segment and circuit level results best for workplan development. Site specific details used post model to develop SH project scope.	Outage location is still based on interruptive device and not incident resulting noisier pixel level results. Circuit segment and circuit level results best for workplan development. Site specific details used post model to develop SH project scope.	Outage location is still based on interruptive device and not incident resulting noisier pixel level results. Circuit segment and circuit level results best for workplan development. Site specific details used post model to develop SH project scope.
Determination of highest risk areas based on model outputs	Output available at pixel, circuit segment and circuit levels, Sec. 12, 13	Output available at pixel, circuit segment and circuit levels, Sec. 21, 22	Output available at pixel, circuit segment and circuit levels.	Output available at pixel, circuit segment and circuit levels.	Output available at pixel, circuit segment and circuit levels.	Output available at pixel, circuit segment and circuit levels.
Use of subject matter expertise for inputs and further verification	Subject matter expert (SME) input on	Subject matter expert (SME) input on	Subject matter expert (SME) input on	SME input on covariate selection to	SME input on covariate selection to	SME input on covariate selection to

Model Outputs						
	WDRM v2 Model		WDRM v3 Model			
Output	Vegetation	Conductor	Vegetation	Conductor	Support Structure	Transformer
	covariate selection to assure that data characterizes mitigation improvements. SME review of model results, Sec. 8, 17	covariate selection to assure that data characterizes mitigation improvements. SME review of model results, Sec. 32	covariate selection to assure that data characterizes mitigation improvements. SME review of model results.	assure that data characterizes mitigation improvements. SME review of model results.	assure that data characterizes mitigation improvements. SME review of model results.	assure that data characterizes mitigation improvements. SME review of model results.

Section 4: Description of any collaborations previously undertaken among the utilities, as well as details on consistency across utilities, including:

- What modeling approaches are already consistent
- Which modeling approaches have the potential for more consistency and how approaches would benefit from consistency
- Where consistency is infeasible or not necessary.

Collaborations with other utilities

As discussed at the October 5, 2021 workshop, since the 2019 WMP process, Southern California Edison Company (SCE), PG&E and San Diego Gas & Electric Company (SDG&E) have conducted benchmarking sessions on various topics, including risk modeling, mitigation effectiveness, vegetation management activities, and PSPS operations.

Specifically, PG&E, SCE, and SDG&E collaborated on at least 10 occasions in 2021 on risk assessment and modeling alignment opportunities. As part of these engagements, the utilities have evaluated elements of risk modeling where near-term alignment are possible and are currently developing a common vision or end-state for long-term alignment on risk modeling that accommodates differences in the respective service territories.

Specific progress has been achieved in three areas. First, in June 2021 the utilities identified a set of minimum alignment requirements that could achieved in the near-term (2020-2022 WMP time periods). Second, an assessment of the different approached towards POI modeling along with potential for a joint end-state has been conducted. Finally, a similar assessment for wildfire consequence has been conducted.

More recently, the collaboration group has been expanded to include Liberty Utilities, Bear Valley Electric Service and Pacificorp.

Section 5: Description of any collaborations previously undertaken and/or ongoing with other entities.

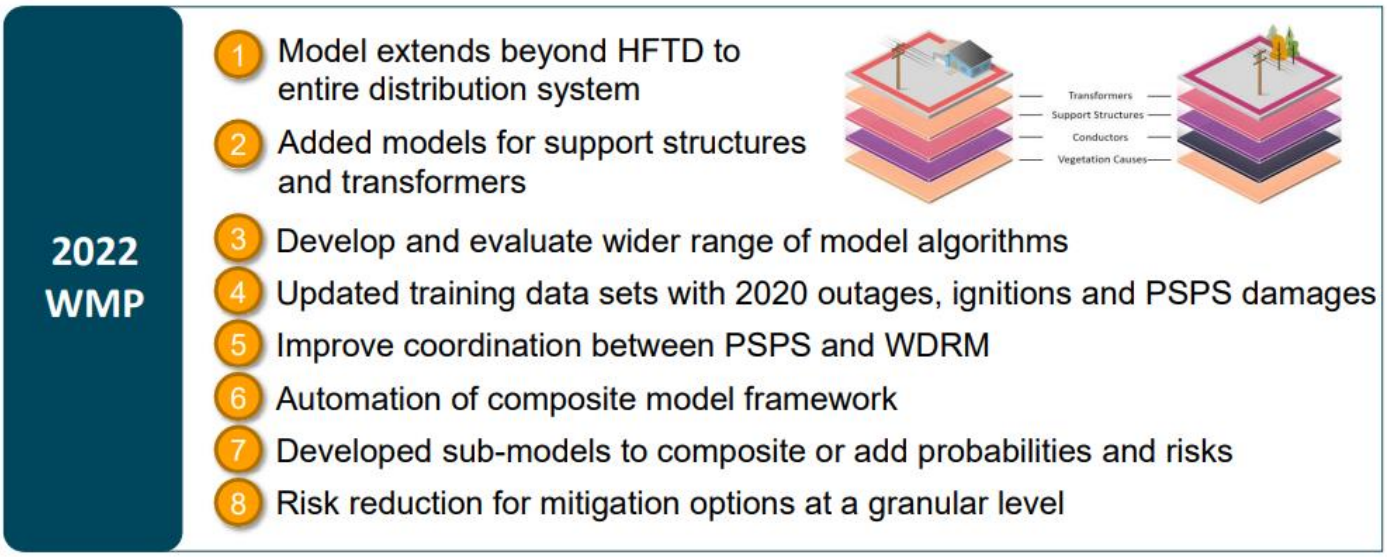
Collaborations with other entities

As part of PG&E's focus on reducing wildfire risk, we collaborate with experts and trade associations to leverage the best research, knowledge, and practices in improving wildfire risk modeling. PG&E has been involved with several utility groups such as the International Wildfire Risk Mitigation Consortium (IWRMC), Edison Electric Institute (EEI), Western Energy Institute (WEI), and Utility Analytics Forum. Beyond these industry groups, PG&E also collaborates with a number of academic groups such as the UCLA Garrick Institute for Risk Science, and Cal Poly SLO. Finally, PG&E continues to collaborate with fire science experts such as CAL FIRE and Technosylva.

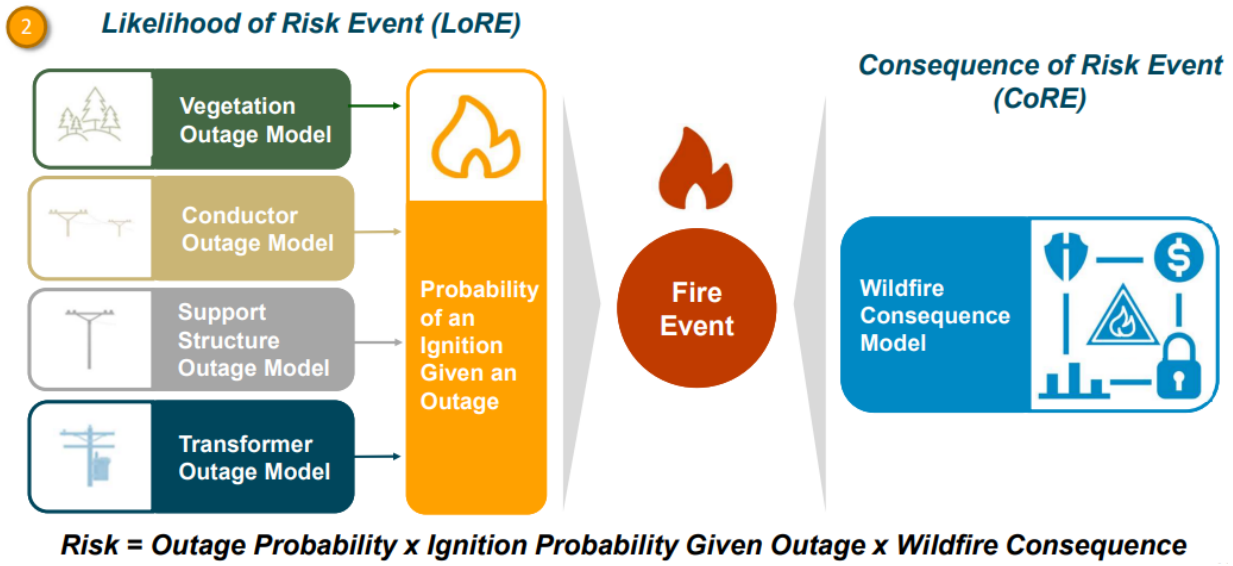
Section 6: Anticipated changes to any of the models between now and the 2022 WMP Update.

PG&E Anticipated changes to any of the models before the 2022 WMP Update

Since it was approved for use in November 2020, the WDRM v2 has not been changed. All updates and improvements to PG&E's WDRM will be included in the WDRM v3. This updated model is still under final review and validation before approval later this year. As discussed in the October 5, 2021 workshop and summarized in the image below, the WDRM v3 makes a number of improvements. Key among these improvements is extending the model to include the entire OH distribution system, adding models to represent support structures and transformers, automation of the composite model code, and the ability to composite or add probabilities and risks to better characterize the total risk at a location on the grid. Finally, an estimate of risk reduction for each mitigation option has been added at a granular level along the distribution system to focus workplans on locations with highest risk reduction for a given mitigation option instead of highest risk.



The model framework has also been adjusted from producing risk as the product of the probability of ignition with wildfire consequence to three steps as outlined in the image below. Due to lower ignition counts for the transformer and support structure models the probability of ignition is now developed as the product of the probability of an outage with the probability of an ignition given an outage.



Section 7: Attachments of any internal or third-party validations completed, and description of any peer review utilized

PG&E Internal or Third-Party Validations

As described in PG&E 2021 WMP Revision Notice response dated June 3, 2021, critical issue No. PGE-02, PG&E conducted both internal and external reviews and validation of the WDRM v2. A detailed explanation of these activities is provided on pages 151 – 154 of the Revised 2021 WMP. As described on page 154 of that section, and as was shared during the October 5, 2021 workshop, PG&E retained Energy and Environmental Economics, Inc. (E3) to perform an independent review of the WDRM v2. The final E3 report was proved as Attachment 2021 WMP_Revision_PGE-02_Atch-01 and is also included with this response.