Reliability Improvements and Data Analytics at Puget Sound Energy

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April, 2022

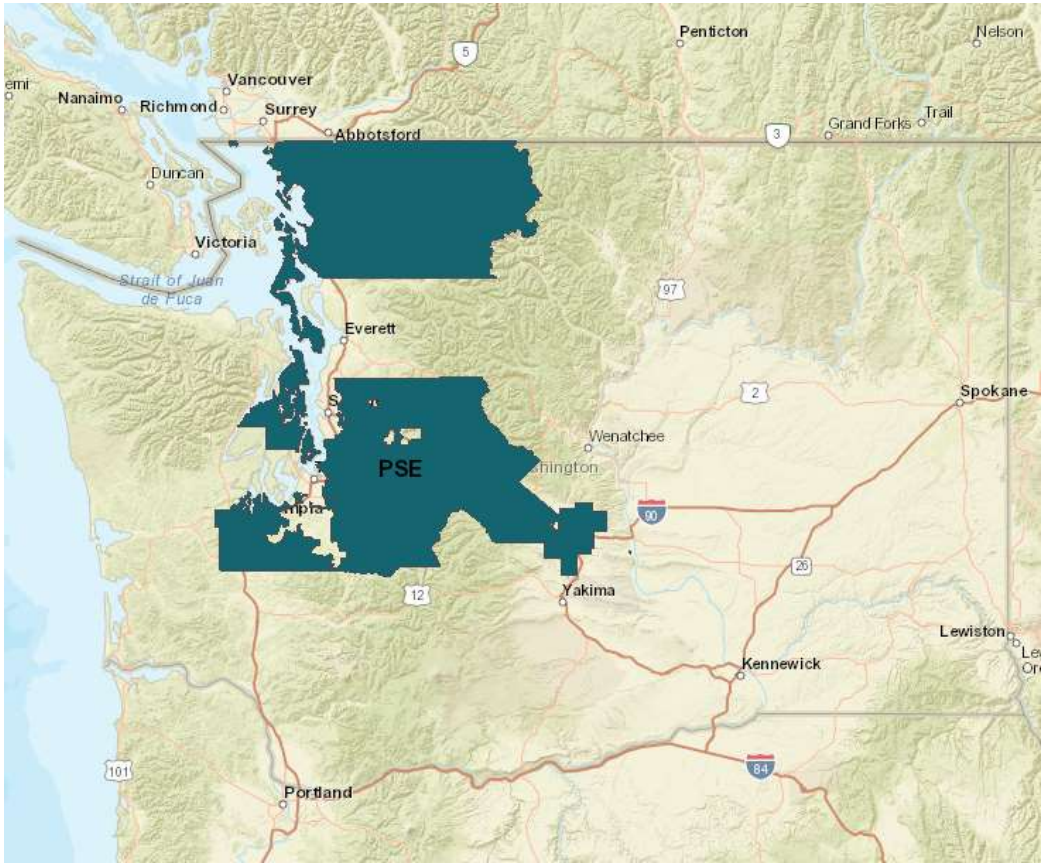
Agenda

- PSE background
  - Territory characteristics
  - Reliability data
  - Reporting
- What we have been working on over the last few years
  - Analysis tools
  - Project benefit verification (backcasting)
  - RCA program
- Summary and future plans

PUGET SOUND ENERGY

Puget Sound Energy – Company Details

- 5k square mile territory (electric only)
- 1.2M electric customers
- 350 substations
- Transmission
  - 3k miles
- Distribution
  - 1.1k circuits
  - 10k overhead miles
  - 14k underground miles



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Puget Sound Energy – Territory Characteristics

- Geography - mountains, islands, rivers, lakes, forests, cities…
- Customers - 10% urban, 45% suburban, 45% rural
- Challenges – trees, accidents, animals, floods, avalanches, fires, heat, cold, vandalism…

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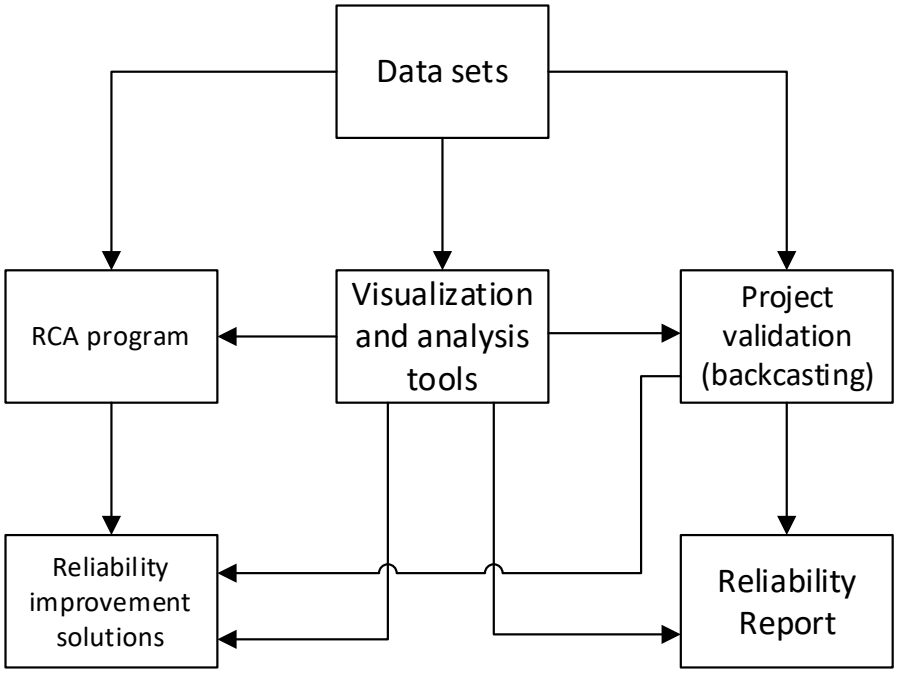
Reliability Data – Creation and Purpose

- Goal of electric system reliability data creation and collection
  - Report reliability performance – reliability report filed annually with WUTC
  - Identify issues, patterns and trends so that solutions can be developed to meet customer reliability expectations



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Reliability Data - Characteristics

- System operators log basic information about interruption events.
  - Their primary function is to get power restored quickly and safely. Documentation requirements try to balance useful information with minimal distraction for operators.
- 15k – 20k interruption event records/year on average
  - 50+ event characteristic fields for each record
    - 15 primary cause codes, 40 sub cause codes
    - 110 equipment codes

REFERENCE CIRCUIT	DATE	TIME	DURATION IN MINS	TOTAL CUST AFFECTED	TOTAL CUST OUTAGE MINS	CAUSE CODE	EQUIPMENT OBJECT PART
LON-17	01/01/2022	2:45:41 PM	48	1	48	EF	
KEN-12	01/01/2022	4:42:59 PM	104	1	104	EF	UPT
PET-15	01/01/2022	11:50:42 AM	154	45	6,943	CP	OPO
PIN-26	01/01/2022	12:02:24 AM	412	1	412	TV	OFU

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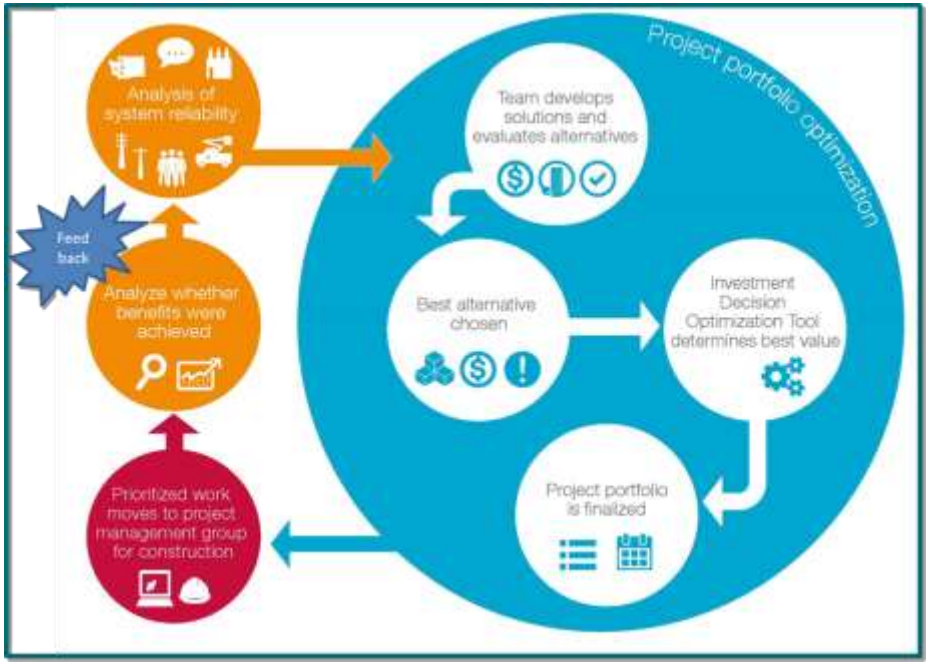
External Reporting – Annual Reliability Report

- Annual report required to be filed with Washington Transportation and Utility Commission
- The report has two main components
  - Reliability performance results
  - Description of plan to maintain or improve reliability

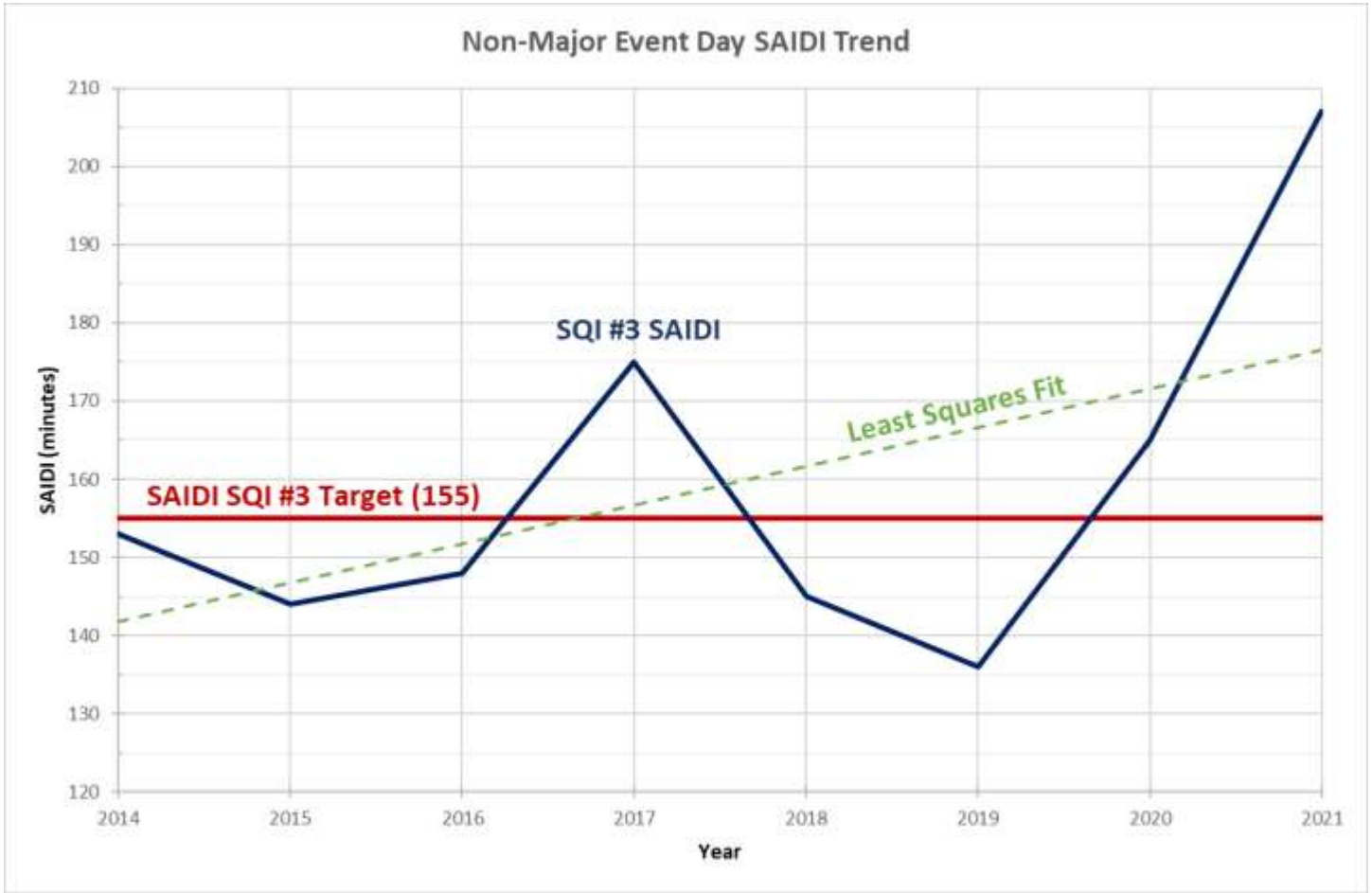
1997-2021 PSE SAIDI Performance in Different Measurements
(Average number of outage minutes per customer per year)

Calendar Year	(a) Annual SAIDI Excluding Any Days That 5% or More Customers Are w/o Power	(b) Annual IEEE SAIDI Excluding Daily Results over T_{MED}	(c) Annual Total SAIDI Results: No Exclusions	(d) Annual Total SAIDI Results with Exclusions	(e) Total SAIDI 5-Year Rolling Annual Average with Exclusions	(f) Annual SQI SAIDI excluding Daily Results over T_{MEDADJ} (SQI-3)
1997	105	109	202	202		
1998	117	119	383	383		
1999	131	118	388	388		
2000	103	111	253	253		
2001	147	110	240	240	293	
2002	106	99	215	215	296	
2003	132	106	532	532	326	
2004	114	115	302	302	308	
2005	128	124	192	192	296	
2006	213	163	2,636			
2007	167	143	312	312	311	
2008	163	155	202	202	308	
2009	190	145	215	215	245	
2010	129	124	512	512	287	
2011	144	144	163	163	281	
2012	134	120	1,400	134[1]	245	
2013	122	125	209	209	247	
2014	173	154	540	540	312	
2015	180	163	760	313[2]	272	
2016	148	154	391	391	317	148
2017	222	175	477	477	386	175
2018	148	145	438	438	432	145
2019	132	136	550	550	434	136
2020	220	171	414	414	454	165
2021	245	207	849	849	546	207

[1] Per UTC approval, excludes the January 2012 Storm Event
[2] Per UTC approval, excludes the August 2015 and November 2015 storm events



External Reporting – SAIDI 2022 Analysis



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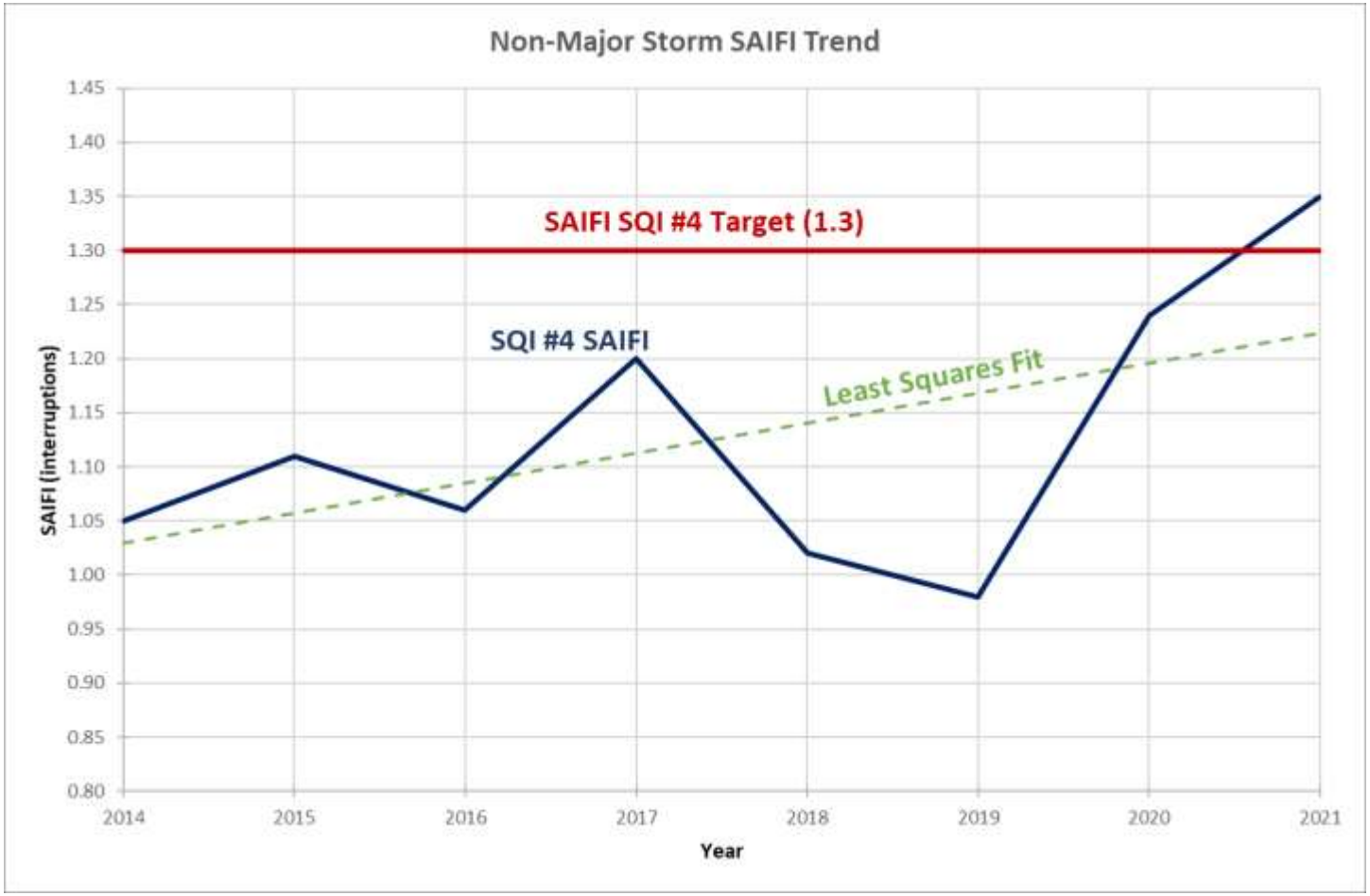
External Reporting – SAIFI 2022 Analysis



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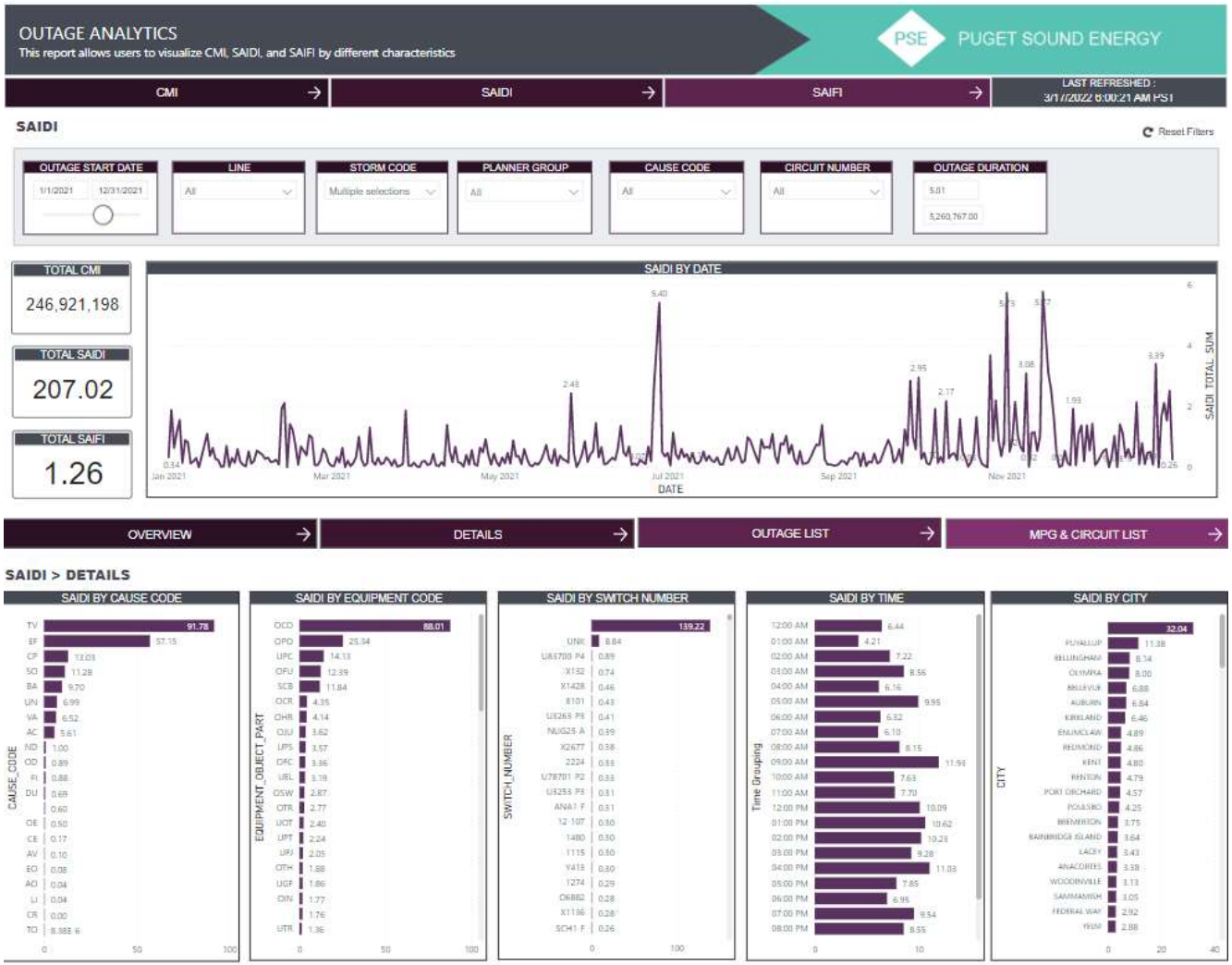
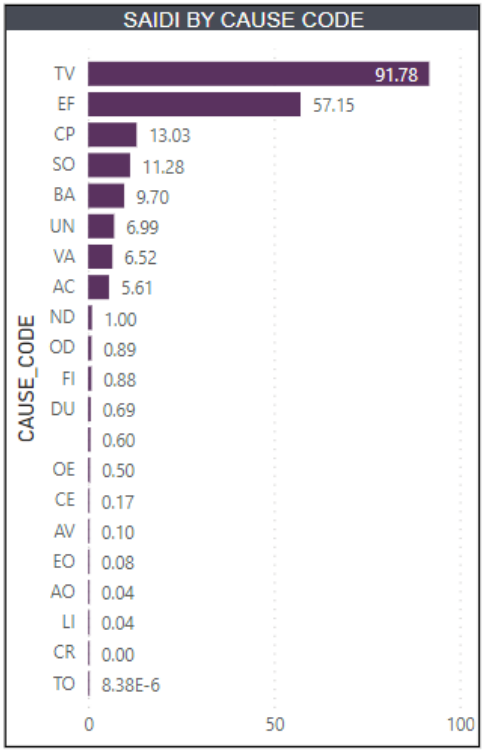
Analysis Tools – Granular SAIDI/SAIFI Analysis





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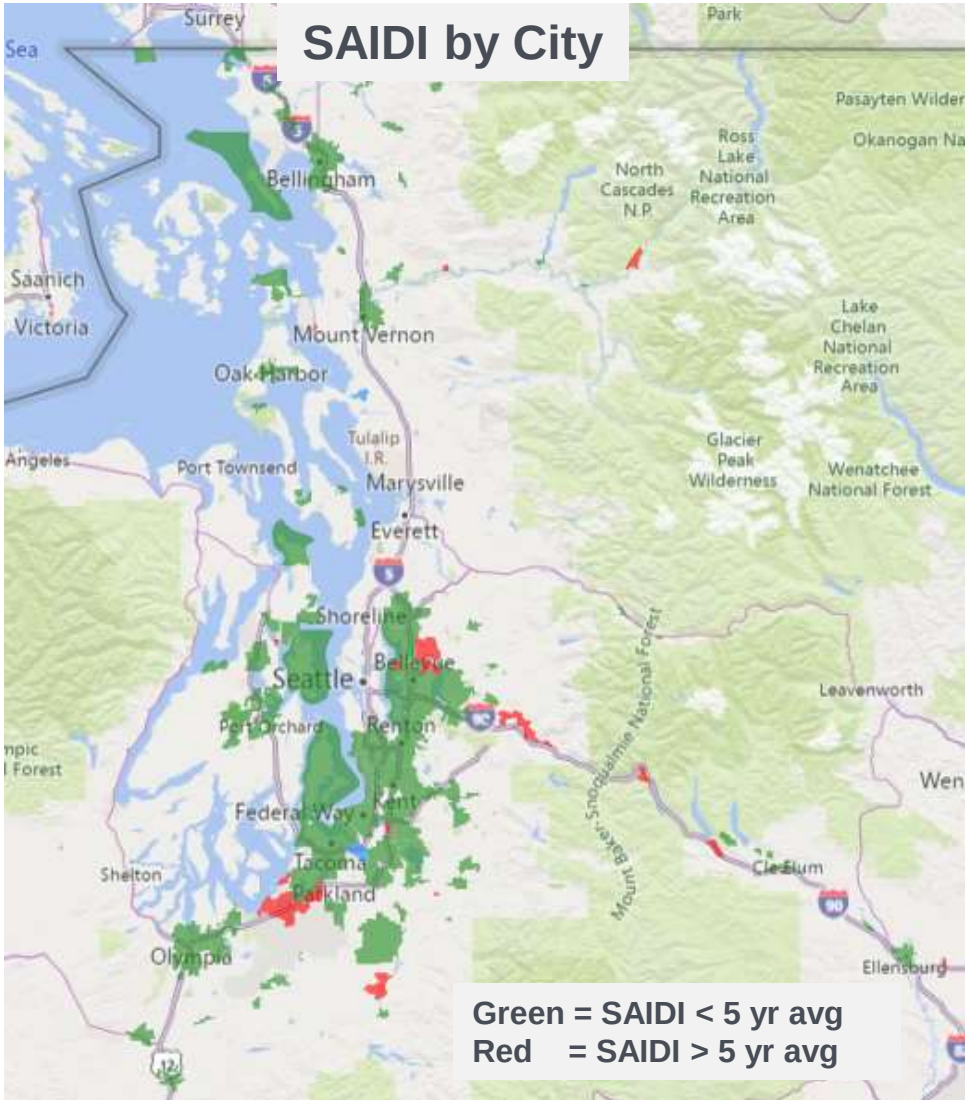
Analysis Tools – SAIDI/SAIFI Mapping



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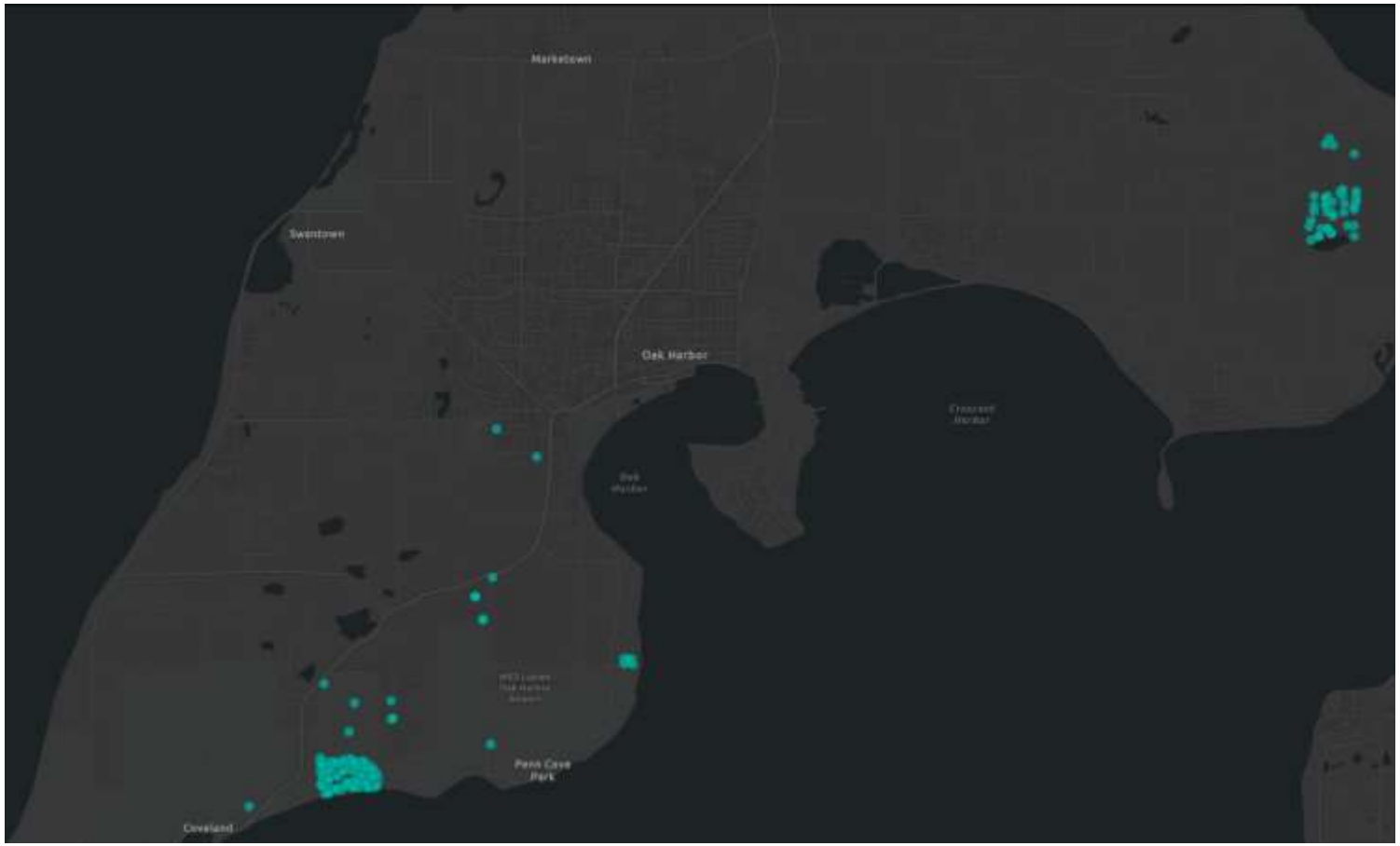
Analysis Tools – Customer Reliability Mapping

- This map shows locations of some customers having 6 or more interruptions in one year



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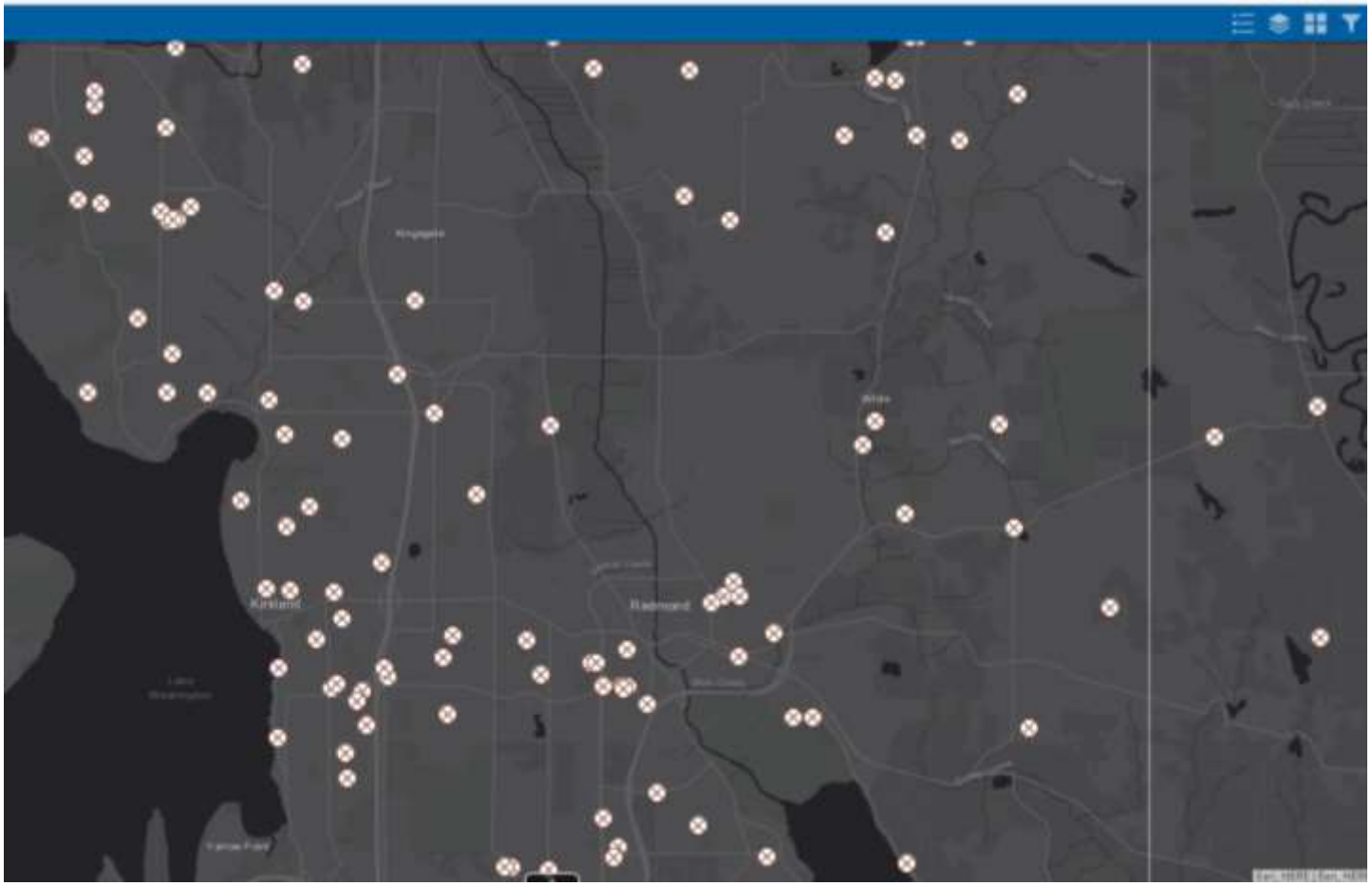
Analysis Tools – Damage Location Mapping

- This map shows the locations of vehicle/pole accidents



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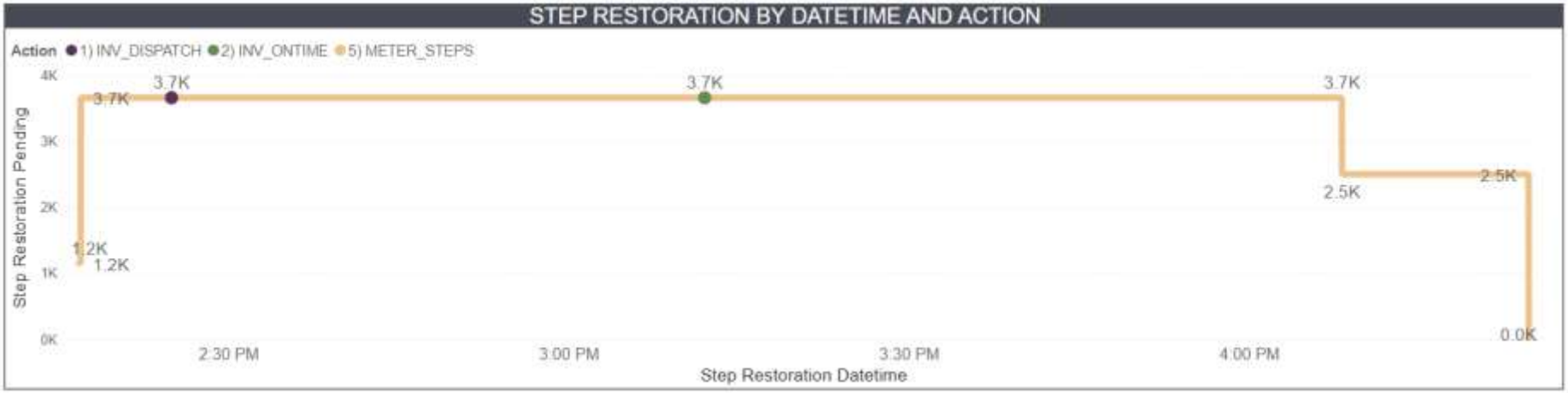
Analysis Tools – Step Restoration

- This tool is useful for visualizing the restoration process. It shows:
  - The number of customers out at various times over the duration of an event
  - When investigators and crews (if relevant) were dispatched and arrived on site



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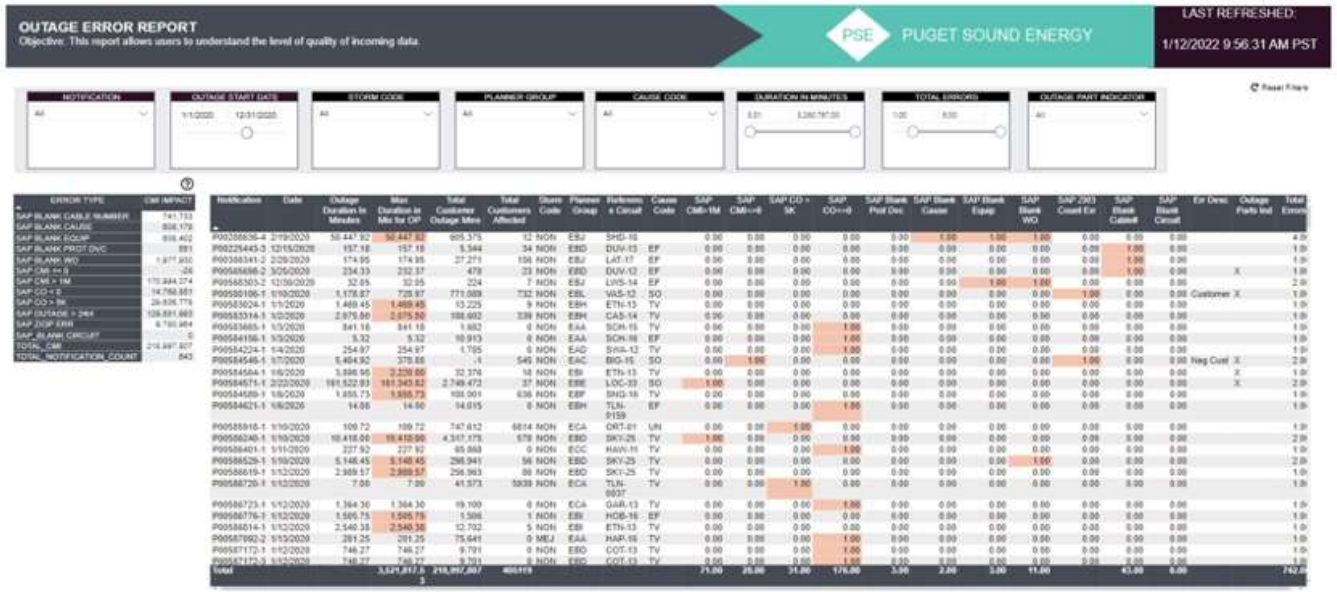
Analysis Tools – Data Quality

- Data quality is critical for analysis to meet goals and manage resources efficiently
- Biggest issues
  - Data entry mistakes – automating/standardizing inputs reduces human error
  - Application interface issues
  - Models don't represent the real world perfectly



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Analysis Tools - Summary

- Benefits
  - Improve ability to identify patterns and trends
  - Improve reliability solution development
- Challenges
  - Data access – connecting to multiple data sets
  - Data accuracy - the real world can be difficult to explain in a database
  - Cause-effect interpretation - underlying causes can be difficult to understand

PSE PUGET SOUND ENERGY

Project Benefit Verification - Backcasting

- How well do solutions perform relative to expectations?
  - In general projects meet expectations, at least in aggregate

Program	Projects completed in 2016	Number of projects reviewed	SAIDI	SAIFI
Cable remediation	258	30	100%	100%
Copper replacement	3	3	100%	100%
Covered conductor	28	28	99%	100%
Overhead rebuild	6	6	100%	100%
Pole replacement	6	6	100%	100%
Reclosers*	22	22	68%	64%
Single phase reclosers	48	31	100%	47%
Underground conversions	2	2	100%	100%
Underground upgrade	2	2	100%	100%
Total	**375**	**130**		

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Project Benefit Verification - Backcasting

- The process creates data that can be used for other analyses
  - What is benefit / cost?
  - How are costs changing over time?
  - How do benefits change over time?

Program	Benefit/Cost
Cable remediation	10
Copper replacement	10
Covered conductor	34
Overhead rebuild	13
Pole replacement	10
Reclosers	57
Single phase reclosers	51
Underground conversions	6

PSE PUGET SOUND ENERGY

Project Benefit Verification - Summary

- Benefits
  - Calculate historical value of a program and inform future program budgets
  - Identify potential issues with benefit and cost expectations
- Challenges
  - Timing - projects are built years after being developed
  - Predictions - past events don’t necessarily predict the future
  - Data accuracy

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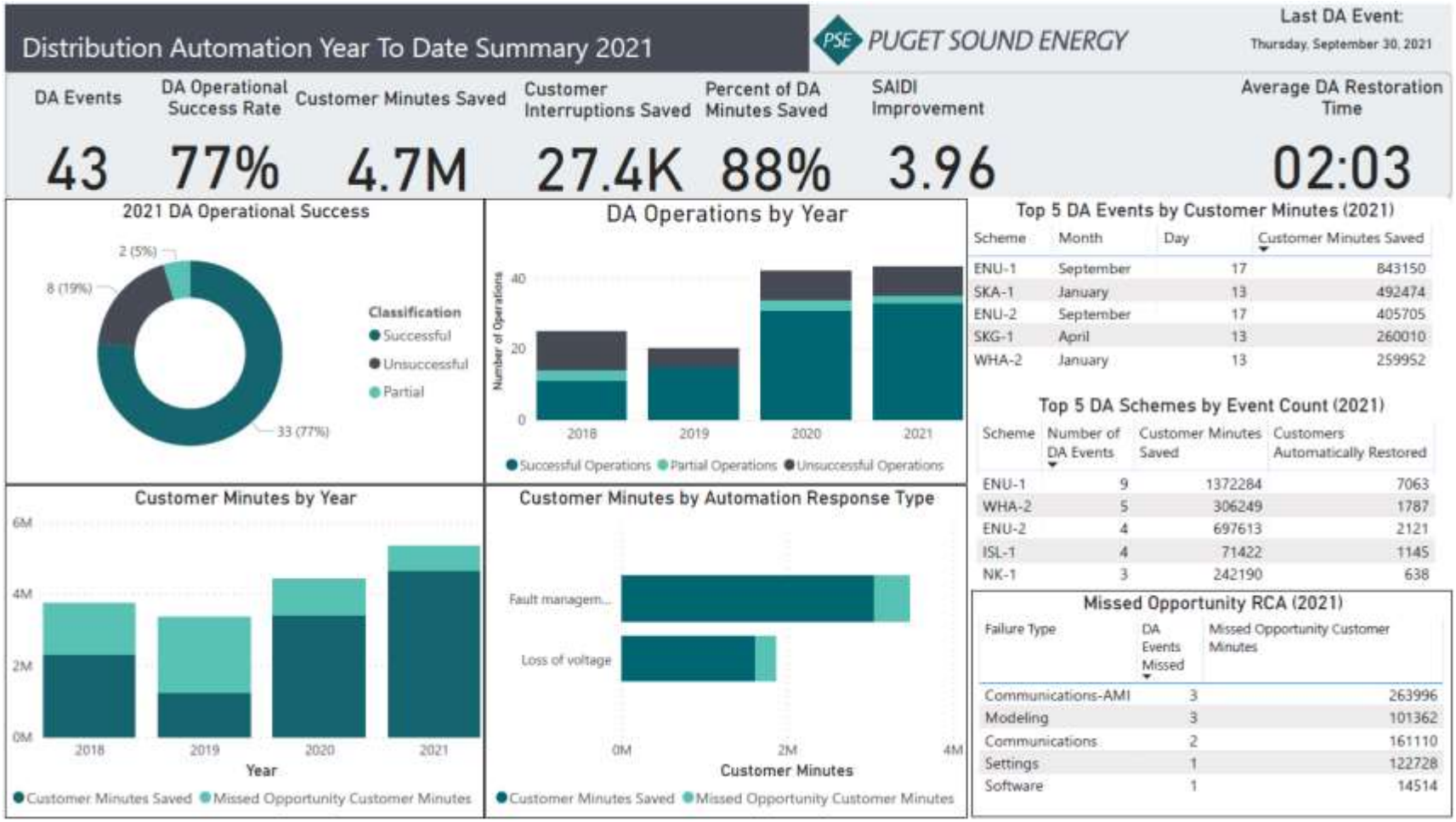
Project Benefit Verification – Real Time Performance



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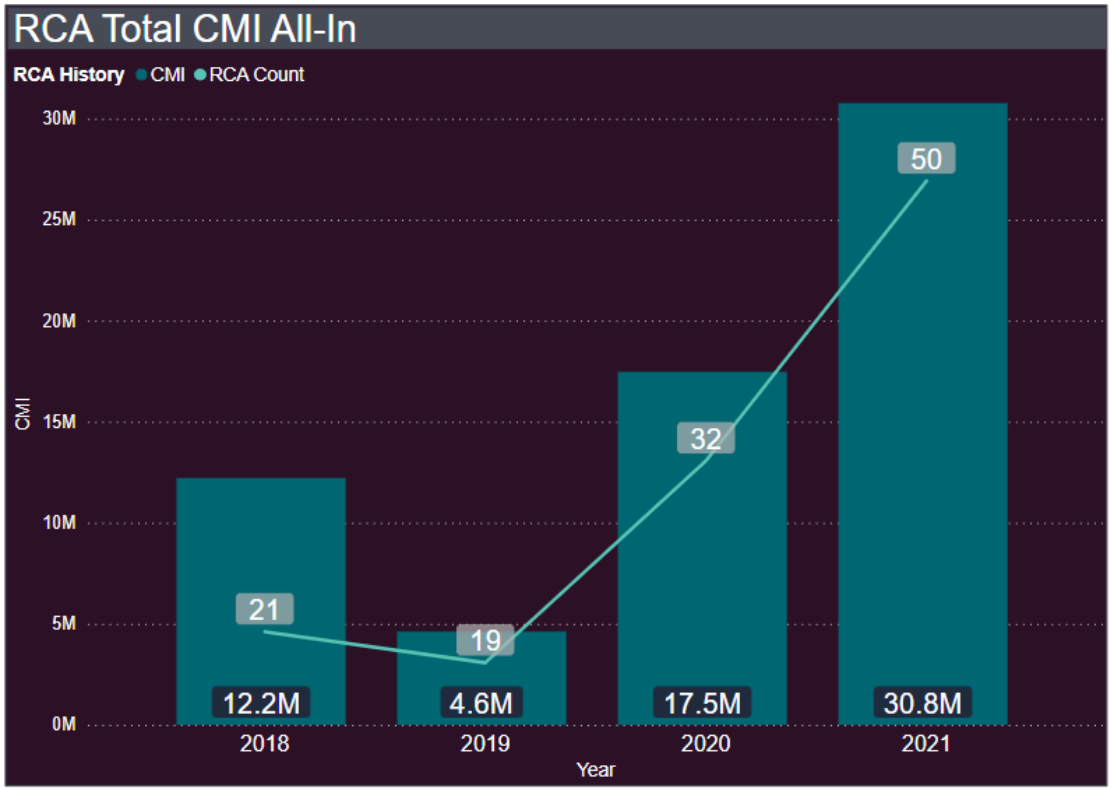
Root Cause Analysis Program

- Aggregate data can be misleading due to errors, inconsistencies and unique risks.
- PSE performs analysis on a small set of individual events to gain deeper understanding



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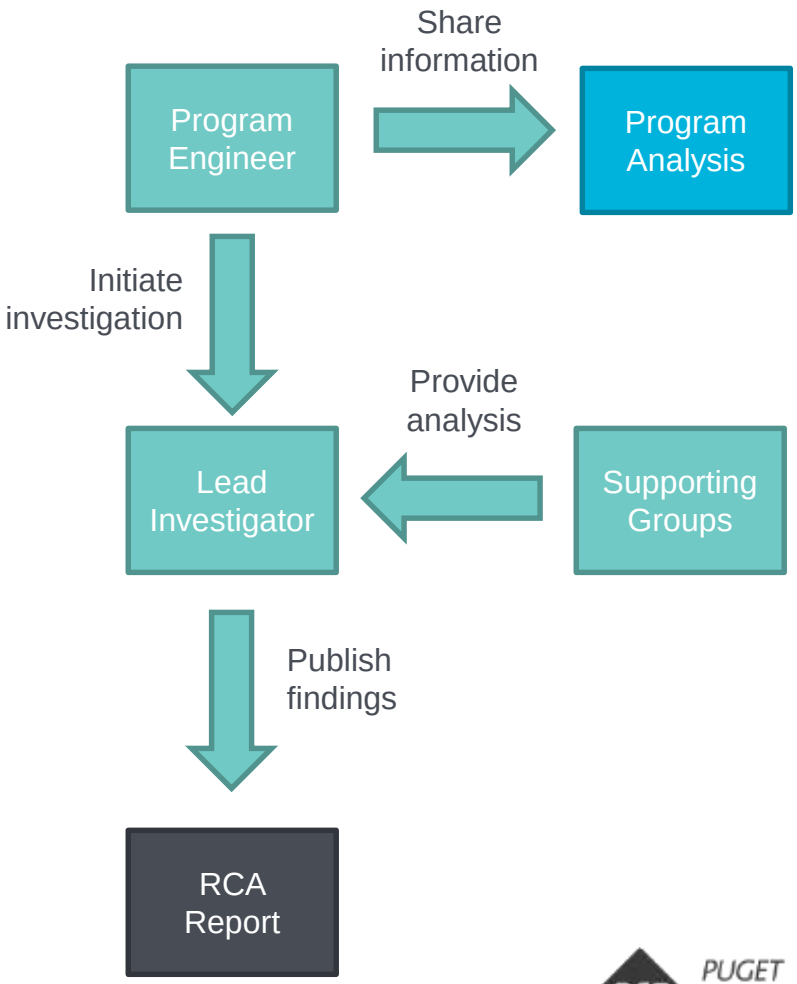
Root Cause Analysis Program - Structure

- Primary involvement
  - Program engineer
  - Lead investigator
- Supporting groups
  - Engineering groups
  - Operation groups
- Communication
  - Various groups meet monthly to discuss issues and solutions



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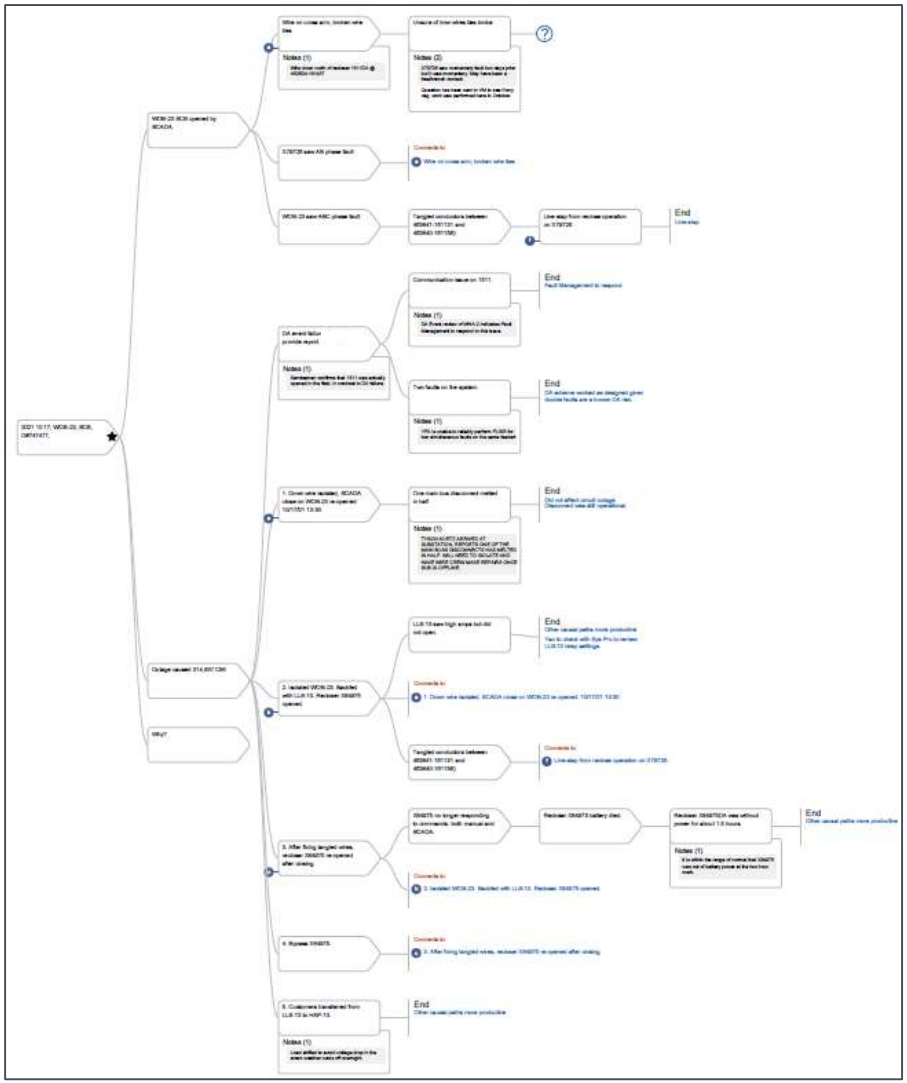
Root Cause Analysis Program - Reports

- Report Components
  - Event details
    - # customers, duration
    - Description
    - Timeline of events
    - Maps
    - Pictures, diagrams
  - Investigation objective
  - Cause-effect chart
  - Findings
  - Recommendations



Root Cause Analysis Program – Report Example

- Example – Summary of circuit outage event on 10-17-2021
- Objective: What caused damage to pole?
  - Finding: Tie wire broke causing fault and burning crossarm
  - Recommendation: None, wire was replaced
- Objective: Why were phases tangled near substation?
  - Finding: Fault caused lines to slap together resulting in second fault
  - Recommendation: Review and revise construction standards to eliminate line slap

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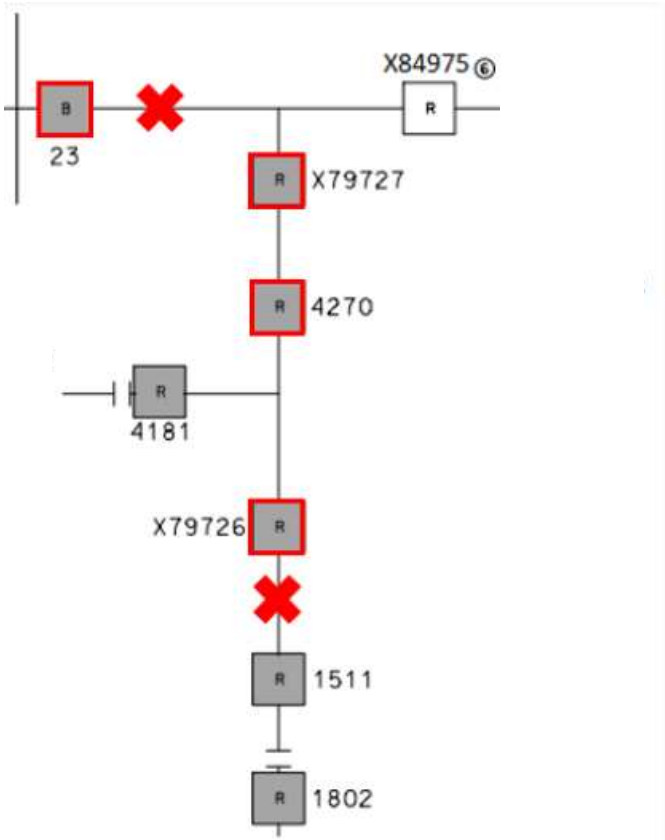
Root Cause Analysis Program – Report Example

- Objective: Why was automatic isolation and restoration unsuccessful?
  - Finding: Simultaneous faults confused automatic restoration logic
  - Recommendation: None, system operated as intended
- Objective: Why were protective devices showing incorrect status in OMS?
  - Finding: Nothing found as part of analysis
  - Recommendation: Small group to continue investigating issue



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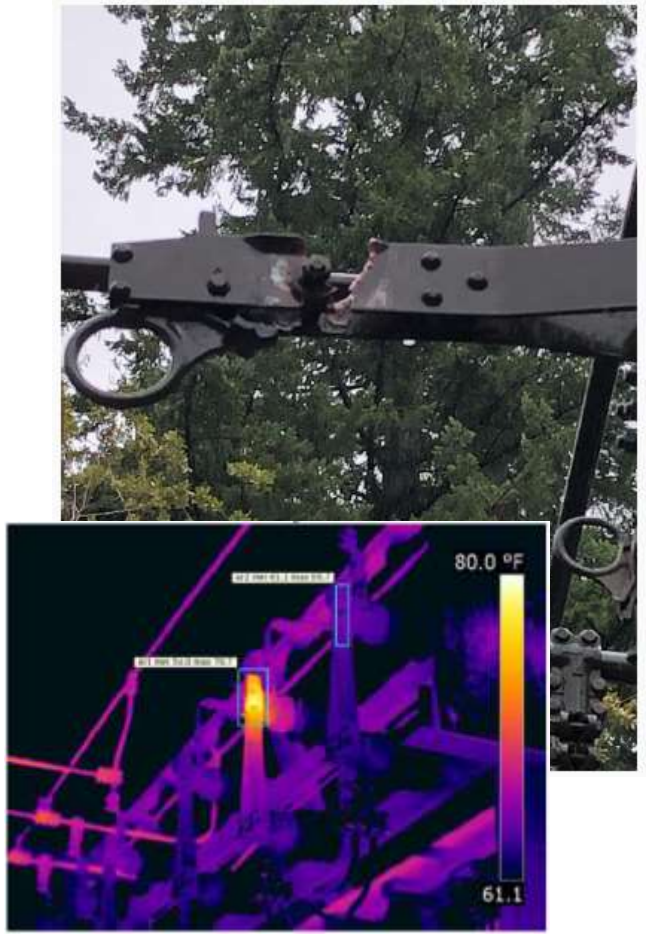
Root Cause Analysis Program – Report Example

- Objective: Why did substation switch melt?
  - Finding: Crack in the disconnect switch prior to fault
  - Recommendation: Consider including bus and disconnect inspections as part of regular maintenance
- Objective: Why did recloser not respond to SCADA commands?
  - Finding: Battery power was too low from previous operations
  - Recommendation: None, system operated as intended



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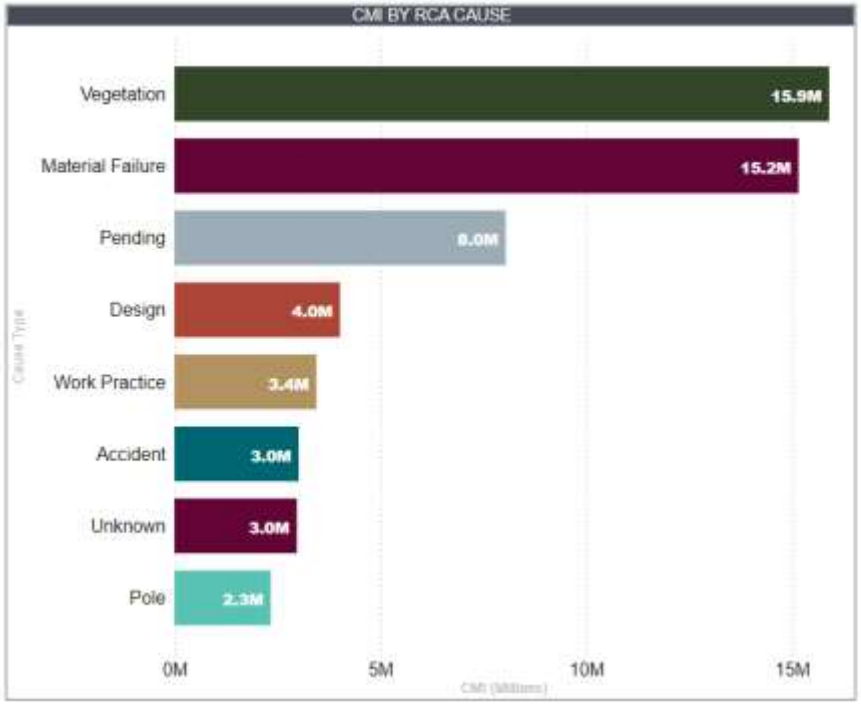
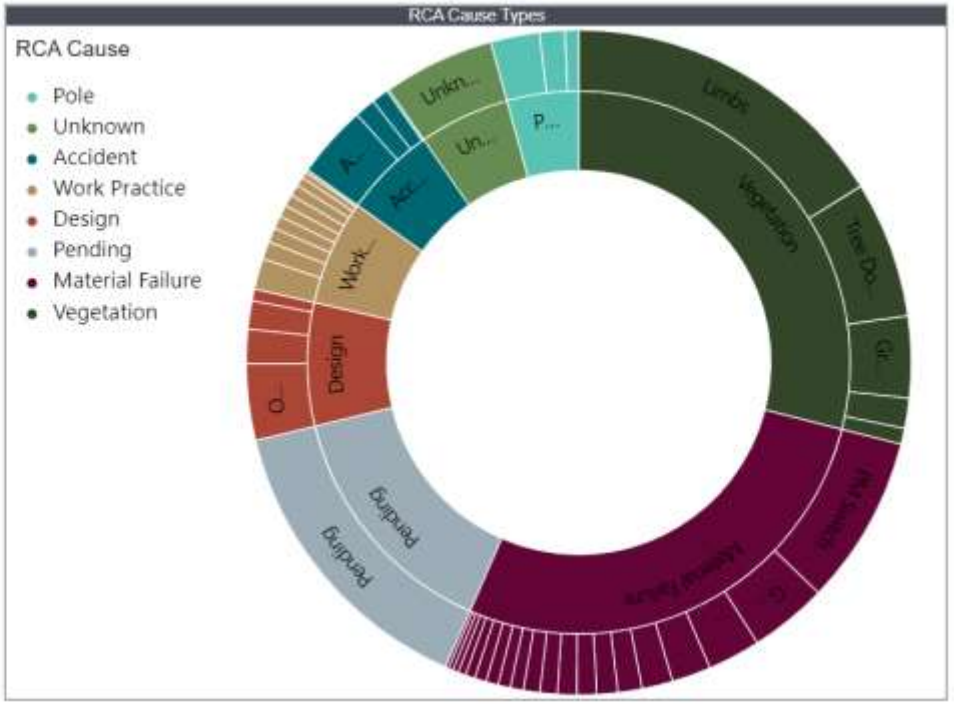
Root Cause Analysis Program - Analysis

Root Cause Analysis





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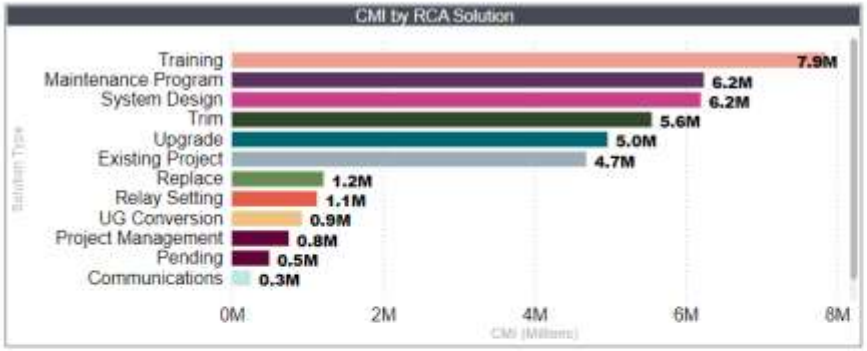
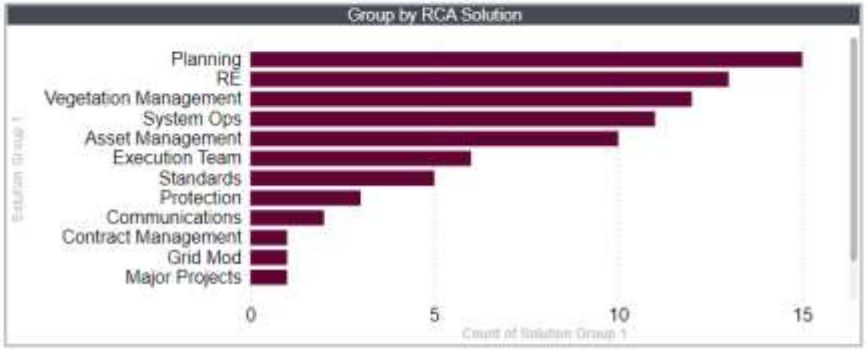
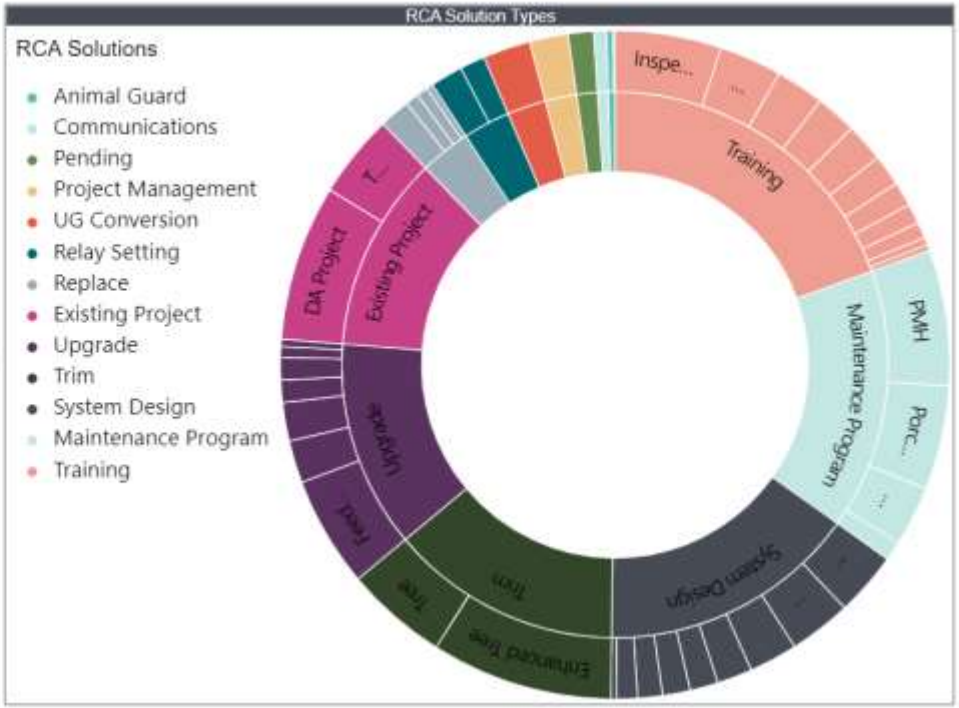
Root Cause Analysis Program - Analysis

Solutions Analysis







PUGET SOUND ENERGY

Root Cause Analysis Program - Summary

- Benefits
  - Identify potential emerging reliability risks and address them with holistic solutions
  - Improves cross departmental cooperation
  - Improve analysis skills and understanding of how everything fits together
- Challenges
  - Coordination - takes time to get everyone aligned
  - Scope - deciding what to investigate
  - Managing improvements - diverse set of action items

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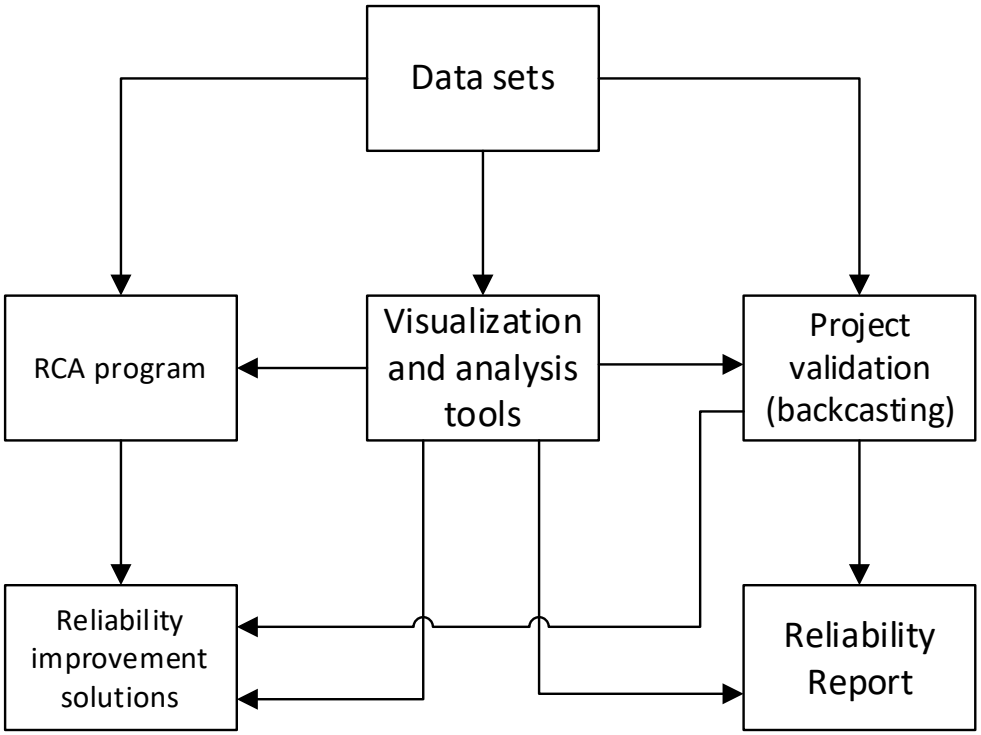
Summary

- Simplified diagram of how everything in this presentation is connected



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Future Plans

- Analysis
  - Prediction
  - Automation
  - Combine more data sets
- Project Benefit Verification (backcasting)
  - More project types and benefit types
  - Streamline the process
- RCA Program
  - More pictures

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Questions?

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