SUSTAINMENT MANAGEMENT SYSTEM TCX

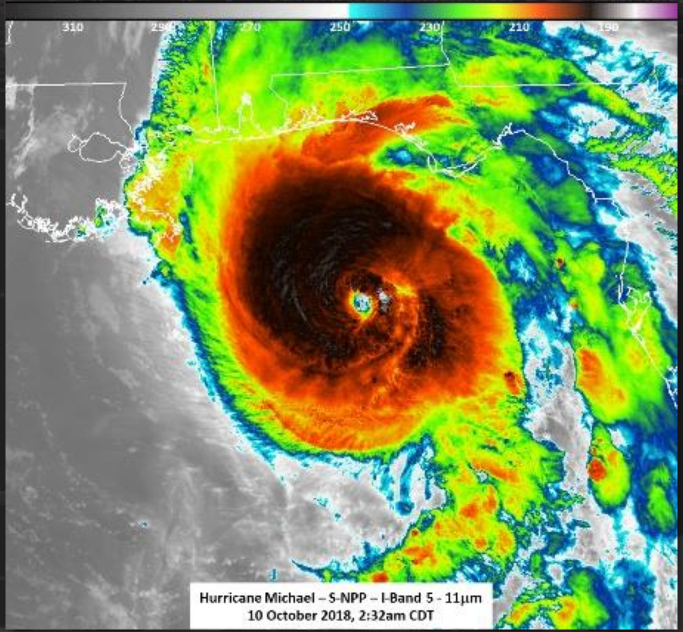
NATIONAL ACADEMIES Sciences Engineering Medicine

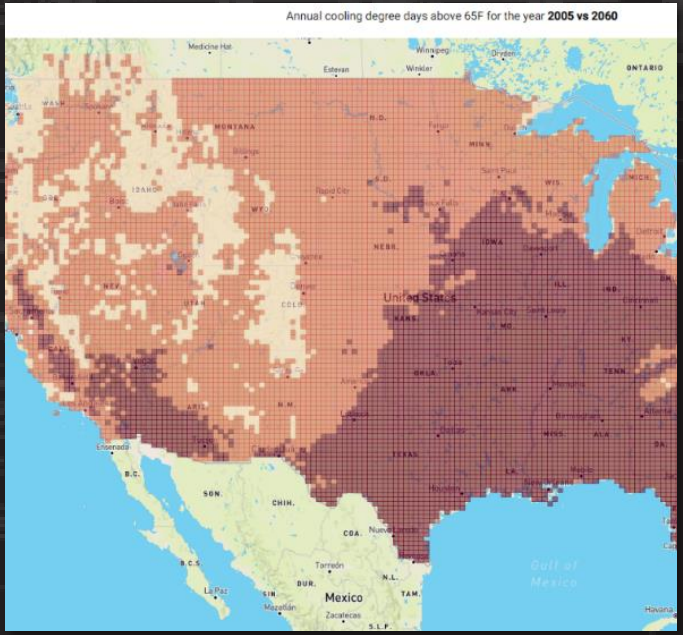
SMS SUMMIT 2023

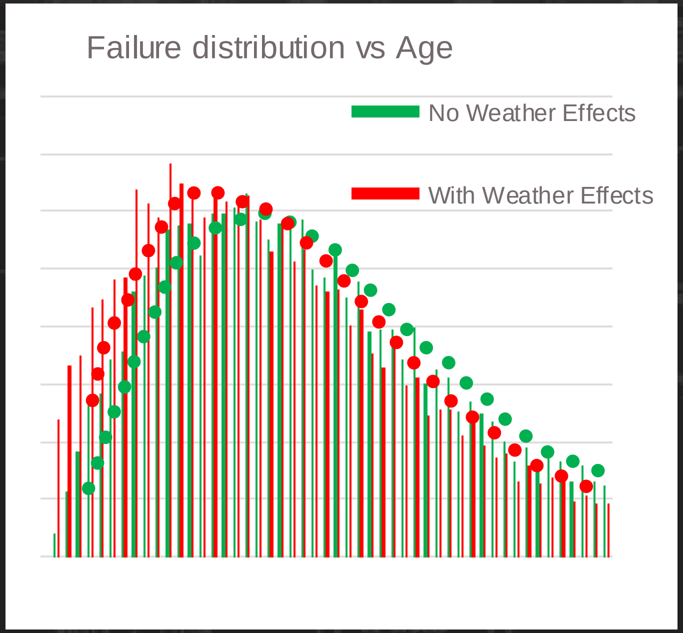
WELDER

WEATHER EFFECTS ON LIFECYCLE DEGRADATION AND EQUIPMENT REPLACEMENT

Engineering Track: Session 3B
Tuesday, Aug 8 – 3:00 – 3:50 PM







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US Army Corps of Engineers®

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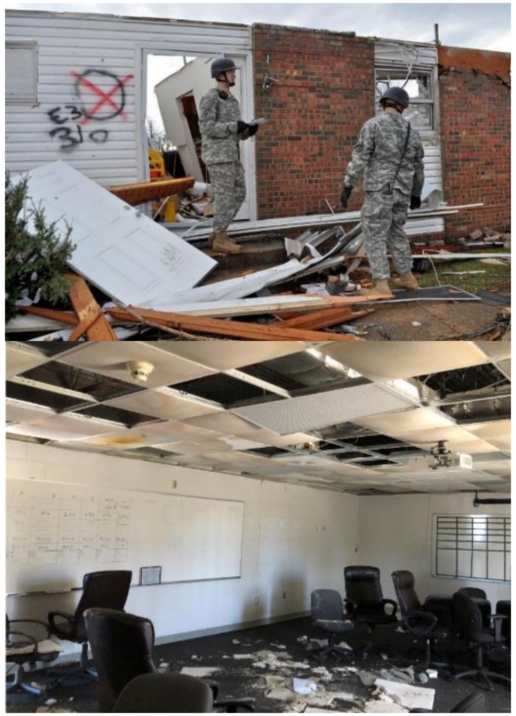
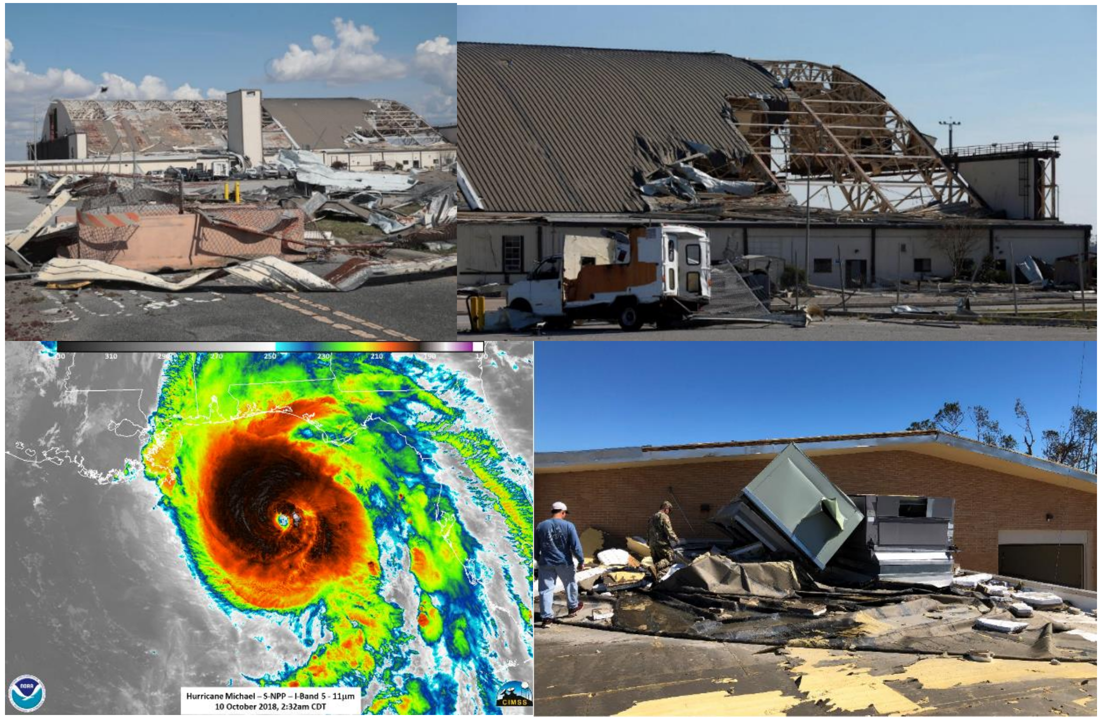
CLIMATE IMPACTS ON THE BUILT ENVIRONMENT

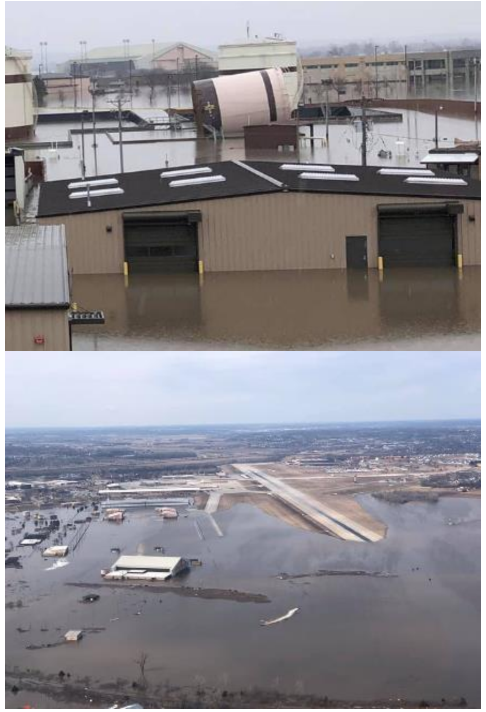
Tornado damage at Fort Leonard Wood, MO (2011)



Hurricane Michael damage at Tyndall AFB, FL (2018)



Flooding at Offutt AFB, NE (2019)



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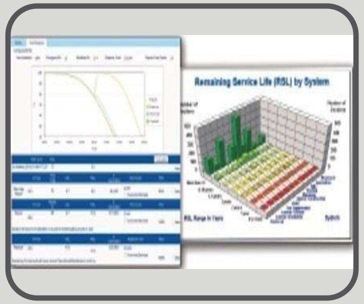
ASSESSING BUILDING COMPONENT CONDITION AND SERVICE LIFE

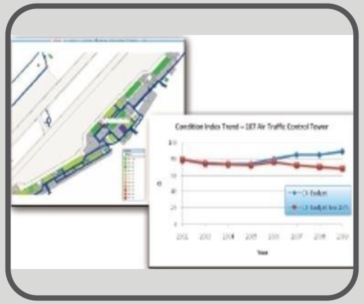
Component Inventory

Condition/ Functionality Assessment



Performance Metrics and Forecasting Models

Work Requirements



Consequence Analysis and Reporting

BUILDER SMS: A structured process for collecting, synthesizing, and organizing information about civil infrastructure and facility assets to support decisions pertaining to their sustainment over their lifecycle

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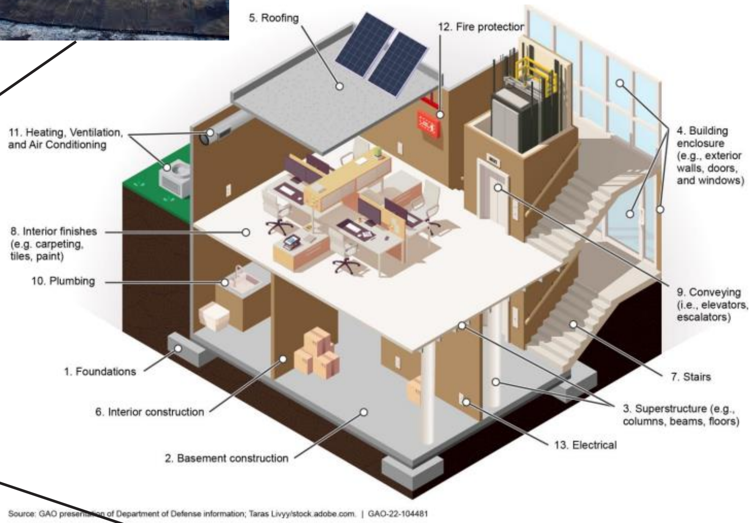
BUILDING COMPONENT INVENTORY

System	Sub-System	Component	Component Type	Name	Quantity	UM	Year
A10 FOUNDATIONS	A1010 STANDARD FOUNDATIONS	A101001 WALL FOUNDATIONS	Strip Footing		30	LF	957
A10 FOUNDATIONS	A1010 STANDARD FOUNDATIONS	A101002 COLUMN FOUNDATIONS & PILE CAPS	Spread Footing		21	EA	1957
B20 EXTERIOR ENCLOSURE	B2010 EXTERIOR WALLS	B201001 EXTERIOR CLOSURE	Concrete Block		3,500	SF	1957
B20 EXTERIOR ENCLOSURE	B2020 EXTERIOR WINDOWS	B202001 WINDOWS	Steel Windows		10	EA	1957
B20 EXTERIOR ENCLOSURE	B2030 EXTERIOR DOORS	B203001 SOLID DOORS	Steel		17	EA	1957
B30 ROOFING	B3010 ROOF COVERINGS	B301002 LOW SLOPE ROOF SYSTEMS	Built-Up		8,196	SF	2003
C10 INTERIOR CONSTRUCTION	C1010 PARTITIONS	C101001 FIXED PARTITIONS	Wall - Concrete Block		890	SF	1957
C10 INTERIOR CONSTRUCTION	C1010 PARTITIONS	C101001 FIXED PARTITIONS	Wall - Drywall w/Stud Framing		1,780	SF	1957
C10 INTERIOR CONSTRUCTION	C1020 INTERIOR DOORS	C102001 STANDARD INTERIOR DOORS	Wood Door/Metal Frame		27	EA	1957
D30 HVAC	D3020 HEAT GENERATING SYSTEMS	D302001 BOILERS	Gas, Hot Water - 500-650 MBH	B-1	1	EA	2000
D30 HVAC	D3020 HEAT GENERATING SYSTEMS	D302004 AUXILIARY EQUIPMENT	Expansion Tank - 40 gal	ET	1	EA	1987
D30 HVAC	D3030 COOLING GENERATING SYSTEMS	D303001 CHILLED WATER SYSTEMS	Chiller, Reciprocating, Water Cooled - 60 TN	CH	1	EA	2001
D30 HVAC	D3030 COOLING GENERATING SYSTEMS	D303001 CHILLED WATER SYSTEMS	Cooling Tower, Galvanized - 60 TN		1	EA	1997
D30 HVAC	D3040 DISTRIBUTION SYSTEMS	D304007 EXHAUST SYSTEMS	Fan System, Wall Exhaust - Wall Exhaust, 6175 CFM	EF-1	1	EA	1998
D30 HVAC	D3040 DISTRIBUTION SYSTEMS	D304008 AIR HANDLING UNITS	Central Station - 10000 CFM	AHU-1	1	EA	2001
D30 HVAC	D3050 TERMINAL & PACKAGE UNITS	D305006 PACKAGE UNITS	A/C Unit, Split Systems w/Air Cooled Condenser - 3 TN	AC-2	2	EA	1997
D30 HVAC	D3050 TERMINAL & PACKAGE UNITS	D305006 PACKAGE UNITS	Heat Pump, Air Source, Roof Top - 10 ton	HP-4	1	EA	1990



STANDARDIZED CONDITION ASSESSMENT

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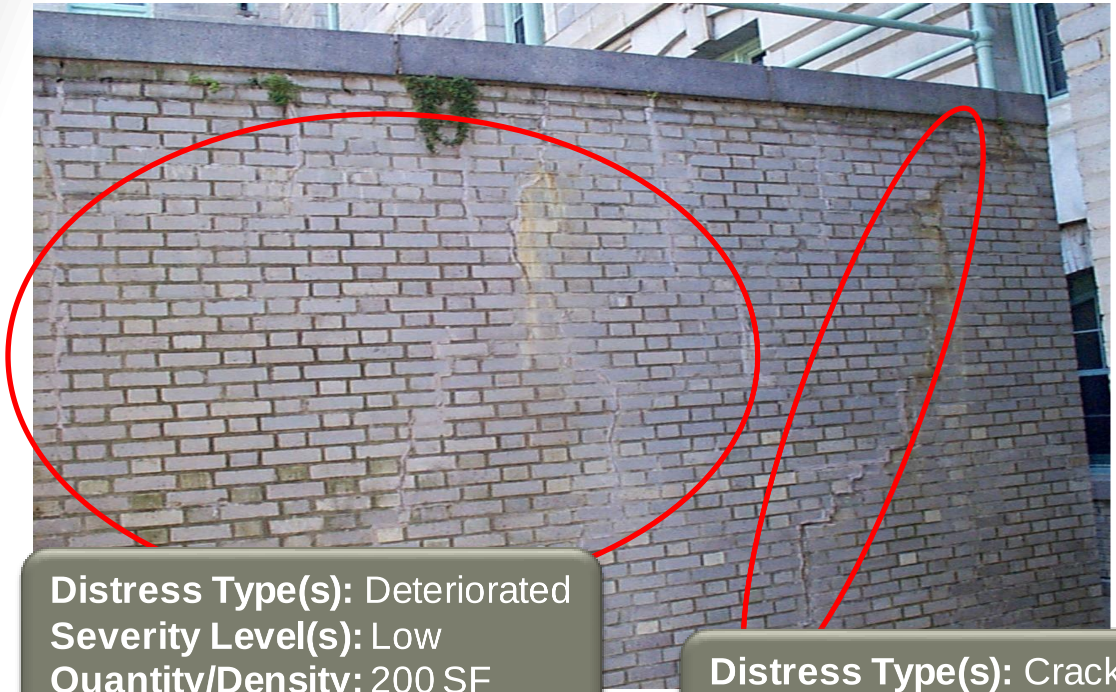
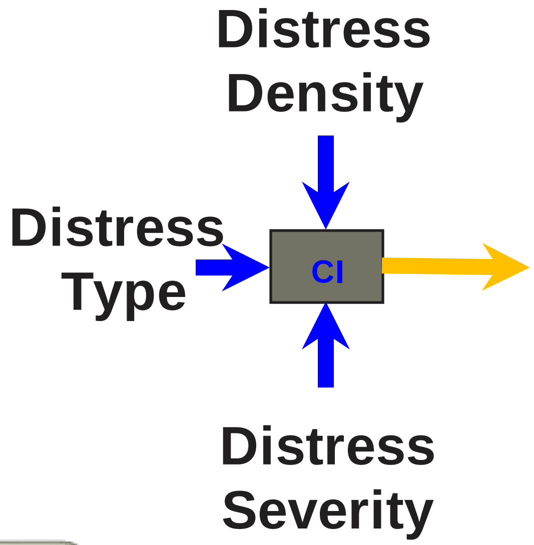


Distress Type(s): Deteriorated
Severity Level(s): Low
Quantity/Density: 200 SF

Distress Type(s): Cracked
Severity Level(s): Med
Quantity/Density: 12 LF



RATING	CI VALUE	RATING DEFINITION
GREEN (+)	100	ENTIRE COMPONENT FREE OF OBSERVABLE DISTRESSES. LIKE NEW CONDITION.
GREEN	95	NO SERVICEABILITY OR RELIABILITY REDUCTION. SLIGHT DEGRADATION BUT NON-CRITICAL. NO WORK OTHER THAN ROUTINE MAINTENANCE.
GREEN (-)	88	SLIGHT OR NO SERVICEABILITY OR RELIABILITY REDUCTION. SOME NOTICEABLE DEGRADATION BUT NON-CRITICAL. NO WORK OTHER THAN ROUTINE MAINTENANCE.
AMBER (+)	80	SERVICEABILITY OR RELIABILITY IS DEGRADED, BUT STILL ADEQUATE. MODERATE DETERIORATION BUT NON-CRITICAL. MINOR REPAIRS NEEDED.
AMBER	71	SERVICEABILITY OR RELIABILITY IS NOTICEABLY IMPAIRED. MODERATE DETERIORATION OR DAMAGE REQUIRES CORRECTIVE REPAIRS.
AMBER (-)	61	SIGNIFICANT SERVICEABILITY OR RELIABILITY LOSS. SIGNIFICANT DEGRADATION OR DAMAGE REQUIRES MAJOR REHABILITATION OR OVERHAUL.
RED	30	SEVERE SERVICEABILITY OR RELIABILITY REDUCTION MAY RESULT IN LOSS OF USE OR SAFETY. IMMEDIATE REPLACEMENT WARRANTED.

CONDITION AND SERVICE LIFE FORECASTING

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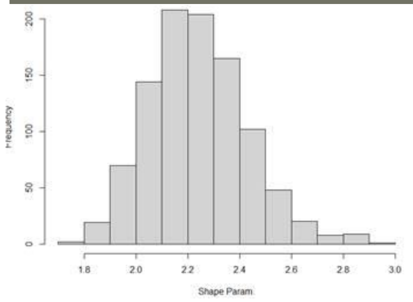
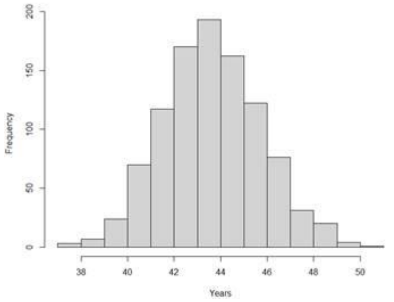
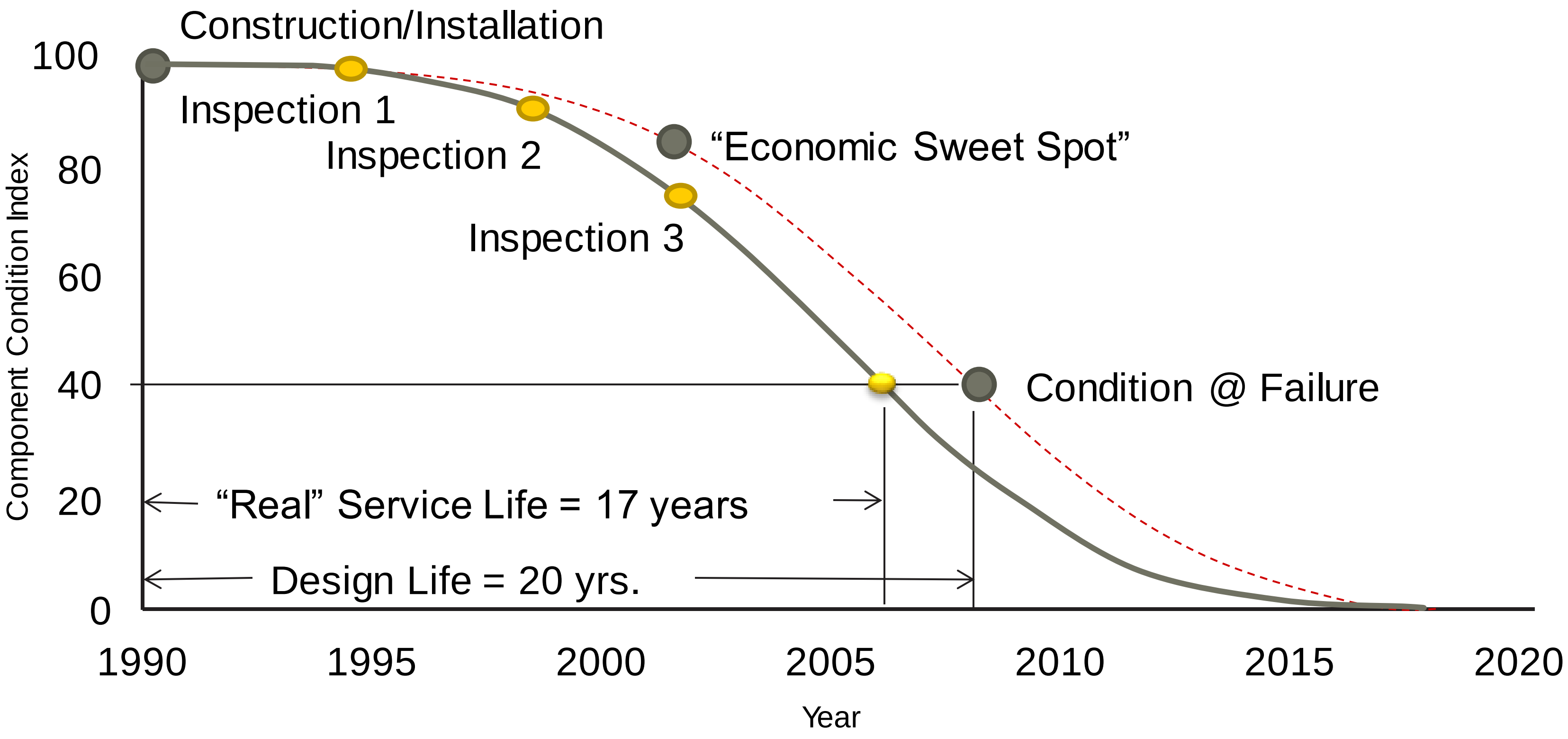
Degradation/Shape parameter



Scale/Service Life parameter





Adaptive model predicts performance of **each** unique component; identifies best time to invest

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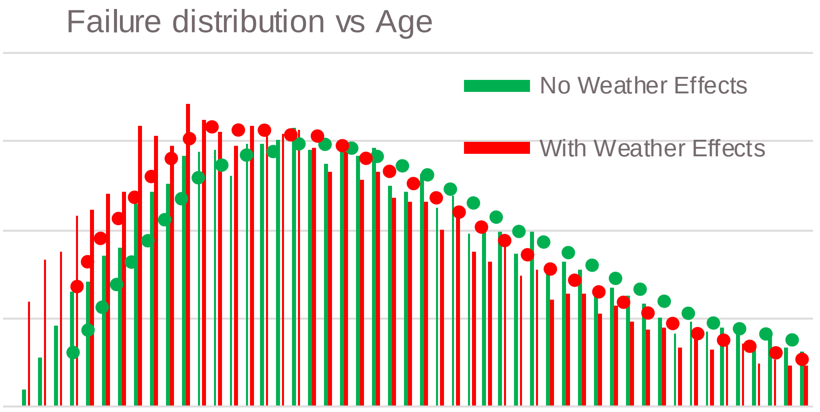
QUESTION: CLIMATE EFFECTS ON DEGRADATION?

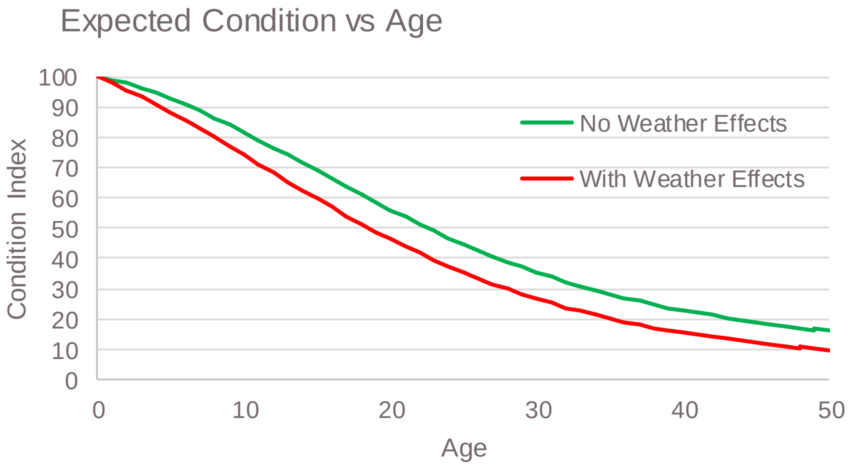
Building Components
Foundation
Super Structure
HVAC
  Rooftop AC Unit
…

Hazard Events →
Severe Storm
Extreme Heat
…

Stressors
Excessive Wind
Increased CCDs
Increased Temp Intensity
…

Damage/Distress Mode	Damage Type	Damage Effect	Weather Variable
Equipment Damage due to excess Wind	Abrupt	Condition Loss / Failure	CDDs
Accelerated HVAC equipment degradation due to increases demand	Gradual	Service Life Reduction	Annual Days above 100
HVAC Equipment failure due to prolonged run-time	Abrupt	Condition Loss / Failure	Wind Speed





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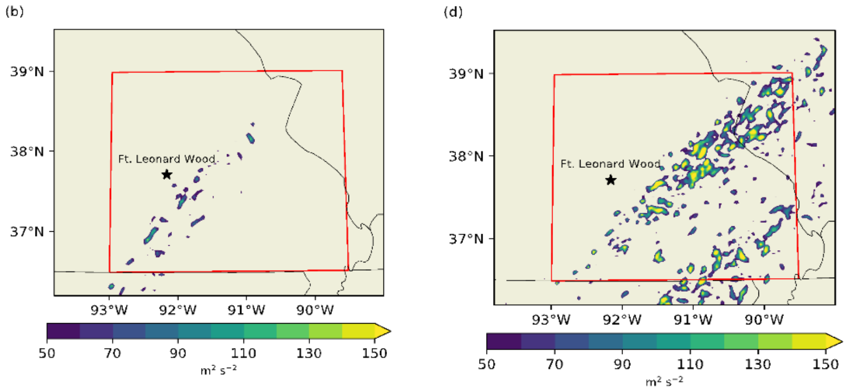
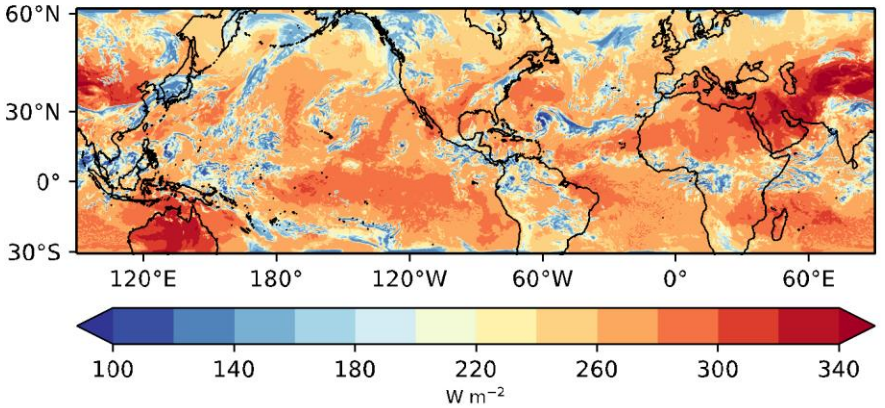
CLIMATE DATA / WEATHER EVENT MODELING

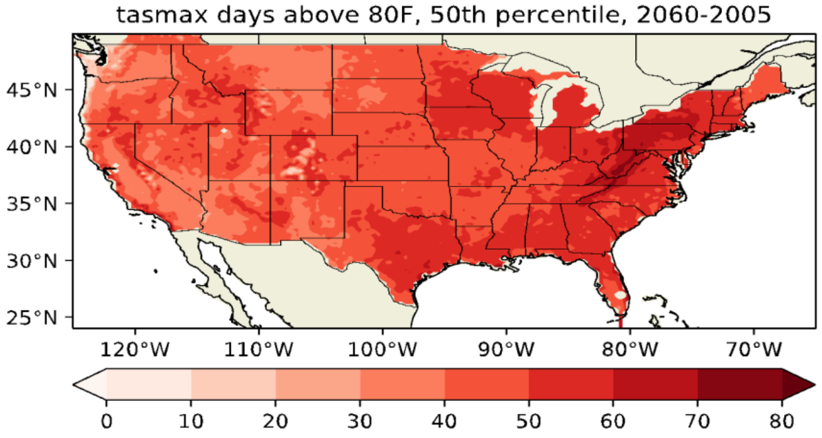
Weather Research and Forecasting (WRF) model simulations at 3km resolution

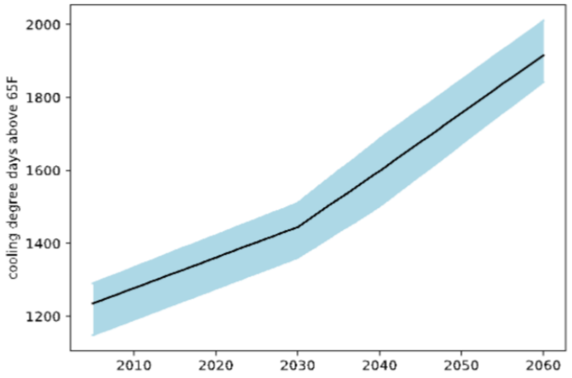


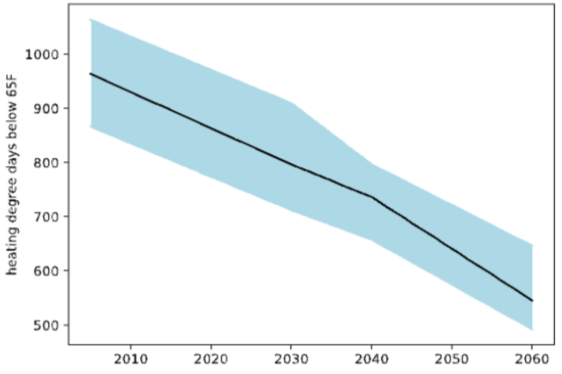
WRF Tropical Channel Model simulations at 27km resolution



Site-specific Forecasted Weather Metrics







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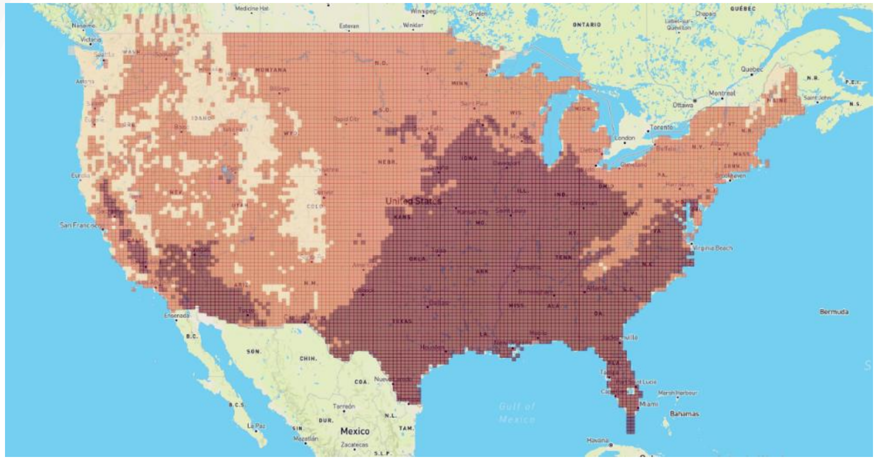
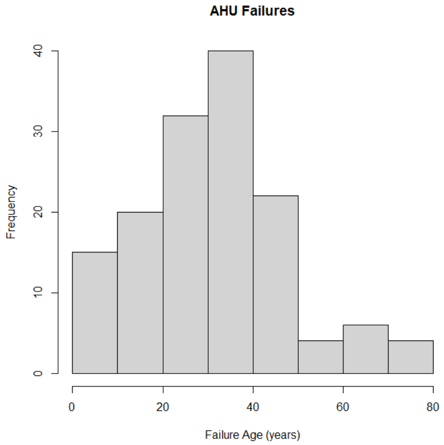
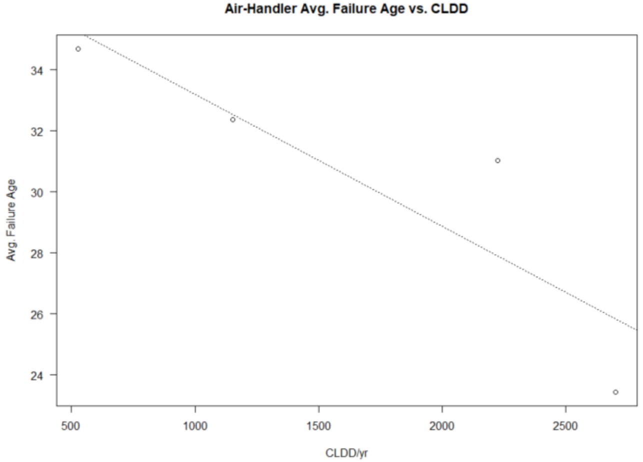
EXPLORING LINKAGE BETWEEN CDDS AND FAILURE AGE

Projected CDD change 2005-2060

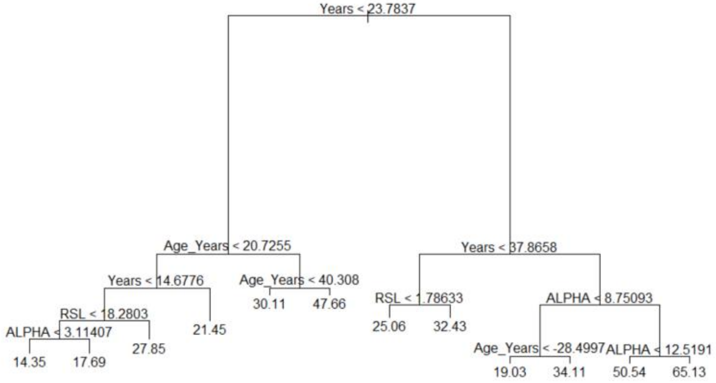


Failure Distribution by CDD bins

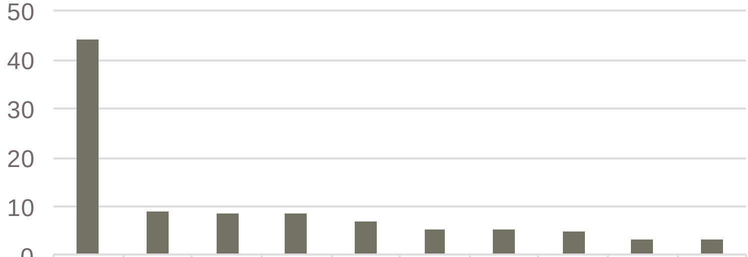




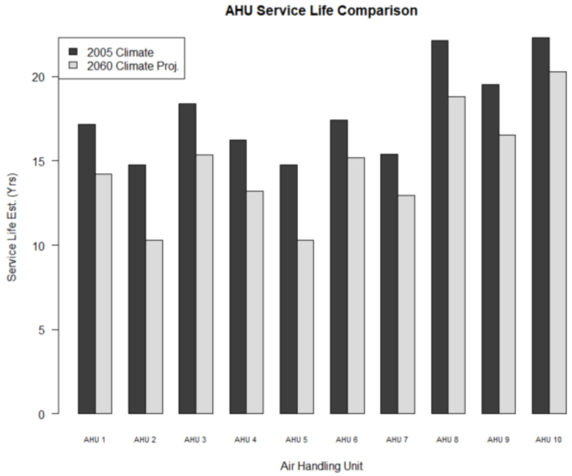
Boosted Decision Tree Approach



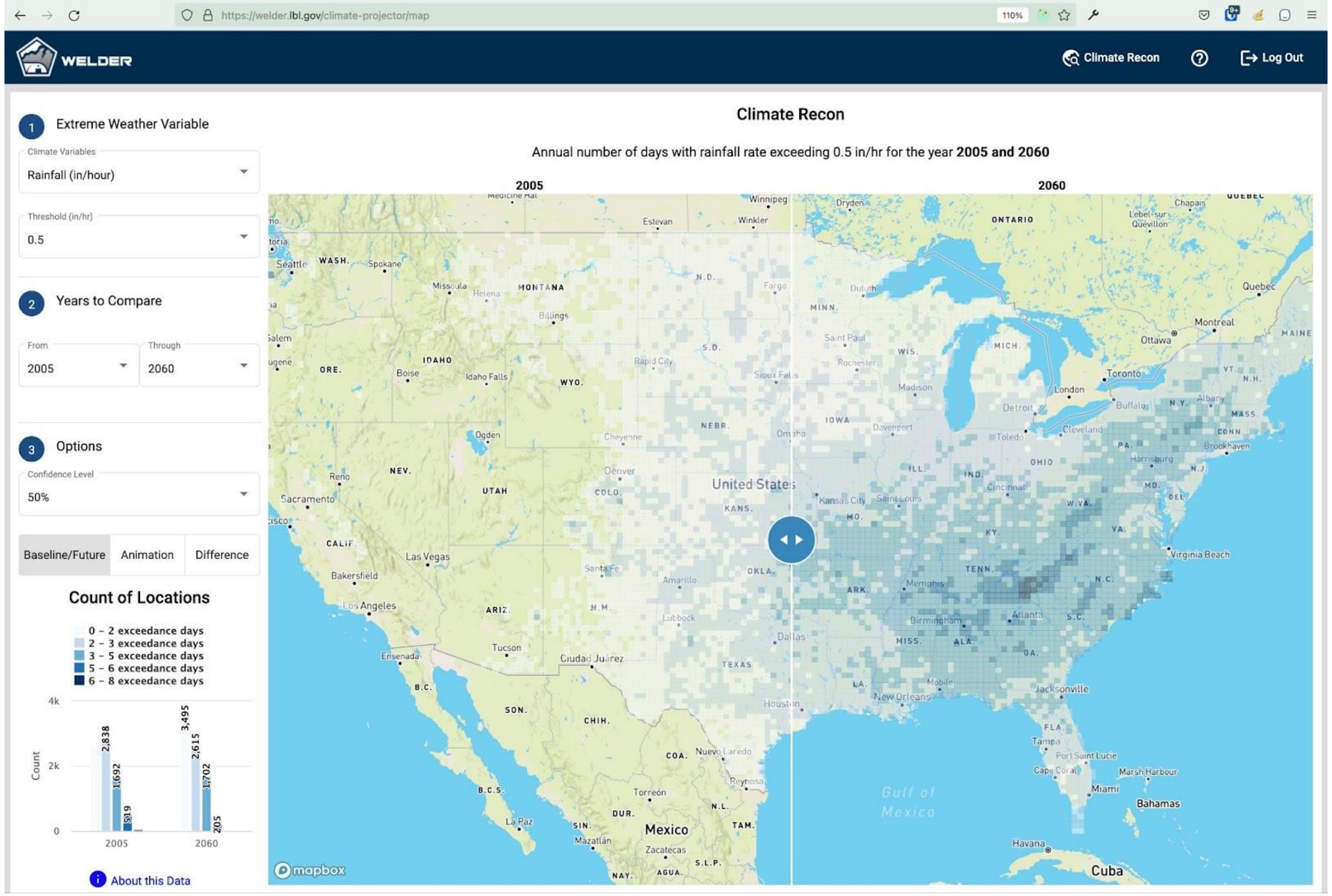
Relative Influence of Model Predictor Variables



	Scale	Shape	CDD	Year Built	Size	BCI	Cost	HDD	FAC	PRV
Relative Influence	44.26	9.09	8.62	8.44	7.04	5.43	5.38	4.96	3.46	3.32



WEATHER EFFECTS ON THE LIFECYCLE OF DOD EQUIPMENT REPLACEMENT (WELDER)



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WELDER: COMPONENT LEVEL IMPACT ANALYSIS

WELDER | Climate Recon | Help/Documentation | Log Out

Organizations: W Nicholas

Sites: Phenix, Avinger, Barrington, Lafitte, Callisburg, Colfax, West Baden Springs, Laguna Heights, El ...

Complexes - N/A

Scenario List > Organizations > Barrington > Boathouse > Component

Scenario

IMCOM_B30_only

Only B30 for all of IMCOM

Years: 3

Hazards

Filter

Systems All

Components All

Component Details

Component: D3030 COOLING GENERATING SYSTEMS

Material Category: D303004 AUXILIARY EQUIPMENT

Component Type: Expansion Tank - 240 gal

Year Built: 2017

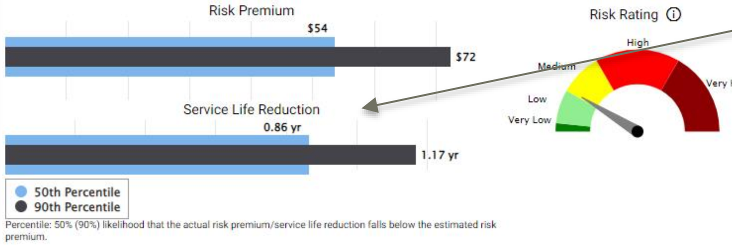
Age: 5

Design Life: 19

Quantity: 1 EA

Risk Analysis

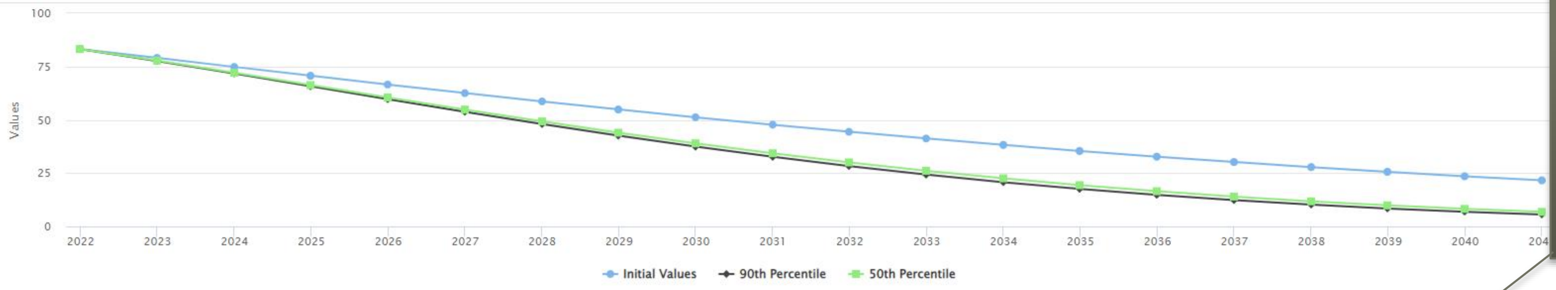
CRV: $10,191



Percentile: 50% (90%) likelihood that the actual risk premium/service life reduction falls below the estimated risk premium.

Component Service Life Reduction

Projected Condition



Based on weather-related damage

Component Specific Damage

Climate Variable	Damage Mode	Damage Type	Damage Effect	Threshold	SL Reduction
Wind	Wind Damage to Exterior HVAC	Abrupt	Condition Loss	50	0.00
Cooling Degree Days	Excessive Runtime for HVAC Cooling Systems	Gradual	Service Life Reduction	65	0.54
Max Temperature	Excessive Runtime for HVAC Cooling Systems	Abrupt	Condition Loss	100	0.32

WELDER: COMPONENT RISK INDICATORS

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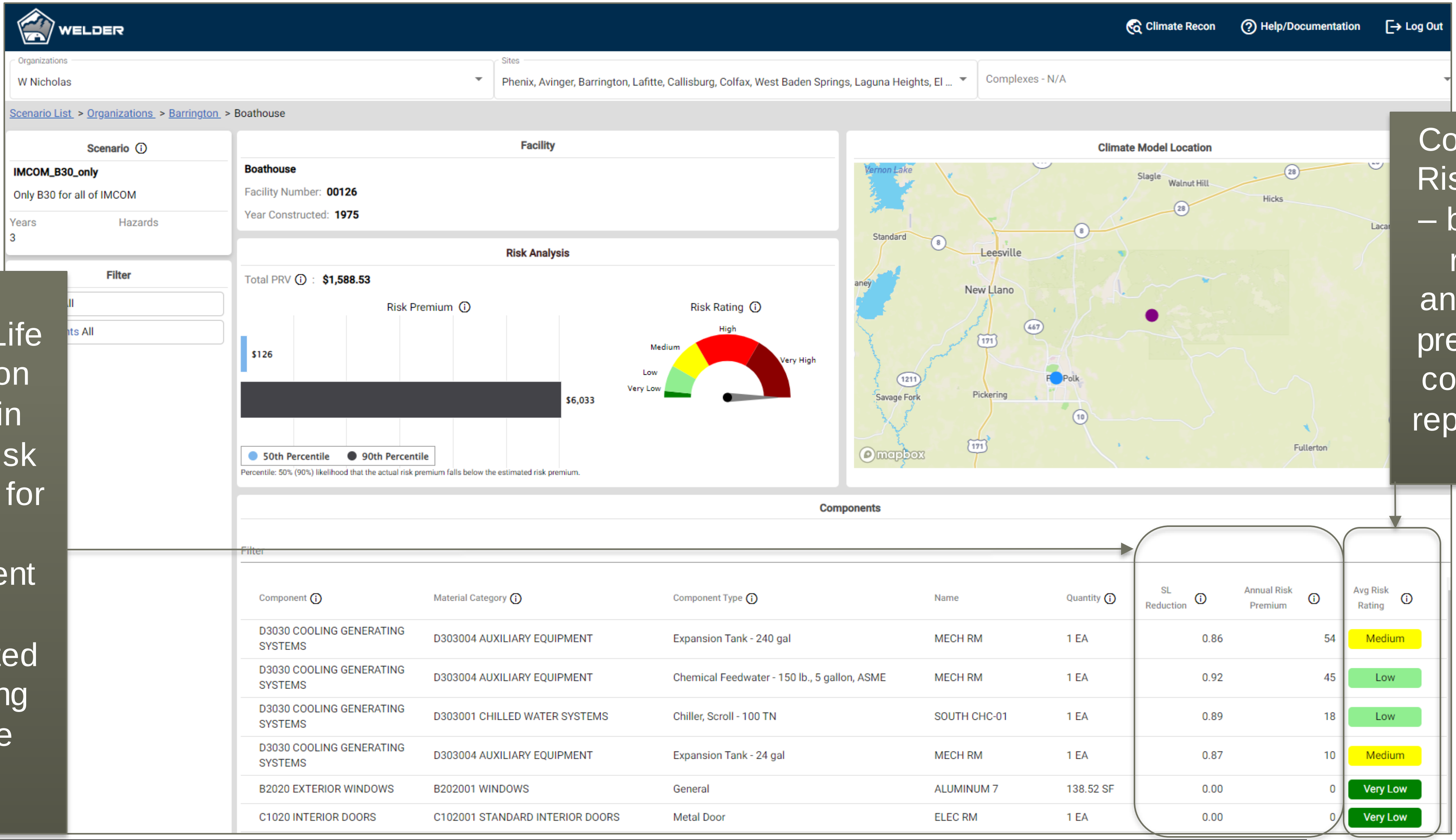

Component	Material Category	Component Type	Name	Quantity	SL Reduction	Annual Risk Premium	Avg Risk Rating
D3030 COOLING GENERATING SYSTEMS	D303004 AUXILIARY EQUIPMENT	Expansion Tank - 240 gal	MECH RM	1 EA	0.86	54	Medium
D3030 COOLING GENERATING SYSTEMS	D303004 AUXILIARY EQUIPMENT	Chemical Feedwater - 150 lb., 5 gallon, ASME	MECH RM	1 EA	0.92	45	Low
D3030 COOLING GENERATING SYSTEMS	D303001 CHILLED WATER SYSTEMS	Chiller, Scroll - 100 TN	SOUTH CHC-01	1 EA	0.89	18	Low
D3030 COOLING GENERATING SYSTEMS	D303004 AUXILIARY EQUIPMENT	Expansion Tank - 24 gal	MECH RM	1 EA	0.87	10	Medium
B2020 EXTERIOR WINDOWS	B202001 WINDOWS	General	ALUMINUM 7	138.52 SF	0.00	0	Very Low
C1020 INTERIOR DOORS	C102001 STANDARD INTERIOR DOORS	Metal Door	ELEC RM	1 EA	0.00	0	Very Low

Service Life Reduction results in annual risk premium for each component – aggregated to building and site levels

Component Risk Rating – based on ratio of annual risk premium to component replacement value

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WELDER: BUILDING RISK INDICATORS

WELDER | Climate Recon | Help/Documentation | Log Out

Organizations: W Nicholas

Sites: Phenix, Avinger, Barrington, Lafitte, Callisburg, Colfax, West Baden Springs, Laguna Heights, El ...

Complexes - N/A

Scenario List > Organizations > Barrington

Scenario

IMCOM_B30_only

Only B30 for all of IMCOM

Years: 3

Hazards

Filter

Systems All

Components All

Site

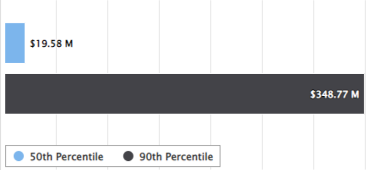
Barrington

Number of Buildings: 507

Risk Analysis

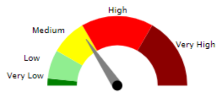
Total PRV: $2.09 B

Risk Premium

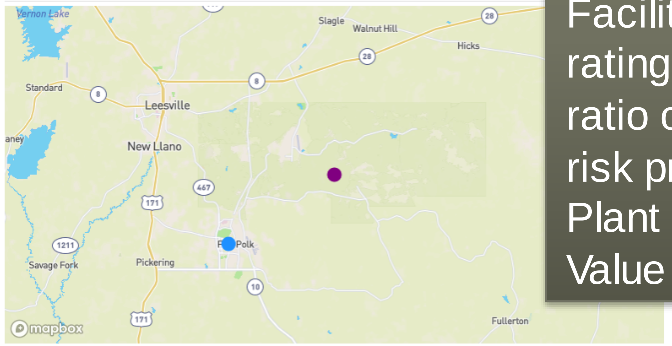


Percentile: 50% (90%) likelihood that the actual risk premium falls below the estimated risk premium.

Risk Rating



Climate Model Location



Facility risk rating based on ratio of annual risk premium to Plant Replace Value

Facilities

Filter

RPUID	Building Number	Name	Year	Category Code	PRV	Annual Risk Premium	Avg Risk Rating
246929	00126	Boathouse	1975	6412	1,589	126	Very High
896908	01194	Water Tower	1974	2386	433,159	8,434	High
19415	08162	Garage	1967	2402	459,387	7,752	High
923759	01227	Observatory	1975	1055	760,318	3,510	Low
109100	02117	Clinic	1968	152	1.02 M	3,402	Low
296957	61008	Marina	2005	6511	35,269	74	Low
752914	07332	Silo	1974	549	95,852	136	Low
640613	01250	Garage	1938	6527	669,332	610	Very Low
313169	00842	Dormitory	1971	12299	2.16 M	1,545	Very Low
623515	06227	Fire Station	1977	2025	5.07 M	3,311	Very Low
151160	00227	Chapel	1969	2718	163,101	101	Very Low
131805	61402	Recycling Center	2004	12112	480,619	294	Very Low
560289	08380	Dormitory	2003	11095	605,152	341	Very Low

List of Individual Facilities at Site – Clicking on a facility goes to analysis details

WELDER CLIMATE LIFECYCLE IMPACT

Calculation Steps

- Step 1. Component Level Info
- Step 2. Calculate Component Metrics
- Step 3. Get Damage Modes and model parameters for component Types
- Step 4. Find Baseline Climate Variables for each Damage Mode
- Step 5. Given a percentile assumption, Find Climate Value Change for each Damage Mode
- Step 6a. Calculate Climate Impact Metrics for Gradual Damage Types
- Step 6b. Calculate Climate Impact Metrics for abrupt Damage Types
- Step 7. Aggregate Service Life Reduction across all damage modes
- Step 8. Calculate weather adjusted degradation parameters across all damage modes
- Step 9. Calculate Annual Risk Premium

STEP 1. COMPONENT LEVEL INFO

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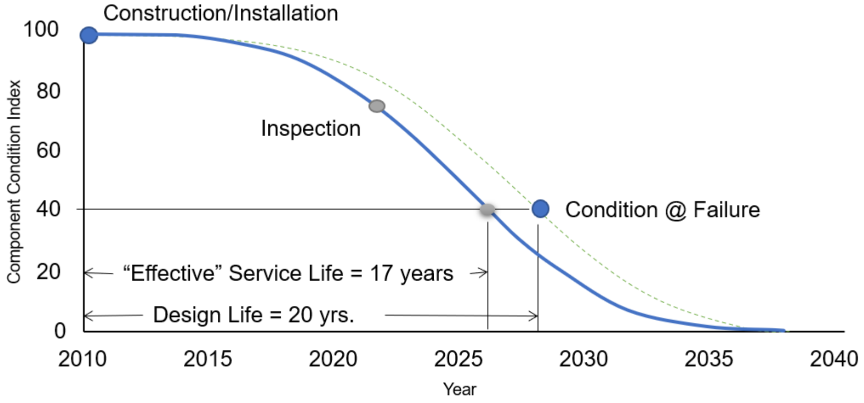
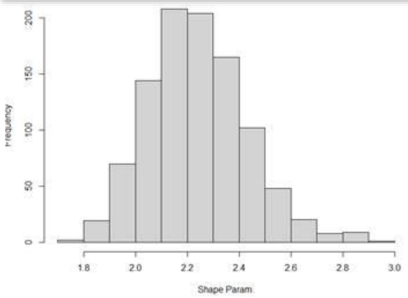
Given a building component in service in a building, we have certain information about that component in BUILDER, including:

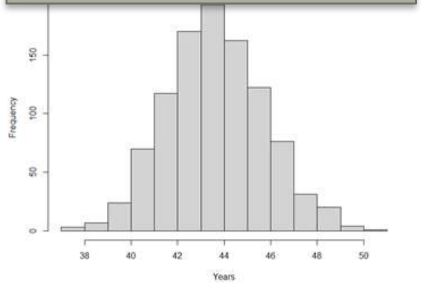
- Building Location: Geographic Location building
- Component Type: Specific Type that component is classified as
- Quantity: The quantity of the component
- Year Installed: Year component was installed or placed in service
- Component Replacement Value: The estimated cost to replace the component
- Design Life: The expected service life of the component from install to replacement
- Alpha: The condition degradation shape parameter
- Beta: The condition degradation scale parameter



Degradation/Shape parameter



Scale/Service Life parameter



WELDER

Climate Recon | Help/Documentation | Log Out

Organizations: W Nicholas

Sites: Phenix, Avinger, Barrington, Lafitte, Callisburg, Colfax, West Baden Springs, Laguna Heights, El...

Complexes - N/A

Scenario List > Organizations > Avinger > Workshop > Component > Calculation Details

Scenario

IMCOM_B30_only

Only B30 for all of IMCOM

Years	Hazards
3	

Filter

Systems All

Components All

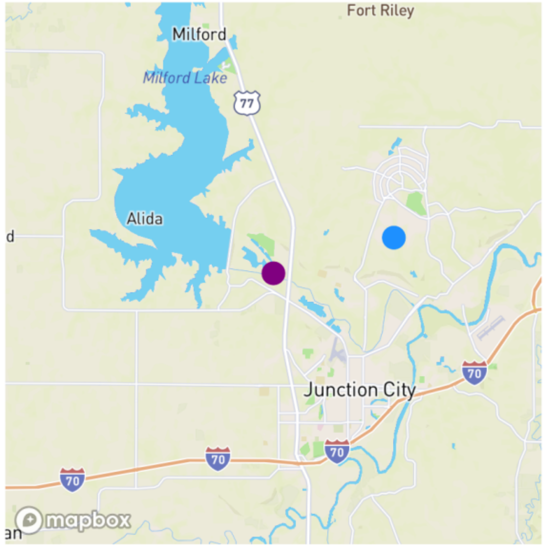
Component Info

Component:	**D3030 COOLING GENERATING SYSTEMS**
Material Category:	**D303001 CHILLED WATER SYSTEMS**
Component Type:	**Cooling Tower, Stainless Steel - 1000 TN**
Replacement Value:	**$686,880.00**
Year Built:	**2019**
Age:	**3**
Design Life:	**15**
Quantity:	**1 EA**
Alpha:	**1.40**
Beta:	**0.89**

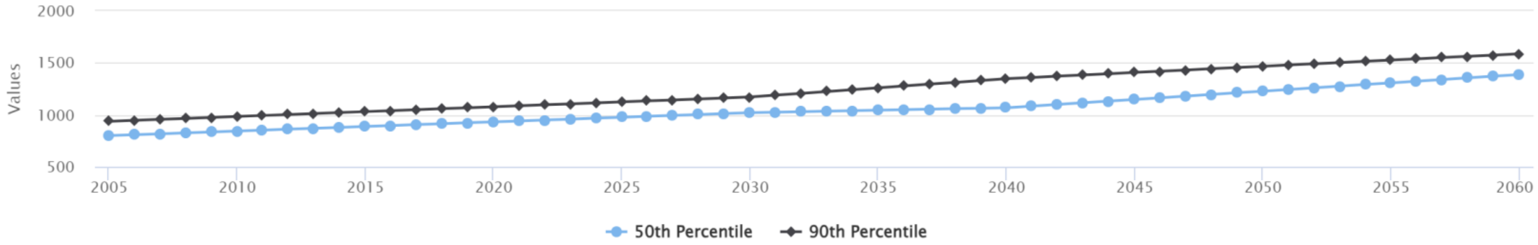
Component Metrics

Current Age:	**3**
Current CI:	**89.2**
Effective Age:	**6.82**
Remaining Design Life (RDL):	**12**
Remaining Service Life (RSL):	**10.3**
Model Year (CurrentYear + RSL):	**2030**

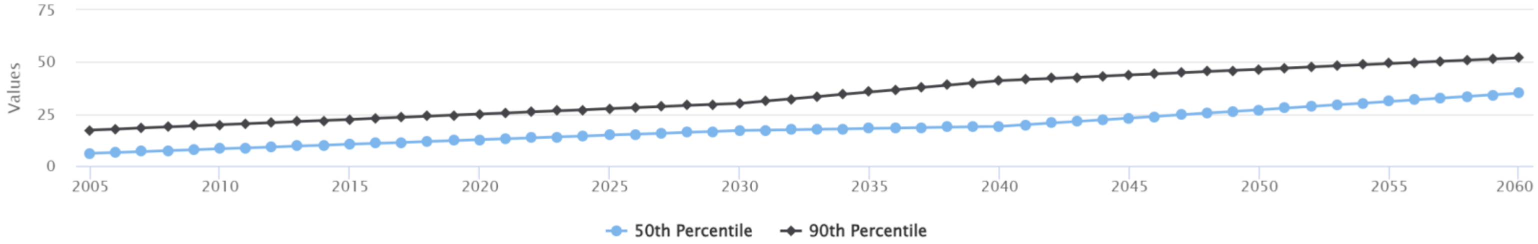
Climate Model Location



Cooling Degree Days



Max Temperature



STEP 2. CALCULATE COMPONENT METRICS

Based on this information, BUILDER calculates various metrics used to inform planning decisions, including:

- Current Age: $CurrentYear - YearInstalled$
- Current CI: $100 \times \left(\frac{100}{CIterminal}\right)^{-\left(\frac{CurrentAge}{DesignLife\ x\ beta}\right)^{alpha}}$
- Effective Age: $DesignLife \times \left(-Log\left(\frac{CurrentCI}{100}, \frac{100}{40}\right)\right)^{\left(\frac{1}{alpha}\right)}$
- Remaining Design Life: $DesignLife - CurrentAge$
- Remaining Service Life: $DesignLife - EffectiveAge$

WELDER

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Organizations: W Nicholas

Sites: Phenix, Avinger, Barrington, Lafitte, Callisburg, Colfax, West Baden Springs, Laguna Heights, El...

Complexes - N/A

Scenario List > Organizations > Avinger > Workshop > Component > Calculation Details

Scenario

IMCOM_B30_only

Only B30 for all of IMCOM

Years	Hazards
3	

Filter

Systems All

Components All

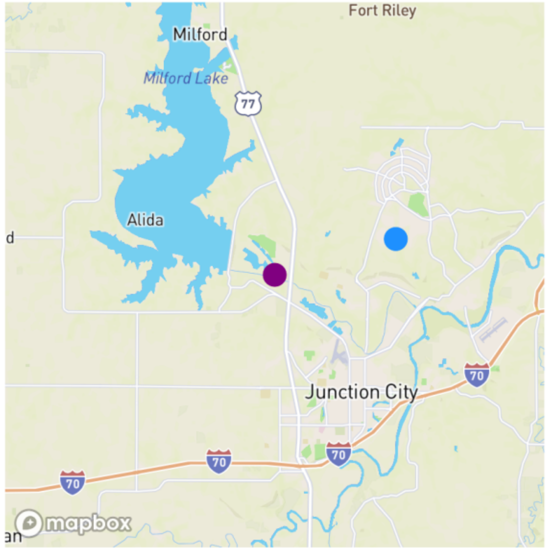
Component Info

Component:	**D3030 COOLING GENERATING SYSTEMS**
Material Category:	**D303001 CHILLED WATER SYSTEMS**
Component Type:	**Cooling Tower, Stainless Steel - 1000 TN**
Replacement Value:	**$686,880.00**
Year Built:	**2019**
Age:	**3**
Design Life:	**15**
Quantity:	**1 EA**
Alpha:	**1.40**
Beta:	**0.89**

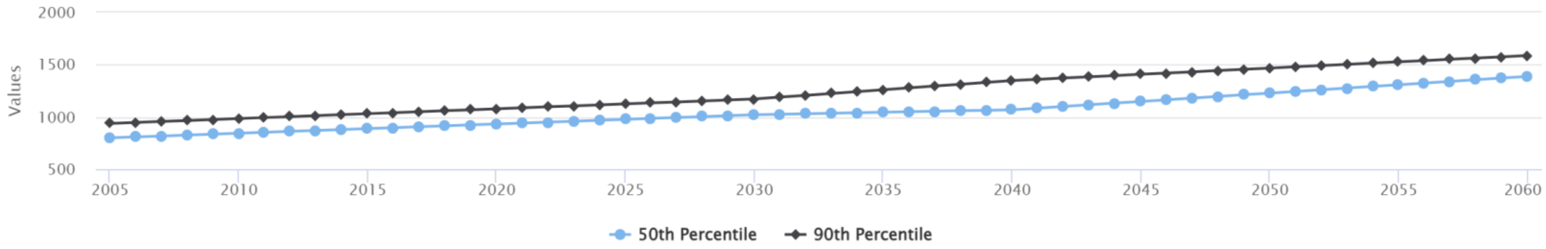
Component Metrics

Current Age:	**3**
Current CI:	**89.2**
Effective Age:	**6.82**
Remaining Design Life (RDL):	**12**
Remaining Service Life (RSL):	**10.3**
Model Year (CurrentYear + RSL):	**2030**

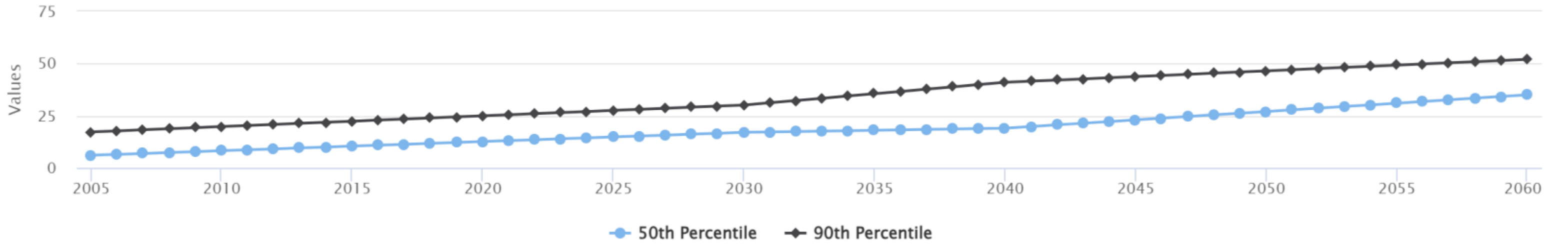
Climate Model Location



Cooling Degree Days



Max Temperature



STEP 3. GET DAMAGE MODES AND MODEL PARAMETERS FOR COMPONENT TYPES

For each component type, a damage association table lists applicable damage modes and associated model parameters

- Damage Mode: A description of the damage type
- Mode Type: Whether the damage mode is abrupt or gradual
- Stressor: The climate factor associated to the damage mode
- Climate Variable: The climate variable that measures intensity of the stressor
- Threshold: The level of the climate variable that is typically results in the damage mode if exceeded.
- Damage Likelihood: The likelihood of damage mode occurring given climate variable threshold is met
- Damage Factor: the extent of the damage on component service, ranging from no effect on condition an/or service life to total loss of component.

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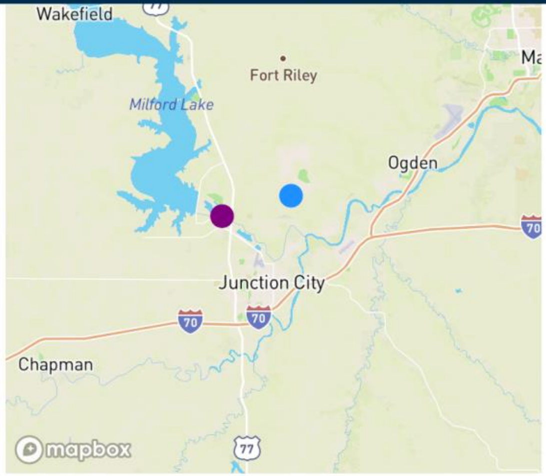

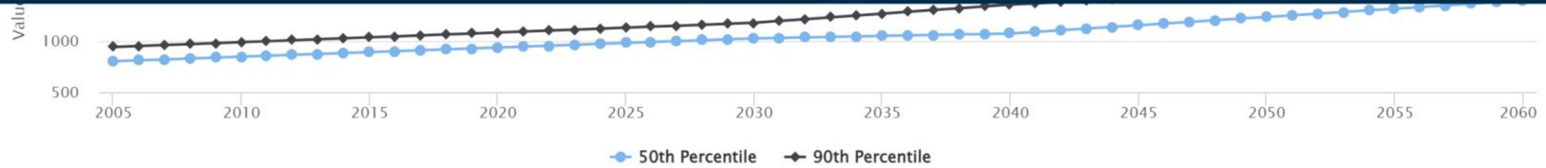

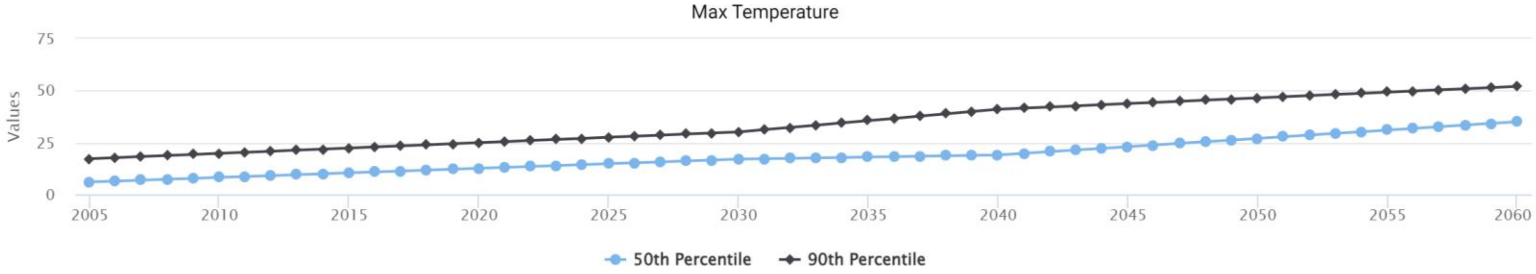

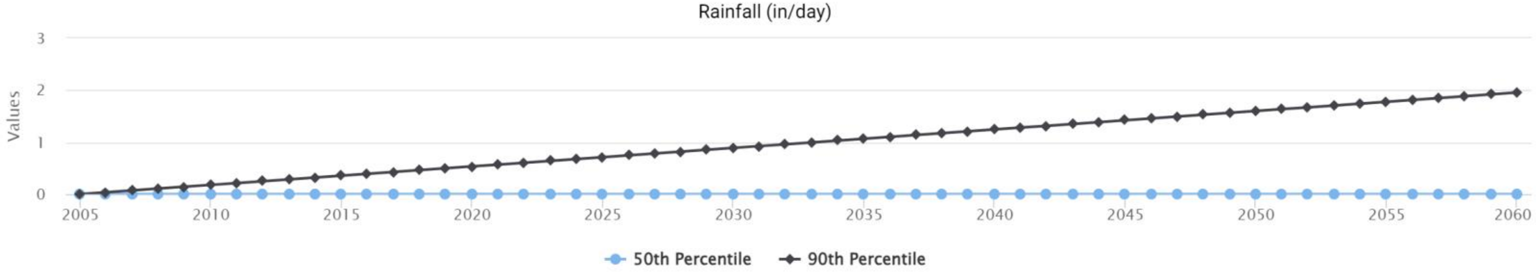

Damage Modes

Climate Variable	**Max Temperature**	**Cooling Degree Days**	**Rainfall (in/day)**	**Totals**
Damage Mode	Excessive Runtime for HVAC Cooling Systems	Excessive Runtime for HVAC Cooling Systems	Water infiltration and flooding cause damage to interiors and services	
Damage Type	Abrupt	Gradual	Abrupt	
Damage Effect	Condition Loss	Service Life Reduction	Condition Loss	
Threshold	100	65	6	
Damage Likelihood	0.75	0.25	0.25	
Damage Extent	0.05	0.5	0.8	
Baseline	12.16	923.22	0.00	

STEP 4. FIND BASELINE CLIMATE VARIABLES FOR EACH DAMAGE MODE

When evaluating a damage mode for a given component:

- Find the climate dataset closest to the building location
- Specific Climate Variable
- Specific Climate threshold for damage mode
- Year = Component Year installed (or 2005 if installed prior to 2005)
- Select the climate value for the 50%. This represents the baseline climate value at or near the beginning of the component's service life

Damage Modes

Climate Variable	Max Temperature	Cooling Degree Days	Rainfall (in/day)	Totals
Damage Mode	Excessive Runtime for HVAC Cooling Systems	Excessive Runtime for HVAC Cooling Systems	Water infiltration and flooding cause damage to interiors and services	
Damage Type	Abrupt	Gradual	Abrupt	
Damage Effect	Condition Loss	Service Life Reduction	Condition Loss	
Threshold	100	65	6	
Damage Likelihood	0.75	0.25	0.25	
Damage Extent	0.05	0.5	0.8	
Baseline	12.16	923.22	0.00	
50th Percentile				
Climate Value	17	1,020.53		
Annualized Increase		0.01		
Degradation Rate		105.27%		
Adjusted RSL		9.81		
Adjusted Alpha		1.43		
Adjusted Beta		0.85		**0.83**
SL Reduction	0.38	0.52		**0.9**
Annual Risk Premium				**3,997**
90th Percentile				
Climate Value	30.1	1,171.28	0.89	
Annualized Increase		0.03		
Degradation Rate		113.43%		
Adjusted RSL		9.1		
Adjusted Alpha		1.49		**1.66**
Adjusted Beta		0.81		**0.7**
SL Reduction	0.39	1.22	1.22	**2.83**
Annual Risk Premium				**12,538**

STEP 5. GIVEN A PERCENTILE ASSUMPTION, FIND CLIMATE VALUE CHANGE FOR EACH DAMAGE MODE

Now find the change in the climate variable value over its expected service life. This change depends on whether evaluating at a 50% probability level (50% probability of value not being exceeded) or a more risk averse 90% probability level (90% probability of value not being exceeded).

- Find the climate dataset closest to the building location
- Specific Climate Variable
- Specific Climate threshold for damage mode
- Year = CurrentYear + RemainingServiceLife
- Select the climate value for the desired confidence level. This represents the projected climate value at or near the end of the component's service life.
- ClimateValueChange: $ProjectedClimateValue - BaselineClimateValue$

Damage Modes

Climate Variable	Max Temperature	Cooling Degree Days	Rainfall (in/day)	Totals
Damage Mode	Excessive Runtime for HVAC Cooling Systems	Excessive Runtime for HVAC Cooling Systems	Water infiltration and flooding cause damage to interiors and services	
Damage Type	Abrupt	Gradual	Abrupt	
Damage Effect	Condition Loss	Service Life Reduction	Condition Loss	
Threshold	100	65	6	
Damage Likelihood	0.75	0.25	0.25	
Damage Extent	0.05	0.5	0.8	
Baseline	12.16	[illegible]	[illegible]	
		50th Percentile		
Climate Value	17	1,020.53		
Annualized Increase		0.01		
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SL Reduction	0.38	0.52		**0.9**
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Climate Value	30.1	1,171.28	0.89	
Annualized Increase		0.03		
Degradation Rate		113.43%		
Adjusted RSL		9.1		
Adjusted Alpha		1.49		**1.66**
Adjusted Beta		0.81		**0.7**
SL Reduction	0.39	1.22	1.22	**2.83**
Annual Risk Premium				**12,538**

STEP 6A. CALCULATE CLIMATE IMPACT METRICS FOR GRADUAL DAMAGE TYPES

For gradual damage mode types, calculate service life reduction as follows:

- Annualized Increase: $\frac{ClimateValueChange}{BaselineValue \times RemainingServiceLife}$
- Degradation Rate: $1 + AnnualizedIncrease \times DamageFactor \times RemainingServiceLife$
- Adjusted RSL: $\frac{RemainingServiceLife}{DegradationRate}$
- Adjusted Beta: If RSL =< 0, then $\frac{CurrentAge + AdjustedRSL}{DesignLife}$, else beta
- Adjusted Alpha: $Log(\left(-Log\left(\frac{CurrentCI}{100}, \frac{100}{CIterminal}\right)\right), \frac{CurrentAge}{DesignLife \times AdjustedBeta})$
- Service Life Reduction: If RSL > 0, 0, else $RemainingServiceLife - AdjustedRSL$

	Damage Modes			
Climate Variable	**Max Temperature**	**Cooling Degree Days**	**Rainfall (in/day)**	**Totals**
Damage Mode	Excessive Runtime for HVAC Cooling Systems	Excessive Runtime for HVAC Cooling Systems	Water infiltration and flooding cause damage to interiors and services	
Damage Type	Abrupt	Gradual	Abrupt	
Damage Effect	Condition Loss	Service Life Reduction	Condition Loss	
Threshold	100	65	6	
Damage Likelihood	0.75	0.25	0.25	
Damage Extent	0.05	0.5	0.8	
Baseline	12.16	923.22	0.00	
		50th Percentile		
Climate Value	17	1,020.53		
Annualized Increase		0.01		
Degradation Rate		105.27%		
Adjusted RSL		9.81		
Adjusted Alpha		1.43		
Adjusted Beta		0.85		**0.83**
SL Reduction	0.38	0.52		**0.9**
Annual Risk Premium				**3,997**
		90th Percentile		
Climate Value	30.1	1,171.28	0.89	
Annualized Increase		0.03		
Degradation Rate		113.43%		
Adjusted RSL		9.1		
Adjusted Alpha		1.49		**1.66**
Adjusted Beta		0.81		**0.7**
SL Reduction	0.39	1.22	1.22	**2.83**
Annual Risk Premium				**12,538**

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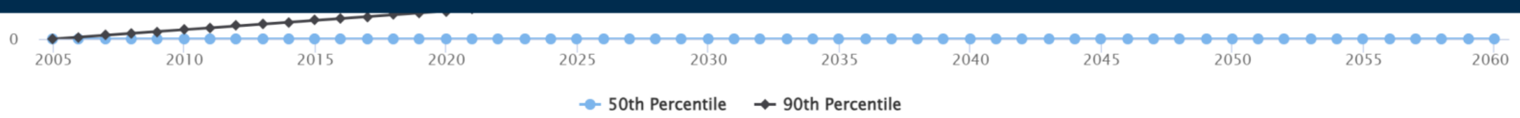
STEP 6B. CALCULATE CLIMATE IMPACT METRICS FOR ABRUPT DAMAGE TYPES

For abrupt damage mode types, calculate service life reduction as follows:

- Service Life Reduction: If RSL =< 0, 0, else $RemainingServiceLife \times DamageLikelihood \times DamageFactor \times (1 - (\frac{365 - ClimateValueChange}{365})^{365})$



	Damage Modes			
Climate Variable	**Max Temperature**	**Cooling Degree Days**	**Rainfall (in/day)**	**Totals**
Damage Mode	Excessive Runtime for HVAC Cooling Systems	Excessive Runtime for HVAC Cooling Systems	Water infiltration and flooding cause damage to interiors and services	
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Damage Extent	0.05	0.5	0.8	
Baseline	12.16	923.22	0.00	
		50th Percentile		
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Annualized Increase		0.01		
Degradation Rate		105.27%		
Adjusted RSL		9.81		
Adjusted Alpha		1.43		
Adjusted Beta		0.85		**0.83**
SL Reduction	0.38	0.52		**0.9**
Annual Risk Premium				**3,997**
		90th Percentile		
Climate Value	30.1	1,171.28	0.89	
Annualized Increase		0.03		
Degradation Rate		113.43%		
Adjusted RSL		9.1		
Adjusted Alpha		1.49		**1.66**
Adjusted Beta		0.81		**0.7**
SL Reduction	0.39	1.22	1.22	**2.83**
Annual Risk Premium				**12,538**

STEP 7. AGGREGATE SERVICE LIFE REDUCTION ACROSS ALL DAMAGE MODES

If there are multiple damage modes applicable for a component, aggregate service life reduction across all n damage modes:

- Total Service Life Reduction: $\sum_{n}^{1} ServiceLifeReduction$

		Damage Modes		
Climate Variable	**Max Temperature**	**Cooling Degree Days**	**Rainfall (in/day)**	**Totals**
Damage Mode	Excessive Runtime for HVAC Cooling Systems	Excessive Runtime for HVAC Cooling Systems	Water infiltration and flooding cause damage to interiors and services	
Damage Type	Abrupt	Gradual	Abrupt	
Damage Effect	Condition Loss	Service Life Reduction	Condition Loss	
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Climate Value	17	1,020.53		
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Annualized Increase		0.03		
Degradation Rate		113.43%		
Adjusted RSL		9.1		
Adjusted Alpha		1.49		**1.66**
Adjusted Beta		0.81		**0.7**
SL Reduction	0.39	1.22	1.22	**2.83**
Annual Risk Premium				**12,538**

STEP 8. CALCULATE WEATHER ADJ. DEGRADATION PARAMETERS ACROSS ALL DAMAGE MODES

- Total Adjusted RSL:
  - $RSL - TotalServiceLifeReduction$
- Total Adjusted Beta:
  - If RSL > 0, then $\frac{Current\ Age + Total\ Adjusted\ RSL}{DesignLife}$, else beta
- Total Adjusted Alpha:
  - $Log\left(\left(-Log\left(\frac{CurrentCI}{100}, \frac{100}{CIterminal}\right)\right), \frac{CurrentAge}{DesignLife \times TotalAdjustedBeta}\right)$

Scenario

IMCOM_B30_only

Only B30 for all of IMCOM

Years: 3
Hazards:

Filter

Systems All

Components All

Component Details

Component : **D3030 COOLING GENERATING SYSTEMS**

Material Category : **D303001 CHILLED WATER SYSTEMS**

Component Type: **Cooling Tower, Stainless Steel - 1000 TN**

Year Built: **2019**

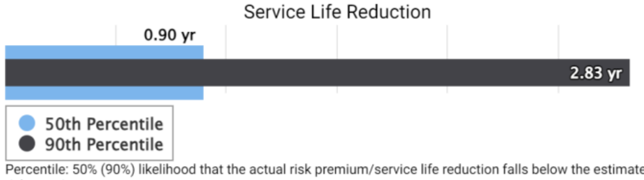
Age: **3**

Design Life: **15**

Quantity: : **1 EA**

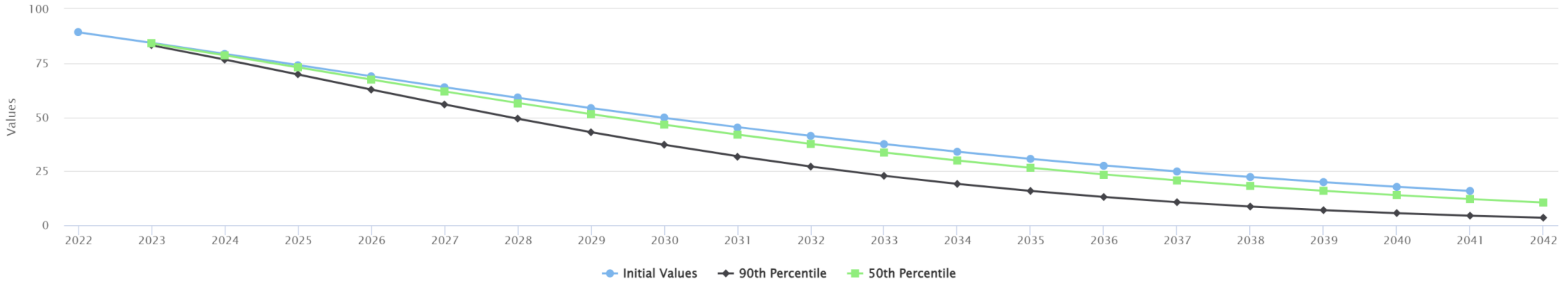
Risk Analysis

CRV : **$686,880**



Percentile: 50% (90%) likelihood that the actual risk premium/service life reduction falls below the estimated risk premium.

Projected Condition



Component Specific Damage

Climate Variable	Damage Mode	Damage Type	Damage Effect	Threshold	SL Reduction
Max Temperature	Excessive Runtime for HVAC Cooling Systems	Abrupt	Condition Loss	100	0.38
Cooling Degree Days	Excessive Runtime for HVAC Cooling Systems	Gradual	Service Life Reduction	65	0.52
Rainfall (in/day)	Water infiltration and flooding cause damage to interiors and services	Abrupt	Condition Loss	6	

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STEP 9. CALCULATE ANNUAL RISK PREMIUM

Annual Risk Premium:

$$\frac{ComponentReplaceValue \times TotalServiceLifeReduction}{DesignLife \text{ x } RemainingServiceLife}$$

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Scenario List > Organizations > Avinger > Workshop > Component

Scenario

IMCOM_B30_only

Only B30 for all of IMCOM

Years	Hazards
3	

Filter

Systems All

Components All

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Material Category : **D303001 CHILLED WATER SYSTEMS**

Component Type: **Cooling Tower, Stainless Steel - 1000 TN**

Year Built: **2019**

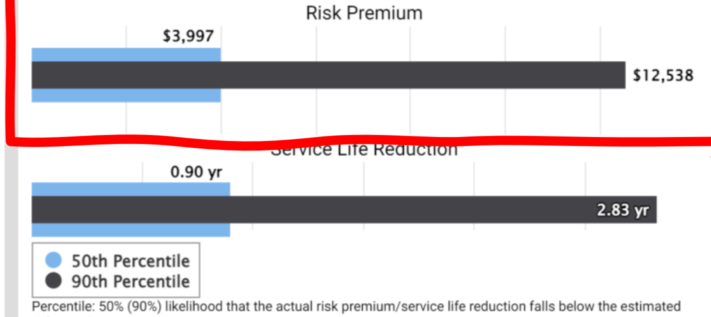
Age: **3**

Design Life: **15**

Quantity: : **1 EA**

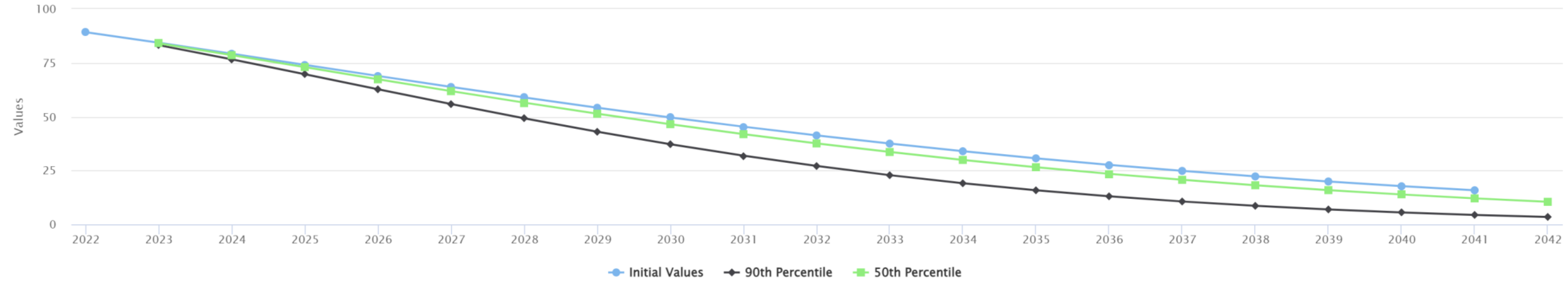
Risk Analysis

CRV : **$686,880**



Percentile: 50% (90%) likelihood that the actual risk premium/service life reduction falls below the estimated risk premium.

Projected Condition



Component Specific Damage

Climate Variable	Damage Mode	Damage Type	Damage Effect	Threshold	SL Reduction
Max Temperature	Excessive Runtime for HVAC Cooling Systems	Abrupt	Condition Loss	100	0.38
Cooling Degree Days	Excessive Runtime for HVAC Cooling Systems	Gradual	Service Life Reduction	65	0.52
Rainfall (in/day)	Water infiltration and flooding cause damage to interiors and services	Abrupt	Condition Loss	6	

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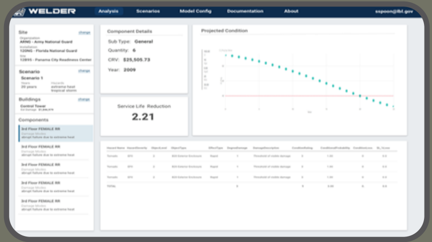
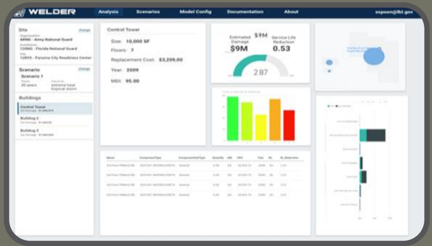
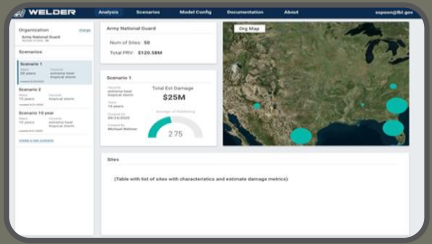
SUMMARY



Incorporate impacts of climate risk on facility condition



Evaluate climate scenarios to identify potential work requirements



Prioritize facility investments that lower risk and improve resilience

QUESTIONS?

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BERKELEY LAB

NERSC

ESTCP

ERDC

CERL CONSTRUCTION ENGINEERING RESEARCH LABORATORY

SUSTAINMENT MANAGEMENT TCX SYSTEM