CPQR Simulation Approach

RASTF

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Joe Bowring

Siva Josyula

Monitoring Analytics

Competitive Offer

- **Unit specific competitive offer for a CP resource:**

$$p = Net\ ACR + Net\ (Expected\ Penalties\ - Expected\ Bonuses)$$

$$or, p = \begin{cases} Net\ ACR + CPBR\ \times H \times (\overline{B} - \overline{A}), & if\ \overline{B} < \overline{A} \\ Net\ ACR + PPR\ \times H \times (\overline{B} - \overline{A}), & if\ \overline{A} < \overline{B} \end{cases}$$

- **Where:**
  - **Net ACR = Gross ACR − Net E&AS revenues**
  - **CPBR is the average bonus payment rate during PAI**
  - **PPR is the average nonperformance charge rate during PAI (PPR values in tariff).**
  - **H is the expected number of PAI divided by 12**
  - **$\overline{A}$ is the expected unit performance during PAI**
  - **$\overline{B}$ is the expected balancing ratio during PAI**

CPQR

- **CPQR includes both the expected net nonperformance charges and the cost to mitigate the risk associated with the estimated net nonperformance charges.**
- **Net nonperformance charges can be simulated to account for uncertainty in the inputs to calculation (A, B, H).**
- **The MMU framework for evaluating the simulation approach was presented on March 24, 2022.**

CPQR

CPQR = E(net penalties) + Cost of mitigating risk

Where:

- ***E(net penalties):*** **expected value (mean) from distribution of simulated outcome**
  - Can be positive, negative, or zero.
- ***Cost of mitigating risk=Risk Cost x (Extreme Value – Mean)***
- **Extreme Value: for example 30th percentile or 95th percentile of distribution of simulated outcomes.**
- **Risk Cost:**
  - Cost of incurring risk of nonperformance penalties
  - Affected by factors including portfolio

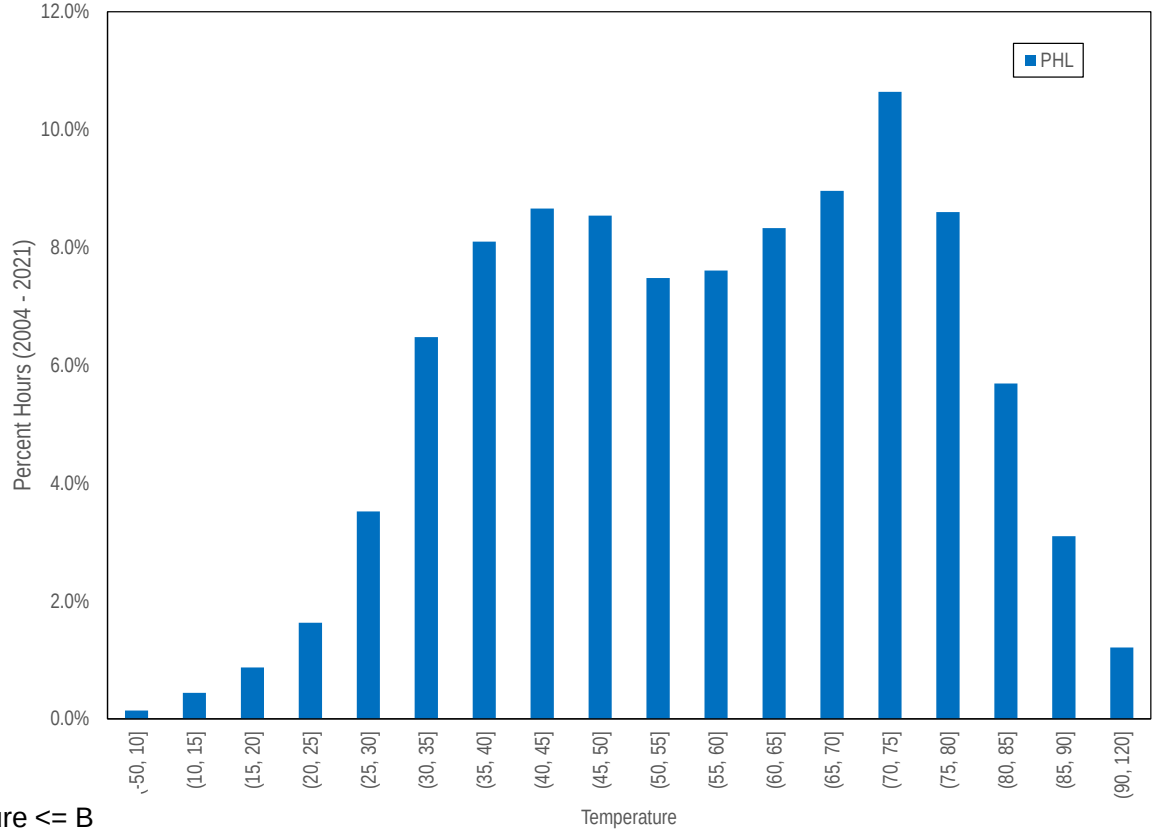
Simulation Model

- **Simulation of CP nonperformance charges and bonus payments.**
- **The key inputs are:**
  - **A: Unit specific performance during PAH**
  - **B: Balancing Ratio during PAH**
  - **H: Number of PAH**
  - **CPBR: Average bonus payment rate during PAI**
  - **PPR: Nonperformance charge rate during PAI for the unit's zone (PPR value in tariff)**
  - **Stop loss limit**
  - **Tax rate**
  - **Historical temperature data.**

Simulation Model – Stage 1

- **Two stage simulation.**
- **First stage simulates future temperature outcomes based on history.**
  - **Location is a proxy weather station close to the unit. For this example, location is PHL.**
  - **Assumes temperature is a multinomial random variable with probability calculated empirically.**
- **500 sample years generated using 18 years (2004 – 2021) of weather history.**
  - **Each sample distributes 8,760 hours into the specified temperature ranges.**

Example: PHL Temperature History



(A, B]: A < Temperature <= B

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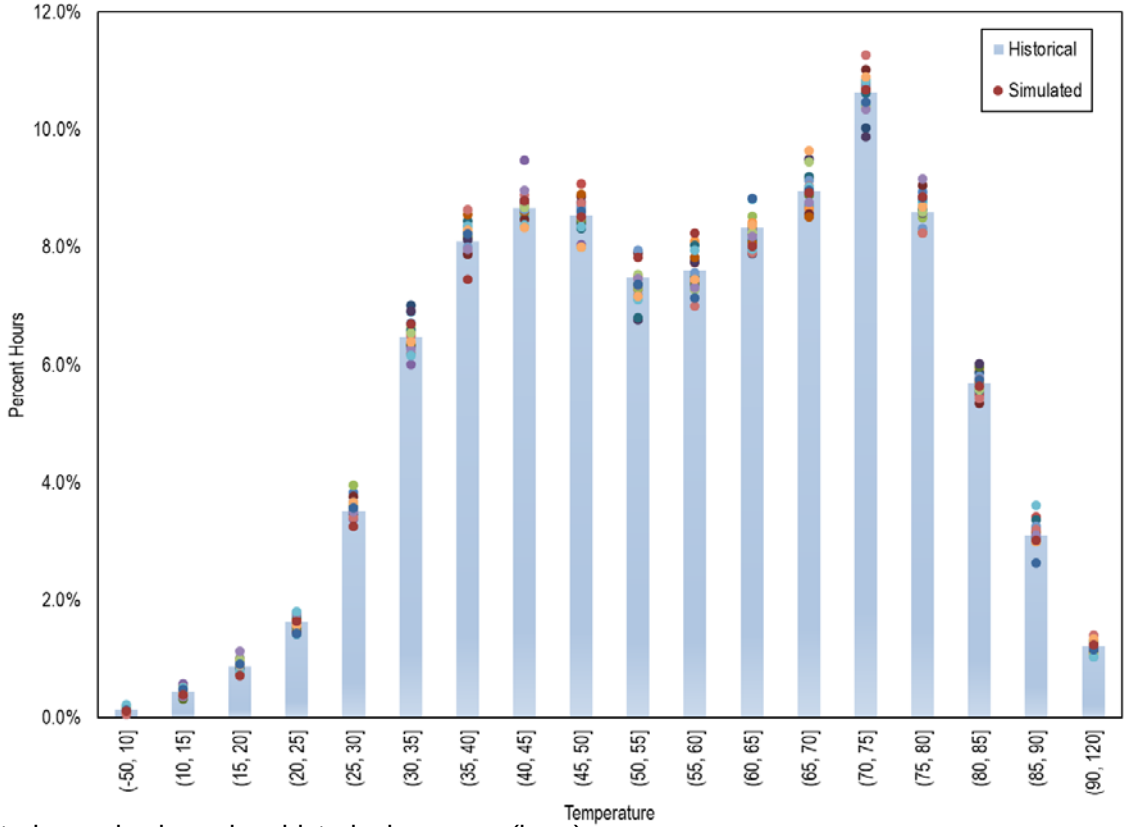
Sample Simulated Temperature Distributions



Circles show 20 simulated samples based on historical average (bars)

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Sample Simulated Temperature Distributions

- **Table shows number of hours out of 8,760 that fall into each temperature category from three sample simulated years.**

T_i	$N(T_i)$		
	Sample Year 1	Sample Year 2	Sample Year 3
(-50, 10]	9	8	11
(10, 15]	36	45	47
(15, 20]	79	87	66
(20, 25]	155	128	155
(25, 30]	335	304	346
(30, 35]	552	572	580
(35, 40]	721	714	718
(40, 45]	761	765	749
(45, 50]	759	795	701
(50, 55]	629	638	640
(55, 60]	640	651	659
(60, 65]	734	691	747
(65, 70]	758	762	802
(70, 75]	933	938	933
(75, 80]	783	773	745
(80, 85]	500	481	490
(85, 90]	280	299	268
(90, 120]	96	109	103
Total	8,760	8,760	8,760

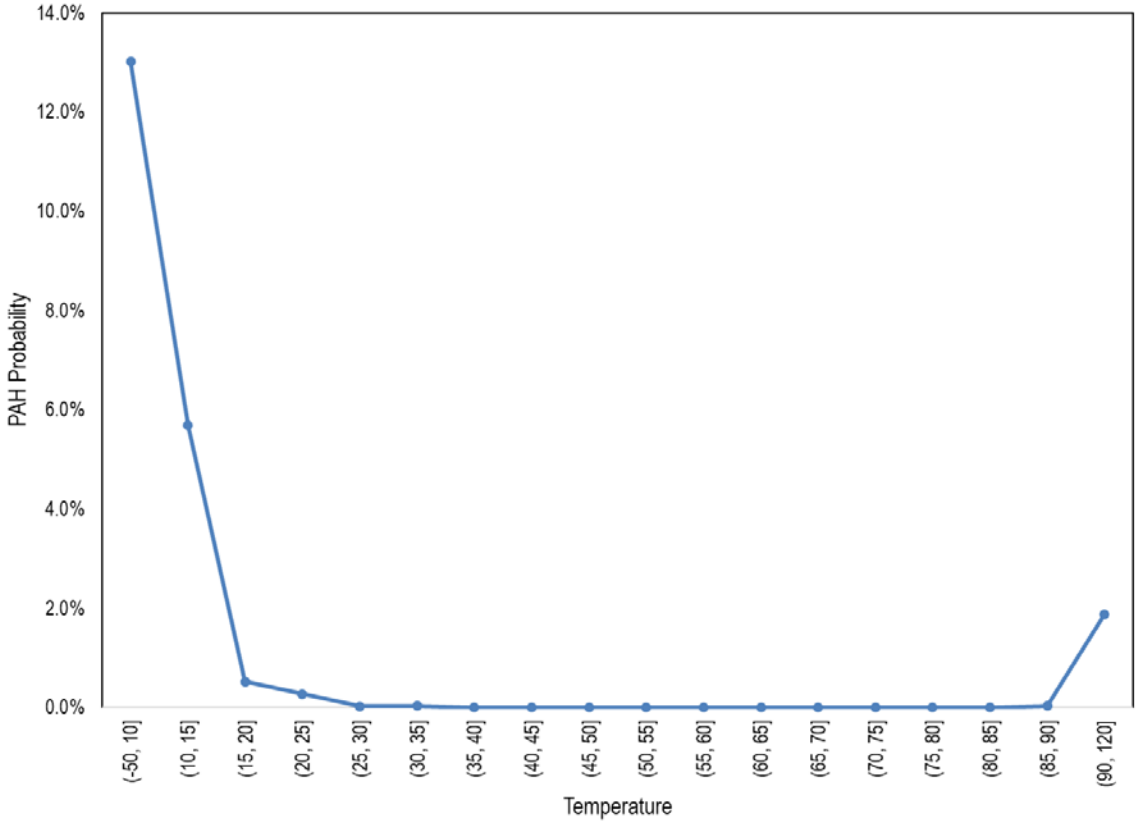
Simulation Model – Stage 2

- **Second stage simulates:**
  - **conditional probability of PAH given temperature,**
  - **conditional probability of forced outage given temperature,**
  - **balancing ratio during PAH given temperature.**

Simulation Model – Stage 2

- **Conditional probability of PAH given a temperature range is based on 10 year history of temperature and PAH or proxy.**
  - **PAH includes emergency actions that would have triggered PAH prior to Capacity Performance.**
  - **Temperature dependent PAH probabilities calculated for the zone where unit is located.**
- **Fewer emergencies since CP implemented.**
- **Ten year history overestimates emergencies.**

PAH Conditional Probabilities

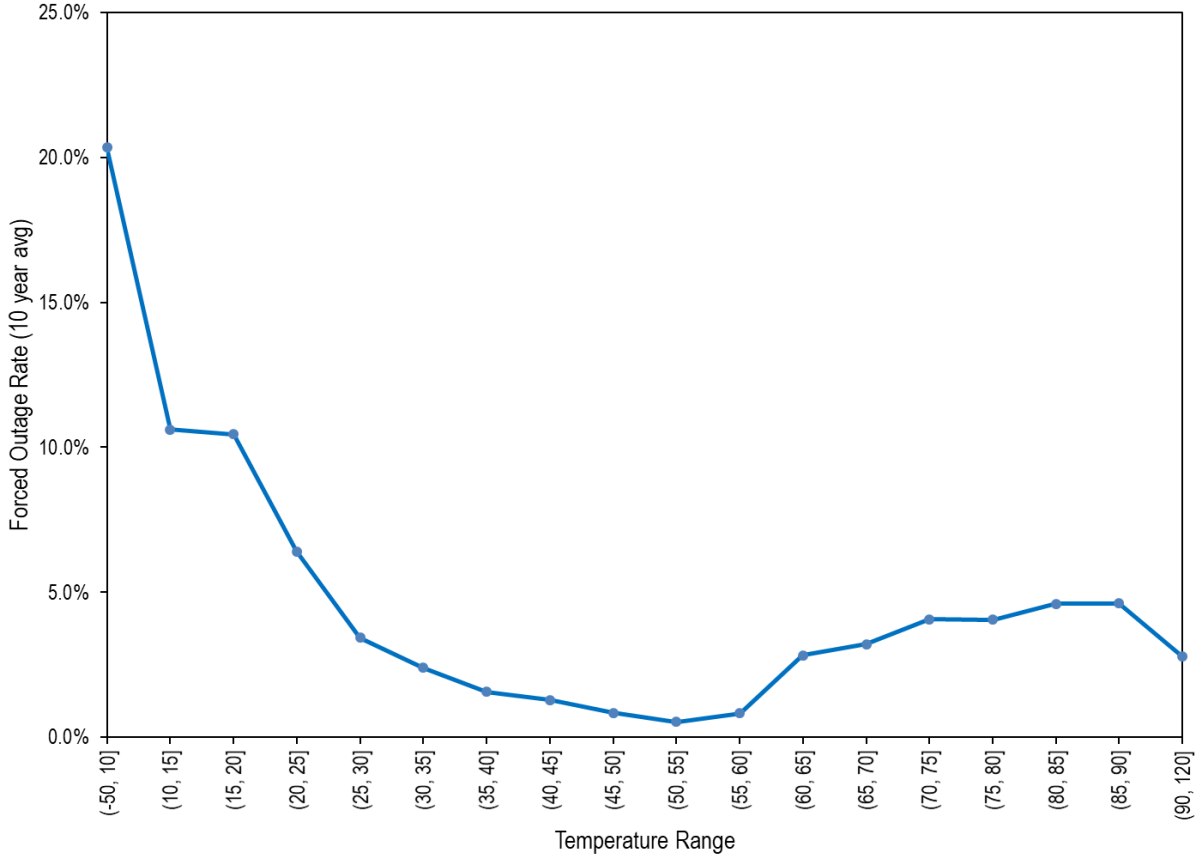


- **Data from 2012 through 2021.**
- **All emergency actions in eastern PJM included:**
  - **RTO**
  - **Mid-Atlantic Dominion**
  - **BGE & Pepco**

Simulation Model – Stage 2

- **Conditional probability of unit forced outages given a temperature range is based on 10 year history of temperature and forced outages**
  - **Unit specific calculation based on GADS reported forced outages.**
  - **Equivalent forced outage rate calculated that includes both derates and full unit forced outages.**
- **Outage rates lower since CP implemented.**
- **Ten year history overestimates forced outage rates.**

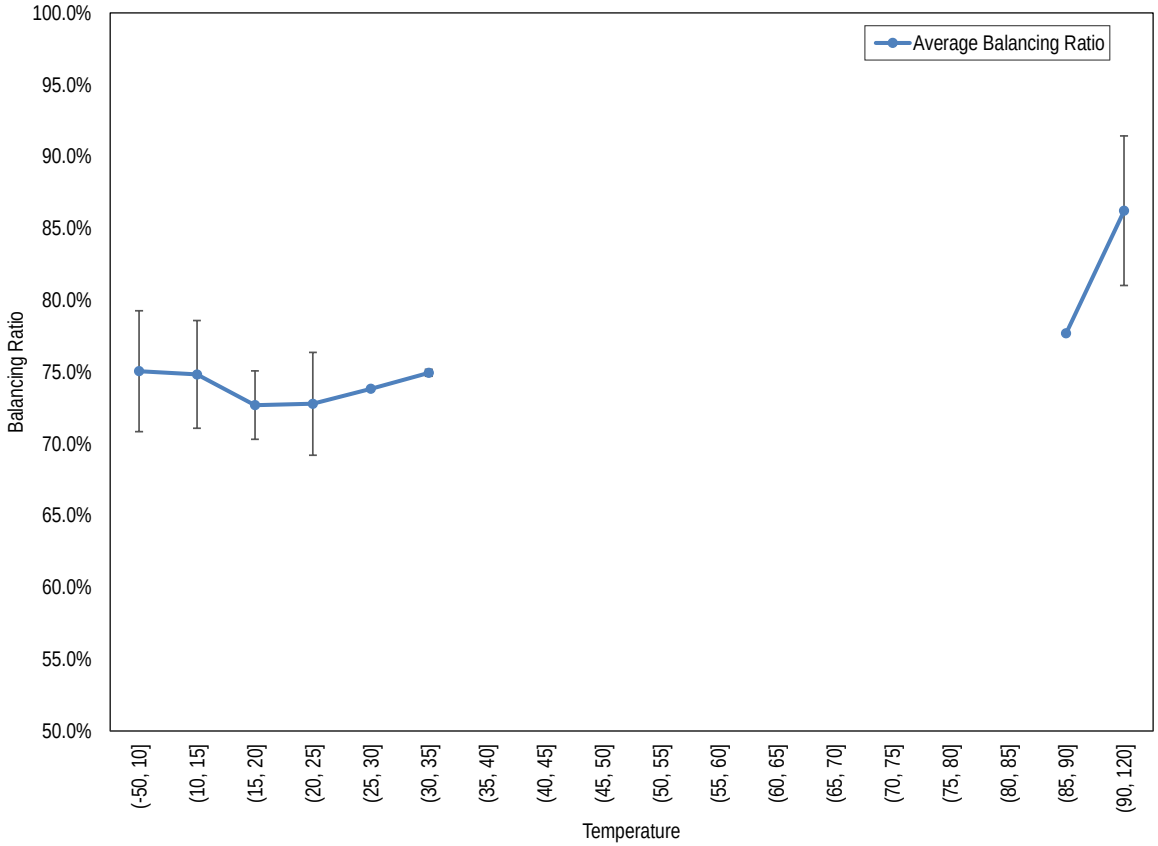
Example Unit Forced Outage Probabilities



Balancing Ratio (B)

- **Conditional value of balancing ratio during a PAH, given a temperature range, is based on 10 year history of balancing ratios during PAH or proxy PAH.**
- **Balancing ratio is used to calculate expected performance for each resource during a PAI.**
- **B calculated for the RTO even if the emergency was regional. Same PAH as used in the PAH history.**
  - **RTO**
  - **Mid-Atlantic & Dominion**
  - **BGE & Pepco**

Balancing Ratio



- **Balancing ratio exists only for categories with historical PAH or proxy PAH.**
- **Error bars show the standard deviation of balancing ratio for each temperature category.**
- **No error bars indicate very few PAH (1 or 2).**

Simulating penalties and bonuses – Stage 2

- For each temperature range, conditional probabilities of PAH and unit forced outages are simulated as results of a binomial process (repeated Bernoulli trials).
- 1,000 Bernoulli trials:
  - PAH = 1 or 0, and FO = 1 or 0.
  - If PAH = 1 and FO = 1, then penalty.
  - If PAH = 1 and FO = 0 then bonus.
  - If PAH = 0, no penalty or bonus regardless of FO.
- For each temperature range, B is simulated as a normal random variable with the historical mean and standard deviation.

Simulating penalties and bonuses – Stage 2

- **Each binomial process generates conditional probabilities for a given temperature range, i:**
  - $Probability\ of\ PAH,\ p(^{PAH}/_{T}) = \sum(PAH)/1,000$
  - $Probability\ of\ penalties, p(^{penalties}/_{T}) = \sum(PAH * FO)/1,000$
  - $Probability\ of\ bonuses, p(^{bonuses}/_{T}) = \sum(PAH * (1 - FO))/1,000$
- **For each penalty or bonus hour, a unit would pay maximum nonperformance charges for MW = B*UCAP.**
- **Similarly, a unit is eligible for bonuses for MW = (1 – B)*UCAP.**
- **Incorporating the simulated B:**
  - $Penalty\ probability\ P(^{pen}/_{T_i}) = \sum(PAH * FO * B_i)/1,000$
  - $Bonus\ probability\ P(^{bon}/_{T_i}) = \sum(PAH * (1 - FO) * (1 - B_i))/1,000$

Net Penalty Probability – Stage 2

- 1,000 such conditional probabilities are generated for each temperature category.
- The net penalty probability for temperature category i is calculated as:

$$p\left(net/T_i\right) = P(pen/T_i) - P(bon/T_i)$$

- Portion of underperformance can be excused.
  - Results in effective penalty rate lower than the tariff defined rate.
  - Results in bonus payment rate lower than penalty rate.

Combining Stage 1 and Stage 2

- **Each of the 1,000 stage 2 simulated outcomes is multiplied by the number of hours in that temperature category $N(T_i)$, for each of the 500 simulated years to get the net penalty hours.**
- $(Net\ Penalty\ Hours)_i = N(T_i) * P(^{net}/_{T_i})$
- **Total net penalty hours =** $\sum_i (Net\ penalty\ hours)_i$
- **Results in 500,000 possible outcomes for each unit for net non performance charges in a year.**
  - **Mean is the expected net penalty hours in a year.**
  - **Percentiles show the distribution of net penalty hours in a year.**

Sample Results: Net nonperformance charges

Net Nonperformance Charges ($/MW-day) UCAP	
Mean (m)	-$7.7
Percentiles	
p5	-$11.2
p10	-$10.4
p25	-$9.1
p50	-$7.7
p75	-$6.3
p90	-$5.2
p95	-$4.4
p95 - Mean (a)	$3.3
Cost of Risk (b)	10%
Risk Premium (c=a*b)	$0.33
Mean + Risk Premium (m+c)	-$7.39

- **Using nonperformance charge rate = $3,366.27 per MWh (EMAAC, 2023/2024 BRA)**
- **Net nonperformance charges ($/MW-day) = Net penalty hours*Rate ($/MWh)/365.**

Notes

- **The simulation outcome is the $/MW-day UCAP value.**
  - **Auction EFORd needed to convert to $/MW-day ICAP terms.**
- **No GADS data for intermittent resources.**
  - **The source of risk is due to both intermittency and forced outages.**
  - **ELCC reduces committed UCAP, reduces risk of penalties.**
- **Newer units without long history need proxy outage rates if they have not operated under extreme temperatures.**
  - **Nonperformance risk is concentrated in extreme temperature ranges.**

Monitoring Analytics, LLC
2621 Van Buren Avenue
Suite 160
Eagleville, PA
19403
(610) 271-8050

MA@monitoringanalytics.com
www.MonitoringAnalytics.com