Southern California Gas Company and San Diego Gas & Electric 2027 CAP

Chapter 2 Workpapers to the Prepared Direct Testimony of Eduardo Martinez

Weather Design

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Weather for SoCalGas: Heating Degree Days –Average and Cold Year Designs; and Winter Peak Day Design Temperatures

October 2025

I. Overview

Southern California Gas Company's service area extends from Fresno County to the Mexican border. To quantify the overall temperature experienced within this region, SoCalGas aggregates daily temperature recordings from fifteen U.S. Weather Bureau weather stations first into six temperature zones and then into one system average heating degree-day ("HDD") figure. The table below lists weather station locations by temperature zones.

Table 1

Weather Stations by Temperature Zones and Weights

Temperature Zone	Weight	Station (After 10/31/2002)	Station (Before 11/1/2002)
1. High mountain	0.0058	Big Bear Lake	Lake Arrowhead
2. Low desert	0.0391	Palm Springs	Palm Springs
		El Centro	Brawley
3. Coastal	0.1831	Los Angeles Airport	Los Angeles Airport
		Newport Beach	Newport Beach Harbor
		Santa Barbara Airport	Santa Barbara Airport
4. High desert	0.0744	Bakersfield	Bakersfield Airport
		Lancaster Airport	Palmdale
		Fresno	Visalia
5. Interior valleys	0.3865	Burbank	Burbank
		Pasadena	Pasadena
		Ontario	Pomona Cal Poly
		Rialto	Redlands
6. Basin	0.3112	Los Angeles Civic Center	Los Angeles Civic Center/ Downtown-USC
		Santa Ana	Santa Ana

SoCalGas uses 65° Fahrenheit to calculate the number of HDDs. One heating degree day is accumulated for each degree that the daily average is below 65° Fahrenheit. To arrive at the HDD figure for each temperature zone, SoCalGas uses the simple average of the weather station HDDs in that temperature zone. To arrive at the system average HDDs figure for its entire service area, SoCalGas weights the HDD figure for each zone using the proportion of gas customers within each temperature zone based on year 2024 customer counts. These weights have been used in calculating the data shown from January 2005 to December 2024.

Daily weather temperatures are from the National Climatic Data Center or from preliminary data that SoCalGas captures each day for various individual weather stations as well as for its system average values of HDD. Annual and monthly HDDs for the entire service area from 2005 to 2024 are listed in Table 2, below.

Table 2

Calendar Month Heating Degree-Days (Jan. 2005 through Dec. 2024)

	Month												Total
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**"Cal-Year"**
2005	288	209	177	116	35	10	4	1	9	43	99	234	**1225**
2006	273	200	338	163	28	3	0	1	5	36	105	279	**1432**
2007	348	216	126	116	49	16	1	1	12	36	126	355	**1402**
2008	347	263	148	124	76	8	1	0	2	24	75	334	**1402**
2009	197	259	195	135	18	15	3	4	1	44	118	321	**1310**
2010	254	222	174	163	72	14	8	9	13	42	203	271	**1446**
2011	252	307	213	105	80	27	2	4	6	39	207	350	**1591**
2012	223	237	223	118	38	11	6	1	1	16	111	301	**1286**
2013	330	264	125	66	16	4	1	2	2	44	104	257	**1216**
2014	142	148	90	76	19	4	0	1	1	5	66	224	**776**
2015	182	94	64	67	69	4	1	0	1	4	163	318	**967**
2016	282	112	113	54	45	7	1	1	3	14	111	270	**1014**
2017	321	208	100	44	50	6	1	0	4	12	51	176	**972**
2018	155	211	181	70	56	6	0	0	1	10	79	248	**1020**
2019	263	349	165	53	76	9	2	1	3	23	125	265	**1336**
2020	242	175	205	108	11	3	2	2	1	10	149	238	**1146**
2021	259	180	232	76	37	7	0	1	9	41	74	338	**1254**
2022	240	204	136	74	40	3	1	0	3	13	191	303	**1209**
2023	341	313	298	125	76	20	2	0	2	14	85	174	**1451**
2024	269	253	211	126	50	8	3	0	4	19	159	231	**1333**
20-Yr-Avg (Jan 2005-Dec 2024)													
Avg.	260.5	221.3	175.7	98.9	47.1	9.3	1.9	1.4	4.2	24.6	120.0	274.4	**1239.4**
St.Dev.	60.4	63.7	67.9	35.7	22.3	6.2	2.0	2.1	3.8	14.5	45.6	53.2	**204.6**
Min.	141.8	94.2	63.8	43.8	11.0	3.2	0.1	0.1	0.7	4.3	50.6	173.8	**776.3**
Max.	348.3	349.5	338.0	162.7	80.2	26.5	8.4	9.3	13.4	44.5	206.7	354.6	**1590.6**

II. Calculations to Define Our Average-Temperature Year

The simple average of the 20-year period (January 2005 through December 2024) was used to represent the Average Year total and the individual monthly values for HDD. In this Cost Allocation Proceeding (CAP), the standard deviation has been calculated using an approach that compensates for the annual HDD values for the years 2014-2018 in SoCalGas' service territory being dramatically lower than in any preceding year going back to 1950[1]. A regression with a time trend and a dummy variable for the years 2014-2018 has been used to estimate a shift in the level of annual HDD that occurred beginning in 2014. A dummy variable takes the value one for some observations to indicate the presence of an effect or membership in a group and zero for the remaining observations. Estimating the effect of the dummy variable gives an estimate of that effect or the impact of membership in that group. A dummy variable is used here to estimate the average effect on annual HDD of a given year having membership in the group of years 2014-2018. The dataset is SoCalGas system-wide annual HDD for the years 2005-2024. The regression equation is:

$$HDD_t = \alpha + \beta * t + \beta_{2014-2018} * D_{2014-2018} + \varepsilon$$

where $D_{2014-2018}$ is a dummy variable for the years 2014-2018 and $\beta_{2014-2018}$is the corresponding dummy coefficient. This regression equation estimates average HDD over the period 2005-2024 controlling for time trends in HDD and the warm weather regime of years 2014-2018. It's important to note that p-value for the estimate of $\beta_{2014-2018}$ is about than 0.001%, indicating an extremely low probability that membership in the group of years 2014-2018 had no effect on annual HDDs. Please see table 3 below for the full regression output.

[1] The same approach to control warm weather regime from 2014 to 2018 when estimating standard deviation was used in last CAP 2024.

Table 3

Dummy Regression for Calculation of Heating Degree-Day Standard Deviation

Regression Statistics					
Multiple R	0.84669176				
R Square	0.716886937				
Adjusted R Square	0.683579518				
Standard Error	115.1066196				
Observations	20				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	570348.4679	285174.2339	21.52334087	2.19614E-05
Residual	17	225242.0759	13249.53388		
Total	19	795590.5438			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	1377.758303	54.0526788	25.4891771	5.50506E-15	
Time	-4.182938582	4.514853073	-0.926483878	0.367161601	
Regime Dummy	-377.7171654	60.12274634	-6.282433661	8.26324E-06	

The dummy variable's estimated effect, $\beta_{2014-2018}$, is subtracted from the actual annual HDD data for years 2014-2018 to adjust the data to remove the level shift. The standard deviation has been calculated using this adjusted dataset. This standard deviation has been used to design the two Cold Years based on a "1-in-10" and "1-in-35" chance, ***c***, that the respective annual "Cold Year" $\boldsymbol{hdd_c}$ value would be exceeded.

A probability model for the annual HDD is based on a t-Distribution with N-1 degrees of freedom, where N is the number of years of HDD data we use, μ is the average of the last 20 years of HDD, and S_{20} is the average of the standard deviations of the 20 most recent 20-year periods:

$U = (HDD_y - \mu)/S_{20}$, has a t-Distribution with N-1 degrees of freedom.

III. Calculating the Cold-Temperature Year Weather Designs

Cold Year HDD Weather Designs

For SoCalGas, cold-temperature-year HDD weather designs are developed with a 1-in-35 annual chance of occurrence. In terms of probabilities this can be expressed as the following for a "1-in-35" cold-year HDD value in equation 1 and a "1-in-10" cold-year HDD value in equation 2, with Annual HDD as the random variable:

(1) Prob { Annual HDD > "1-in-35" Cold-Yr HDD } = 1/35 = 0.0286

(2) Prob { Annual HDD > "1-in-10" Cold-Yr HDD } = 1/10 = 0.1000

An area of 0.0286 under one tail of the T-Distribution translates to 2.025 standard deviations above an average-year based on a t-statistic with 19 degrees of freedom. Using the standard deviation calculated as described earlier, which is 111.7 HDD, these equations yield values of about 1,465 HDD for a "1-in-35" cold year and 1,387 HDDs for a "1-in-10" cold year. (An area of 0.1000 under one tail of the T-Distribution translates to 1.328 standard deviations above an average-year based on a t-statistic with 19 degrees of freedom.) For example, the "1-in-35" cold-year HDD is calculated as follows:

(3) Cold-year HDD = 1,465, which equals approximately
1,239 average-year HDDs + 2.025 * 111.7

Table 4 shows monthly HDD figures for "1-in-35" cold year, "1-in-10" cold year and, average year temperature designs. The monthly average-temperature-year HDDs are calculated from weighted monthly HDDs from 2005 to 2024, as shown as the bottom of Table 2, above. For example, the average-year December value of 274.3 HDD equals the simple average of the twenty December HDD figures from 2005 to 2024. SoCalGas calculates the cold--temperature-year monthly HDD values using the same distribution of average-year HDDs. For example, 22.14 percent (274.3 / 1239) of average-temperature-year HDDs occurred in December, so the estimated number of HDDs during December for a 1-in-35 cold-year is equal to 1,465 HDDs multiplied by 22.1 percent, or 324.3 HDDs.

Table 4

Calendar Month Heating Degree-Day Designs

	Cold		Average	Hot	
	1-in-35 Design	**1-in-10 Design**		**1-in-10 Design**	**1-in-35 Design**
January	307.9	291.5	260.4	229.3	212.9
February	261.6	247.7	221.2	194.8	180.9
March	207.6	196.6	175.6	154.6	143.6
April	116.9	110.7	98.9	87.0	80.8
May	55.7	52.8	47.1	41.5	38.5
June	11.1	10.5	9.3	8.2	7.6
July	2.2	2.1	1.9	1.7	1.6
August	1.7	1.6	1.4	1.2	1.2
September	5.0	4.7	4.2	3.7	3.5
October	29.1	27.6	24.6	21.7	20.1
November	141.9	134.3	120.0	105.7	98.1
December	324.3	307.0	274.3	241.5	224.2
	1465	**1387**	**1239**	**1091**	**1013**

IV. Adjusting Forecasted HDDs for a Climate-Change Trend

SoCalGas incorporates a climate-change warming trend that reduces HDDs by 7 HDDs per year over the forecast period. The annual reduction is based on the latest twenty-year trend in 20-year-averaged HDDs. That is, they are based on the observed trend in changes starting with average HDDs for years 1986-2005, then 1987-2006, 1988-2007...and ending with the average HDDs for years 2005-2024.

Table 5 below shows system HDDs, rolling 20-year-averaged HDDs, and the annual changes in those rolling 20-year averages. The actual average annual change is -7.3 HDDs for the most recent twenty of the 20-year averages (with ending years from 2005 through 2024). A simple "ordinary least squares" regression-fitted time trend (using Microsoft Excel's "LINEST" function) was applied to those same annual changes, resulting in a fitted estimation of -8.9 HDDs per year. Based on the fitted trend, it was decided to decrease average-year and cold-year forecasted HDDs by 7 HDDs per year, starting with the first forecast year of 2025.

Table 5

Average Annual Changes in 20-Year Averaged Heating-Degree Days

Average Annual Changes in 20-Year-Averaged HDDs			
		Regression Fitted trend	Actual
	20 Year: (2005-2024)	-8.9	**-7.3**
Year	SCG System HDDs	20-year averaged HDDs	Annual change in 20-year averaged HDDs
1985	1589		
1986	1094		
1987	1504		
1988	1372		
1989	1361		
1990	1446		
1991	1407		
1992	1256		
1993	1213		
1994	1469		
1995	1246		
1996	1189		
1997	1158		
1998	1569		
1999	1538		
2000	1369		
2001	1690		
2002	1499		
2003	1339		
2004	1392	1385.0	
2005	1225	1366.8	-18.2
2006	1432	1383.8	16.9
2007	1402	1378.6	-5.1
2008	1402	1380.2	1.5
2009	1310	1377.6	-2.6
2010	1446	1377.6	0.0
2011	1591	1386.7	9.2
2012	1286	1388.3	1.5
2013	1216	1388.4	0.1
2014	776	1353.7	-34.6
2015	967	1339.8	-14.0
2016	1014	1331.0	-8.7
2017	972	1321.8	-9.3
2018	1020	1294.3	-27.5
2019	1336	1284.2	-10.1
2020	1146	1273.1	-11.1
2021	1254	1251.3	-21.8
2022	1209	1236.8	-14.5
2023	1451	1242.4	5.6
2024	1333	1239.4	-2.9

Below tables 6.1 – 6.3 show the complete monthly weather design:

Table 6.1

Calendar Month Heating Degree-Day Designs with Climate-Change Trend

	Cold		Average	Hot	
	1-in-35 Design	**1-in-10 Design**		**1-in-10 Design**	**1-in-35 Design**
Jan-2025	306.4	290.0	258.9	227.8	211.4
Feb-2025	260.3	246.4	220.0	193.6	179.6
Mar-2025	206.7	195.6	174.6	153.6	142.6
Apr-2025	116.3	110.1	98.3	86.5	80.3
May-2025	55.5	52.5	46.9	41.2	38.3
Jun-2025	11.0	10.4	9.3	8.2	7.6
Jul-2025	2.2	2.1	1.9	1.7	1.5
Aug-2025	1.7	1.6	1.4	1.2	1.1
Sep-2025	5.0	4.7	4.2	3.7	3.4
Oct-2025	29.0	27.4	24.5	21.6	20.0
Nov-2025	141.2	133.7	119.3	105.0	97.4
Dec-2025	322.7	305.5	272.7	240.0	222.7
Jan-2026	304.9	288.6	257.4	226.3	210.0
Feb-2026	259.1	245.2	218.7	192.3	178.4
Mar-2026	205.7	194.6	173.6	152.6	141.6
Apr-2026	115.8	109.5	97.7	85.9	79.7
May-2026	55.2	52.2	46.6	41.0	38.0
Jun-2026	10.9	10.4	9.2	8.1	7.5
Jul-2026	2.2	2.1	1.9	1.7	1.5
Aug-2026	1.7	1.6	1.4	1.2	1.1
Sep-2026	5.0	4.7	4.2	3.7	3.4
Oct-2026	28.8	27.3	24.4	21.4	19.9
Nov-2026	140.5	133.0	118.6	104.3	96.8
Dec-2026	321.2	303.9	271.2	238.4	221.1
Jan-2027	303.5	287.1	256.0	224.9	208.5
Feb-2027	257.8	243.9	217.5	191.1	177.1
Mar-2027	204.7	193.6	172.6	151.7	140.6
Apr-2027	115.2	109.0	97.2	85.4	79.1
May-2027	54.9	52.0	46.3	40.7	37.7
Jun-2027	10.9	10.3	9.2	8.1	7.5
Jul-2027	2.2	2.1	1.9	1.6	1.5
Aug-2027	1.6	1.6	1.4	1.2	1.1
Sep-2027	4.9	4.7	4.2	3.7	3.4
Oct-2027	28.7	27.2	24.2	21.3	19.7
Nov-2027	139.8	132.3	118.0	103.6	96.1
Dec-2027	319.6	302.4	269.6	236.9	219.6

Table 6.2

Calendar Month Heating Degree-Day Designs with Climate-Change Trend

	Cold		Average	Hot	
	1-in-35 Design	1-in-10 Design		1-in-10 Design	1-in-35 Design
Jan-2028	302.0	285.6	254.5	223.4	207.0
Feb-2028	256.6	242.7	216.2	189.8	175.9
Mar-2028	203.7	192.6	171.6	150.7	139.6
Apr-2028	114.6	108.4	96.6	84.8	78.6
May-2028	54.7	51.7	46.1	40.4	37.5
Jun-2028	10.8	10.3	9.1	8.0	7.4
Jul-2028	2.2	2.1	1.9	1.6	1.5
Aug-2028	1.6	1.5	1.4	1.2	1.1
Sep-2028	4.9	4.6	4.1	3.6	3.4
Oct-2028	28.6	27.0	24.1	21.1	19.6
Nov-2028	139.2	131.6	117.3	103.0	95.4
Dec-2028	318.1	300.8	268.1	235.3	218.0
Jan-2029	300.5	284.1	253.0	221.9	205.5
Feb-2029	255.3	241.4	215.0	188.6	174.6
Mar-2029	202.7	191.6	170.6	149.7	138.6
Apr-2029	114.1	107.9	96.1	84.3	78.0
May-2029	54.4	51.4	45.8	40.2	37.2
Jun-2029	10.8	10.2	9.1	8.0	7.4
Jul-2029	2.2	2.1	1.8	1.6	1.5
Aug-2029	1.6	1.5	1.4	1.2	1.1
Sep-2029	4.9	4.6	4.1	3.6	3.3
Oct-2029	28.4	26.9	23.9	21.0	19.4
Nov-2029	138.5	130.9	116.6	102.3	94.7
Dec-2029	316.5	299.3	266.5	233.8	216.5
Jan-2030	299.1	282.7	251.6	220.5	204.1
Feb-2030	254.1	240.2	213.7	187.3	173.4
Mar-2030	201.7	190.6	169.7	148.7	137.6
Apr-2030	113.5	107.3	95.5	83.7	77.5
May-2030	54.1	51.2	45.5	39.9	36.9
Jun-2030	10.7	10.1	9.0	7.9	7.3
Jul-2030	2.2	2.1	1.8	1.6	1.5
Aug-2030	1.6	1.5	1.4	1.2	1.1
Sep-2030	4.9	4.6	4.1	3.6	3.3
Oct-2030	28.3	26.7	23.8	20.9	19.3
Nov-2030	137.8	130.3	115.9	101.6	94.0
Dec-2030	315.0	297.7	265.0	232.2	214.9
Jan-2031	297.6	281.2	250.1	219.0	202.6
Feb-2031	252.8	238.9	212.5	186.1	172.1
Mar-2031	200.7	189.6	168.7	147.7	136.6
Apr-2031	113.0	106.8	94.9	83.1	76.9
May-2031	53.9	50.9	45.3	39.6	36.7
Jun-2031	10.7	10.1	9.0	7.9	7.3

Table 6.3

Calendar Month Heating Degree-Day Designs with Climate-Change Trend

	Cold		Average	Hot	
	1-in-35 Design	**1-in-10 Design**		**1-in-10 Design**	**1-in-35 Design**
Jul-2031	2.2	2.1	1.8	1.6	1.5
Aug-2031	1.6	1.5	1.4	1.2	1.1
Sep-2031	4.8	4.6	4.1	3.6	3.3
Oct-2031	28.2	26.6	23.7	20.7	19.2
Nov-2031	137.1	129.6	115.3	100.9	93.4
Dec-2031	313.4	296.2	263.4	230.7	213.4
Jan-2032	296.1	279.7	248.6	217.5	201.1
Feb-2032	251.6	237.7	211.2	184.8	170.9
Mar-2032	199.7	188.7	167.7	146.7	135.6
Apr-2032	112.4	106.2	94.4	82.6	76.4
May-2032	53.6	50.6	45.0	39.4	36.4
Jun-2032	10.6	10.0	8.9	7.8	7.2
Jul-2032	2.2	2.0	1.8	1.6	1.5
Aug-2032	1.6	1.5	1.3	1.2	1.1
Sep-2032	4.8	4.6	4.0	3.5	3.3
Oct-2032	28.0	26.5	23.5	20.6	19.0
Nov-2032	136.5	128.9	114.6	100.2	92.7
Dec-2032	311.9	294.6	261.9	229.1	211.8

V. Calculating the Peak-Day Design Temperature

SoCalGas' 1-in-35 Peak-Day design temperature of 40.6 degrees Fahrenheit, denoted "Deg-F," is determined from a statistical analysis of observed annual minimum daily system average temperatures constructed from daily temperature recordings from the fifteen U.S. Weather Bureau weather stations discussed above. Since we have a time series of daily data by year, the following notation will be used for the remainder of this discussion:

(1) $AVG_{y,d}$ = system avg value of temperature for calendar year "y" and day "d".

The calendar year, y, can range from 1950 through 2024, while the day, d, can range from 1 to 365, for non-leap years, or from 1 to 366 for leap years. The "upper" value for the day, d, thus depends on the calendar year, y, and will be denoted by n(y)=365, or 366, respectively, when y is a non-leap year or a leap year.

For each calendar year, we calculate the following statistic from our series of daily system average temperatures defined in equation (1) above:

$$(2) \qquad MinAVG_y = \min_{d=1}^{n(y)}\{ AVG_{y,d} \}, \text{ for } y=1950, 1951, \ldots, 2024.$$

(The notation used in equation 2 means "For a particular year, y, list all the daily values of system average temperature for that year, then pick the smallest one.")

The resulting minimum annual temperatures are shown in Tables 7.1 and 7.2, below. Most of the minimum temperatures occur in the months of December, January, or February; for a few calendar years the minimums occurred in March or November.

The statistical methods we use to analyze this data employ software developed to fit three generic probability models: the Generalized Extreme Value (GEV) model, the Double-Exponential or GUMBEL (EV1) model and a 2-Parameter Students' T-Distribution (T-Dist) model. [The GEV and EV1 models have the same mathematical specification as those implemented in a DOS-based executable-only computer code that was developed by Richard L. Lehman and described in a paper published in the Proceedings of the Eighth Conference on Applied Climatology, January 17-22, 1993, Anaheim, California, pp. 270-273, by the American Meteorological Society, Boston, MA., with the title "Two Software Products for Extreme Value Analysis: System Overviews of ANYEX and DDEX." At the time he wrote the paper, Dr. Lehman was with the Climate Analysis Center, National Weather Service/NOAA in Washington, D.C., zip code 20233.] The Statistical Analysis System (SAS) procedure for nonlinear statistical model estimation (PROC MODEL) was used to do the calculations. Further, the calculation procedures were implemented to fit the probability models to observed *maxima* of data, like heating degrees. By recognizing that:

$$-\text{MinAVG}_y = -\min_{d=1}^{n(y)}\{\text{AVG}_{y,d}\} = \max_{d=1}^{n(y)}\{-\text{AVG}_{y,d}\}, \text{ for } y=1950, \ldots, 2024$$

`

this same software, when applied to the *negative* of the minimum temperature data, yields appropriate probability model estimation results.

The calculations done to fit any one of the three probability models choose the parameter values that provide the "best fit" of the parametric probability model's calculated cumulative distribution function (CDF) to the empirical cumulative distribution function (ECDF). Note that the ECDF is constructed based on the variable "-MinAVG_y" (which is a *maximum* over a set of *negative* temperatures) with values of the variable MinAVG_y that are the same as shown in Tables 7.1 and 7.2, below.

In Tables 8.1 and 8.2, the data for -MinAVG_y are shown after they have been sorted from "lowest" to "highest" value. The ascending *ordinal* value is shown in the column labeled "RANK" and the empirical cumulative distribution function is calculated and shown in the next column. The formula used to calculate this function is:

$$\text{ECDF} = (\text{RANK} - \alpha)/[\text{MaxRANK} + (1 - 2\,\alpha)],$$

where the parameter "α" (shown as *alpha* in Table 8.1 and Table 8.2) is a "small" positive value (usually less than ½) that is used to bound the ECDF away from 0 and 1.

Of the three probability models considered (GEV, EV1, and T_Dist) the results obtained for the T_Dist model were selected since the fit to the ECDF was better than that of either the GEV model or the EV1 model. (Although convergence to stable parameter estimates is occasionally a problem with fitting a GEV model to the ECDF, the T_Dist model had no problems with convergence of the iterative procedure to estimate parameters.)

The T_Dist model used here is a three-parameter probability model where the varable $z = (-\text{MinAVG}_y - \gamma) / \theta$, for each year, y, is presumed to follow a T_Dist with location parameter, γ, and scale parameter, θ, and a third parameter, ν, that represents the number of degrees of freedom. For a given number of years of data, N, then ν=N-2.

The following mathematical expression specifies the T_Dist model we fit to the data for "-MinAVG_y " shown in Table 8.1 and Table 8.2, below.

(3) $\text{ECDF}(-\text{MinAVG}_y) = \text{Prob}\{-T < -\text{MinAVG}_y\} = \text{T\_Dist}\{z; \gamma, \theta, \nu=N-2\}$,

where "T_Dist{ . }" is the cumulative probability distribution function for Student's T-Distribution[2], and

[2] A common mathematical expression for Student's T-Distribution is provided at http://en.wikipedia.org/wiki/Student%27s_t-distribution; with a probability density function

$$f(t) = \frac{\Gamma(\frac{\nu+1}{2})}{\sqrt{\nu\pi}\,\Gamma(\frac{\nu}{2})}\left(1+\frac{t^2}{\nu}\right)^{-\frac{\nu+1}{2}},$$

(4) $z = (-MinAVG_y - \gamma) / \theta$, for each year, y, and

the parameters "γ" and "θ" are estimated for this model for given degrees of freedom ν=N-2. The estimated values for γ and θ are shown in Table 8.2 along with the fitted values of the model CDF (the column: "Fitted" Model CDF).

Now, to calculate a *peak-day design temperature*, $TPDD_\delta$, with a specified likelihood, δ, that a value less than $TPDD_\delta$ would be observed, we use the equation below:

(5) $\delta = Prob\ \{ T \leq TPDD_\delta \}$, which is equivalent to

(6) $\delta = Prob\ \{ [(-T - \gamma) / \theta] \geq [(-TPDD_\delta - \gamma) / \theta] \}, = Prob\ \{ [(-T - \gamma) / \theta] \geq [z_\delta] \}$, where $z_\delta = [(-TPDD_\delta - \gamma) / \theta]$. In terms of our probability model,

(7) $\delta = 1 - T\_Dist\{ z_\delta; \gamma, \theta, \nu=N-2\}$,

which yields the following equation for z_δ,

(7') $z_\delta = \{ TINV\_Dist\{ (1-\delta); \gamma, \theta, \nu=N-2\}$, where "TINV_Dist{ . }" is the inverse function of the T_Dist{ . } function[3]. The implied equation for $TPDD_\delta$ is:

(8) $TPDD_\delta = - [\gamma + (z_\delta)(\theta)]$.

To calculate the minimum daily (system average) temperature to define our extreme weather event, we specify that this COLDEST-Day be one where the temperature would be lower with a "1-in-35" likelihood. This criterion translates into two equations to be solved based on equations (7) and (8) above:

(9) solve for "z_δ" from equation (7') above with (1-δ) = (1 - 1/35) = 1 - 0.0286,

(10) solve for "$TPDD_\delta$" from $TPDD_\delta = - [\gamma + (z_\delta)(\theta)]$.

The value of $z_\delta = 1.935$ and $TPDD_\delta = - [\gamma + (z_\delta)(\theta)] = 40.6$ degrees Fahrenheit, with values for "ν=N-2"; along with "γ" and "θ" in Tables 8.1 & 8.2, below.

SoCalGas' 1-in-10 peak-day design temperature of 42.3 degrees Fahrenheit, is calculated in a methodologically similar way as for the 40.6 degree peak day temperature. The criteria specified in equation (9) above for a "1-in-35" likelihood would be replaced by a "1-in-10" likelihood.

(9') solve for "z_δ" from equation (7') above with (1-δ) = (1 - 1/10) = 1 - 0.1000,

which yields a "z_δ" value of $z_\delta = 1.294$ and, $TPDD_\delta = - [\gamma + (z_\delta)(\theta)] = 42.3$ with values for "ν=N-2"; along with "γ" and "θ" in Tables 8.1 and 8.2, below.

such that $T\_Dist\{z; \gamma, \theta, \nu=N-2\}=\int f(t)\, dt$, from t=-∞ to t=z. Also, the notation Γ(.) is known in mathematics as the GAMMA function; see http://www.wikipedia.org/wiki/Gamma_function for a description. Also, see *Statistical Theory*, 3rd Ed., B.W. Lindgren, MacMillian Pub. Inc, 1976, pp. 336-337.

[3] Computer software packages such as SAS and EXCEL have implemented statistical and mathematical functions to readily calculate values for T_Dist{ . } and TINV_Dist{ . } as defined above.

A plot of the cumulative distribution function for $MinAVG_y$ based on "ν=N-2", the fitted model parameters, "γ" and "θ" with values in Tables 8.1 and 8.2, below, is shown in Figure 1.

Table 7.1

YEAR	MINAVG	Month(MinAvg)
1950	40.83	Jan
1951	44.45	Dec
1952	43.12	Jan
1953	45.51	Feb
1954	45.63	Dec
1955	45.83	Dec
1956	44.84	Feb
1957	39.49	Jan
1958	46.34	Nov
1959	48.26	Feb
1960	42.23	Jan
1961	47.20	Dec
1962	43.41	Jan
1963	42.42	Jan
1964	45.28	Nov
1965	44.71	Jan
1966	46.82	Jan
1967	40.80	Dec
1968	40.46	Dec
1969	44.85	Jan
1970	46.81	Dec
1971	42.97	Jan
1972	41.43	Dec
1973	45.24	Jan
1974	43.02	Jan
1975	44.56	Jan
1976	44.68	Jan
1977	48.22	Jan
1978	41.66	Dec
1979	41.45	Jan
1980	50.23	Jan
1981	49.27	Jan
1982	45.42	Jan
1983	48.67	Jan
1984	46.80	Dec
1985	45.23	Feb
1986	48.68	Feb
1987	43.47	Dec
1988	43.38	Dec
1989	40.45	Feb
1990	39.09	Dec
1991	48.65	Mar
1992	47.51	Dec
1993	46.11	Jan
1994	47.07	Nov

Table 7.2

YEAR	MINAVG	Month(MinAvg)
1995	49.63	Dec
1996	44.77	Feb
1997	48.36	Jan
1998	43.53	Dec
1999	48.86	Jan
2000	48.85	Mar
2001	47.15	Jan
2002	45.94	Jan
2003	47.19	Dec
2004	48.22	Nov
2005	47.30	Jan
2006	45.70	Mar
2007	41.42	Jan
2008	45.95	Dec
2009	45.31	Dec
2010	44.57	Dec
2011	46.99	Feb
2012	46.77	Dec
2013	43.76	Jan
2014	47.93	Dec
2015	45.59	Jan
2016	46.89	Dec
2017	47.46	Jan
2018	47.35	Feb
2019	47.31	Feb
2020	50.03	Feb
2021	47.02	Jan
2022	48.16	Dec
2023	46.35	Feb
2024	50.21	Jan

Table 8.1 (alpha=0.375)

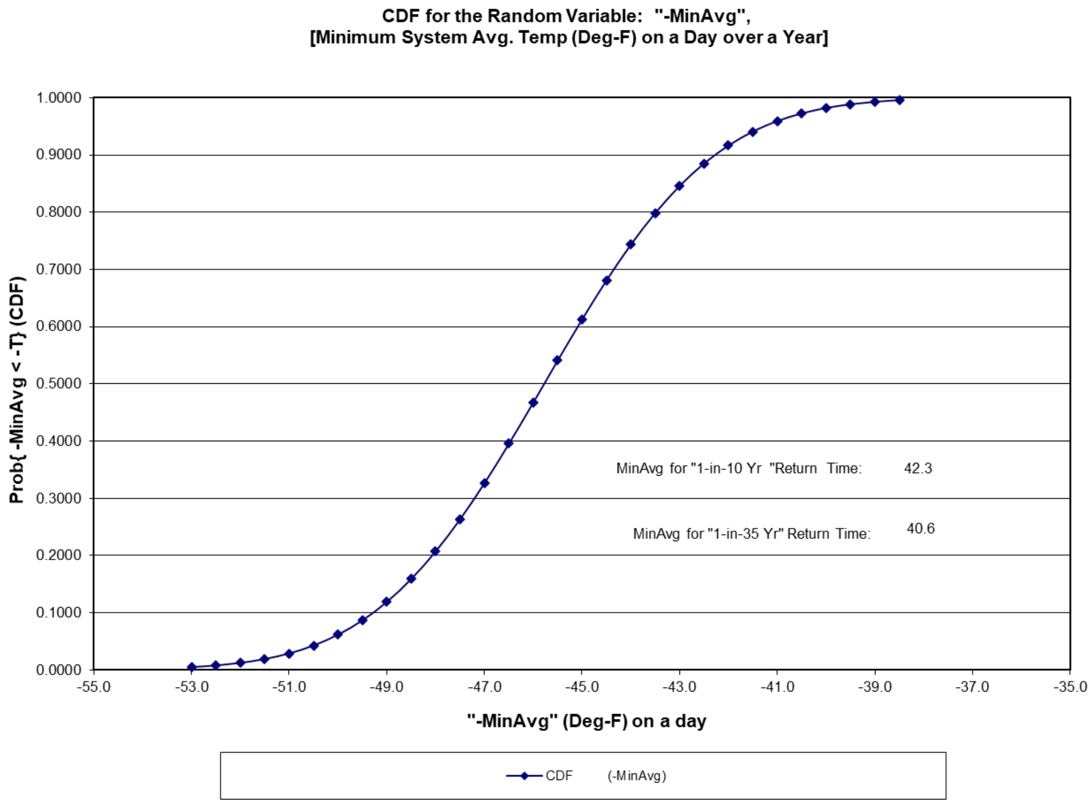
Year	-MinAvg	Month(-MinAvg)	Rank	Empirical CDF	Model - [(-MinAvg - γ)/θ]	Model - Fitted CDF
1980	-50.2320	Jan	1	0.0083	-1.6446	0.0522
2024	-50.2139	Jan	2	0.0216	-1.6379	0.0529
2020	-50.0283	Feb	3	0.0349	-1.5694	0.0604
1995	-49.6294	Dec	4	0.0482	-1.4220	0.0796
1981	-49.2736	Jan	5	0.0615	-1.2905	0.1005
1999	-48.8587	Jan	6	0.0748	-1.1372	0.1296
2000	-48.8456	Mar	7	0.0880	-1.1324	0.1306
1986	-48.6762	Feb	8	0.1013	-1.0698	0.1441
1983	-48.6666	Jan	9	0.1146	-1.0662	0.1449
1991	-48.6494	Mar	10	0.1279	-1.0599	0.1463
1997	-48.3606	Jan	11	0.1412	-0.9532	0.1718
1959	-48.2588	Feb	12	0.1545	-0.9156	0.1815
1977	-48.2240	Jan	13	0.1678	-0.9027	0.1848
2004	-48.2213	Nov	14	0.1811	-0.9017	0.1851
2022	-48.1637	Dec	15	0.1944	-0.8804	0.1908
2014	-47.9338	Dec	16	0.2076	-0.7955	0.2145
1992	-47.5066	Dec	17	0.2209	-0.6376	0.2629
2017	-47.4622	Jan	18	0.2342	-0.6212	0.2682
2018	-47.3484	Feb	19	0.2475	-0.5792	0.2821
2019	-47.3085	Feb	20	0.2608	-0.5644	0.2871
2005	-47.3048	Jan	21	0.2741	-0.5630	0.2876
1961	-47.1985	Dec	22	0.2874	-0.5237	0.3010
2003	-47.1853	Dec	23	0.3007	-0.5189	0.3027
2001	-47.1498	Jan	24	0.3140	-0.5058	0.3073
1994	-47.0652	Nov	25	0.3272	-0.4745	0.3183
2021	-47.0190	Jan	26	0.3405	-0.4574	0.3244
2011	-46.9859	Feb	27	0.3538	-0.4452	0.3287
2016	-46.8876	Dec	28	0.3671	-0.4089	0.3419
1966	-46.8247	Jan	29	0.3804	-0.3857	0.3504
1970	-46.8136	Dec	30	0.3937	-0.3815	0.3520
1984	-46.8021	Dec	31	0.4070	-0.3773	0.3535
2012	-46.7677	Dec	32	0.4203	-0.3646	0.3582
2023	-46.3471	Feb	33	0.4336	-0.2092	0.4175
1958	-46.3423	Nov	34	0.4468	-0.2074	0.4181
1993	-46.1139	Jan	35	0.4601	-0.1230	0.4512
2008	-45.9464	Dec	36	0.4734	-0.0611	0.4757
2002	-45.9428	Jan	37	0.4867	-0.0598	0.4762
1955	-45.8344	Dec	38	0.5000	-0.0197	0.4921
2006	-45.6981	Mar	39	0.5133	0.0306	0.5122
1954	-45.6304	Dec	40	0.5266	0.0556	0.5221
2015	-45.5942	Jan	41	0.5399	0.0690	0.5274
1953	-45.5123	Feb	42	0.5532	0.0993	0.5394
1982	-45.4166	Jan	43	0.5664	0.1346	0.5534
2009	-45.3076	Dec	44	0.5797	0.1749	0.5692
1964	-45.2846	Nov	45	0.5930	0.1834	0.5725
1973	-45.2409	Jan	46	0.6063	0.1996	0.5788
1985	-45.2315	Feb	47	0.6196	0.2030	0.5802
1969	-44.8499	Jan	48	0.6329	0.3440	0.6341

Table 8.2 (alpha=0.375)

Year	-MinAvg	Month(-MinAvg)	Rank	Empirical CDF	Model - [(-MinAvg - γ)/θ]	Model - Fitted CDF
1956	-44.8409	Feb	49	0.6462	0.3474	0.6353
1996	-44.7701	Feb	50	0.6595	0.3735	0.6451
1965	-44.7135	Jan	51	0.6728	0.3944	0.6528
1976	-44.6809	Jan	52	0.6860	0.4065	0.6572
2010	-44.5719	Dec	53	0.6993	0.4467	0.6718
1975	-44.5588	Jan	54	0.7126	0.4516	0.6735
1951	-44.4532	Dec	55	0.7259	0.4906	0.6874
2013	-43.7603	Jan	56	0.7392	0.7466	0.7712
1998	-43.5347	Dec	57	0.7525	0.8300	0.7954
1987	-43.4730	Dec	58	0.7658	0.8528	0.8017
1962	-43.4085	Jan	59	0.7791	0.8766	0.8082
1988	-43.3816	Dec	60	0.7924	0.8865	0.8109
1952	-43.1218	Jan	61	0.8056	0.9825	0.8355
1974	-43.0222	Jan	62	0.8189	1.0194	0.8443
1971	-42.9680	Jan	63	0.8322	1.0394	0.8490
1963	-42.4199	Jan	64	0.8455	1.2419	0.8909
1960	-42.2309	Jan	65	0.8588	1.3117	0.9031
1978	-41.6586	Dec	66	0.8721	1.5232	0.9340
1979	-41.4546	Jan	67	0.8854	1.5986	0.9429
1972	-41.4261	Dec	68	0.8987	1.6091	0.9440
2007	-41.4162	Jan	69	0.9120	1.6128	0.9444
1950	-40.8348	Jan	70	0.9252	1.8276	0.9641
1967	-40.8029	Dec	71	0.9385	1.8394	0.9650
1968	-40.4596	Dec	72	0.9518	1.9662	0.9735
1989	-40.4454	Feb	73	0.9651	1.9715	0.9738
1957	-39.4891	Jan	74	0.9784	2.3248	0.9886
1990	-39.0896	Dec	75	0.9917	2.4724	0.9921

"Gamma" (Fitted) =	**-45.78**
"Theta" (Fitted) =	**2.71**
Deg. Freedom=	**73**

Figure 1



CDF for the Random Variable: "-MinAvg",
[Minimum System Avg. Temp (Deg-F) on a Day over a Year]
Prob{ -MinAvg < -T} (CDF)
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
-55.0
-53.0
-51.0
-49.0
-47.0
-45.0
-43.0
-41.0
-39.0
-37.0
-35.0
MinAvg for "1-in-10 Yr "Return Time: 42.3
MinAvg for "1-in-35 Yr" Return Time: 40.6
"-MinAvg" (Deg-F) on a day
CDF (-MinAvg)

VI. Estimating the Uncertainty in the Peak-Day Design Temperature

The calculated peak-day design temperatures in section V above also have a statistical uncertainty associated with them. The estimated measures of uncertainty recommended for our use are calculated from the fitted model for the probability distribution and are believed to be reasonable, although rough, approximations.

The basic approach used the estimated parameters for the probability distribution (see the results provided in Tables 8.1 and 8.2, above) to calculate the fitted temperatures as a function of the empirical CDF listed in Tables 8.1 and 8.2, above. These fitted temperatures are then compared with the observed temperatures by calculating the difference = "observed" – "fitted" values. The full set of differences are then separated into the lower third (L), the middle third (M) and the upper third (U) of the distribution. Finally, values of the root-mean-square error (RMSE) of the differences in each third of the distribution are calculated, along with the RMSE for the entire set of differences overall. The data in Tables 9.1 and 9.2, below, show the temperature data and the resulting RMSE values.

The formula below is used to calculate the RMSE for a specified set of "N" data differences:

$$\text{RMSE} = \text{SQRT}\left\{ \left(\sum_{i=1, \ldots, N} e[\,i\,]^2 \right) / \, (N-2) \right\},$$

where e[i] = *observed* less *fitted* value of temperature, T[i]. The number of estimated parameters (3 for the GEV model, 2 for the T-Dist and EV1 models) is subtracted from the respective number of data differences, N, in the denominator of the RMSE expression.

Since both the "1-in-35" and "1-in-10" peak-day temperature values are in the lower third quantile of the fitted distribution, the calculated standard error for these estimates is 0.58 Deg-F.

Table 9.1

Quantile: (Lower, Middle, Upper 3rd's)	Observed $T_{[i]}$ Temp. Ranked	Fitted Value of $T_{[i]}$	Residual $e_{[i]}$: Obs'd. less Fitted Value of $T_{[i]}$	Square of $e_{[i]}$:
U	50.2320	52.4163	-2.1843	4.7712
U	50.2139	51.3500	-1.1360	1.2906
U	50.0283	50.7620	-0.7337	0.5383
U	49.6294	50.3401	-0.7107	0.5051
U	49.2736	50.0048	-0.7312	0.5346
U	48.8587	49.7233	-0.8645	0.7474
U	48.8456	49.4784	-0.6327	0.4004
U	48.6762	49.2602	-0.5840	0.3411
U	48.6666	49.0625	-0.3959	0.1567
U	48.6494	48.8807	-0.2313	0.0535
U	48.3606	48.7119	-0.3513	0.1234
U	48.2588	48.5538	-0.2949	0.0870
U	48.2240	48.4046	-0.1806	0.0326
U	48.2213	48.2629	-0.0416	0.0017
U	48.1637	48.1278	0.0359	0.0013
U	47.9338	47.9983	-0.0645	0.0042
U	47.5066	47.8738	-0.3671	0.1348
U	47.4622	47.7535	-0.2913	0.0848
U	47.3484	47.6370	-0.2886	0.0833
U	47.3085	47.5239	-0.2154	0.0464
U	47.3048	47.4138	-0.1090	0.0119
U	47.1985	47.3063	-0.1079	0.0116
U	47.1853	47.2012	-0.0159	0.0003
U	47.1498	47.0983	0.0515	0.0027
U	47.0652	46.9972	0.0680	0.0046
M	47.0190	46.8978	0.1212	0.0147
M	46.9859	46.7999	0.1860	0.0346
M	46.8876	46.7034	0.1842	0.0339
M	46.8247	46.6080	0.2168	0.0470
M	46.8136	46.5136	0.2999	0.0900
M	46.8021	46.4202	0.3819	0.1459
M	46.7677	46.3275	0.4402	0.1938
M	46.3471	46.2354	0.1116	0.0125
M	46.3423	46.1439	0.1984	0.0394
M	46.1139	46.0528	0.0611	0.0037
M	45.9464	45.9620	-0.0157	0.0002
M	45.9428	45.8715	0.0714	0.0051
M	45.8344	45.7810	0.0534	0.0029
M	45.6981	45.6905	0.0076	0.0001
M	45.6304	45.5999	0.0305	0.0009
M	45.5942	45.5091	0.0851	0.0072
M	45.5123	45.4180	0.0943	0.0089
M	45.4166	45.3265	0.0901	0.0081
M	45.3076	45.2345	0.0731	0.0053
M	45.2846	45.1418	0.1428	0.0204
M	45.2409	45.0483	0.1925	0.0371
M	45.2315	44.9540	0.2775	0.0770
M	44.8499	44.8586	-0.0087	0.0001
M	44.8409	44.7620	0.0788	0.0062
M	44.7701	44.6641	0.1059	0.0112

Table 9.2

Quantile: (Lower, Middle, Upper 3rd's)	Observed $T_{[i]}$ Temp. Ranked	Fitted Value of $T_{[i]}$	Residual $e_{[i]}$: Obs'd. less Fitted Value of $T_{[i]}$	Square of $e_{[i]}$:
L	44.7135	44.5648	0.1488	0.0221
L	44.6809	44.4637	0.2172	0.0472
L	44.5719	44.3607	0.2112	0.0446
L	44.5588	44.2556	0.3032	0.0919
L	44.4532	44.1482	0.3051	0.0931
L	43.7603	44.0381	-0.2777	0.0771
L	43.5347	43.9249	-0.3902	0.1523
L	43.4730	43.8085	-0.3355	0.1125
L	43.4085	43.6882	-0.2797	0.0782
L	43.3816	43.5636	-0.1820	0.0331
L	43.1218	43.4341	-0.3123	0.0975
L	43.0222	43.2990	-0.2769	0.0766
L	42.9680	43.1574	-0.1894	0.0359
L	42.4199	43.0082	-0.5883	0.3461
L	42.2309	42.8501	-0.6192	0.3834
L	41.6586	42.6812	-1.0226	1.0457
L	41.4546	42.4995	-1.0449	1.0919
L	41.4261	42.3017	-0.8756	0.7667
L	41.4162	42.0836	-0.6674	0.4454
L	40.8348	41.8387	-1.0039	1.0077
L	40.8029	41.5571	-0.7543	0.5689
L	40.4596	41.2219	-0.7623	0.5811
L	40.4454	40.8000	-0.3546	0.1258
L	39.4891	40.2120	-0.7229	0.5225
L	39.0896	39.1457	-0.0561	0.0031

Overall RMSE ($e_{[i]}$):	**0.51**	**°F**
Upper 3rd RMSE ($e_{[i]}$):	**0.66**	**°F**
Middle 3rd RMSE ($e_{[i]}$):	**0.19**	**°F**
Lower 3rd RMSE ($e_{[i]}$):	**0.58**	**°F**

VII. The Relationship between Annual Likelihoods for Peak-Day Temperatures and "Expected Return Time"

The event whose probability distribution we've modeled is the likelihood that the minimum daily temperature over a calendar year is less than a specified value. And, in particular, we've used this probability model to infer the value of a temperature, our *peak-day design temperature* ($TPDD_\delta$), that corresponds to a pre-defined likelihood, δ, that the observed minimum temperature is less than or equal to this design temperature.

(1) δ = Prob{ Minimum Daily Temperature over the Year < $TPDD_\delta$ }.

For some applications, it is useful to think of how this specified likelihood (or "risk level" δ) relates to the expected number of years until this Peak-Day event would first occur. This expected number of years is what is meant by the *return period*. The results stated below are found in the book: ***Statistics of Extremes***, E.J. Gumbel, Columbia University Press, 1958, on pages 21-25.

(2) E[#Yrs for Peak-Day Event to Occur] = 1 / δ,

1 / Prob{ Minimum Daily Temperature over the Year < $TPDD_\delta$ }.

For our peak-day design temperature (40.6°F) associated with a 1-in-35 annual likelihood, the return period is 35 years (δ=1/35). For the 42.3°F peak-day design temperature, the return period is 10 years (δ=1/10). Occasionally, a less precise terminology is used. For example, the 40.6°F peak-day design temperature may be referred to as a "1-in-35 year cold day"; and the 42.3°F peak-day design temperature may be referred to as a "1-in-10 year cold day."

The probability model for the *return period*, as a random variable, is a geometric (discrete) distribution with positive integer values for the *return period*. The parameter δ = Prob{ Minimum Daily Temperature over the Year < $TPDD_\delta$ }.

(3) Prob{ *return period* = r } = $(1 - \delta)^{(r-1)}\,\delta$, for r = 1, 2, 3, . . .

The expected value of the *return period* is already given in (2) above; the variance of the *return period* is:

(4) Var[*return period*] = (E[*return period*])^2 x (1- (1 / E [*return period*])),

(4') Var[*return period*] = (E[*return period*]) x (E [*return period*] - 1).

Equations (4) and (4') indicate that the standard deviation (square root of the variance) of the *return period* is nearly equal to its expected value. Thus, there is substantial variability about the expected value—a *return period* is not very precise.

Weather for SDG&E: Heating Degree Days – Average and Cold Year Designs; and Winter Peak Day Design Temperatures

October 2025

I. Overview

San Diego Gas and Electric Company's service area for natural gas extends from southern Orange County throughout San Diego County to the Mexican border. To quantify the overall temperature experienced within this region, SDG&E aggregates daily temperature recordings from three U.S. Weather Bureau weather stations into one system average heating degree-day ("HDD") figure. The table below lists weather station locations along with its associated temperature zone(s).

Table 1

Representative Weather Stations with Temperature Zones

Station Location	Weight	Temperature Zone
1. Miramar Naval Air Station	1/3	Coastal and Inland
2. San Diego Lindbergh Field (International Airport)	1/3	Coastal
3. El Cajon	1/3	Inland

SDG&E uses 65° Fahrenheit to calculate the number of HDDs. One heating degree-day is accumulated for each degree that the daily average is *below* 65° Fahrenheit. To arrive at the system average HDDs figure for its entire service area, SDG&E weights the HDD figure for each zone using the weights[1] shown in Table 1. These weights are used in calculating the data shown from January 2005 to December 2024.

Daily maximum and minimum temperatures, for each individual weather station in the table above, are from the National Climatic Data Center or from preliminary data that SoCalGas captures each day for various individual weather stations as well as for its system average values of HDD. For each station, the average temperature is computed as the (maximum + minimum)/2 and this value is used to compute the heating degrees (i.e., the *daily* HDD) for each station as well. System average values of HDD are then computed using the weights for each respective station. Annual and monthly HDDs for the entire SDG&E service area from 2005 to 2024 are listed in Table 2, below.

[1] The location of the station for Miramar is at the boundary of the Coastal and Inland zones. Correspondingly, both the Coastal and Inland zones are considered represented in the data for the Miramar station.

Table 2

Calendar Month Heating Degree-Days (Jan. 2005 through Dec. 2024)

	Month												Total
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**"Cal-Year"**
2005	247	201	160	118	32	4	0	0	3	37	95	230	**1126**
2006	276	205	307	143	31	0	0	0	1	35	88	287	**1373**
2007	367	228	153	137	62	18	0	0	4	28	110	342	**1448**
2008	331	277	184	129	88	15	0	0	0	13	59	289	**1385**
2009	177	248	203	141	30	10	0	0	0	40	123	293	**1265**
2010	240	215	194	179	87	21	9	1	3	32	184	242	**1407**
2011	222	279	196	97	73	20	0	0	1	24	174	342	**1427**
2012	232	240	225	126	36	12	0	0	0	18	103	269	**1261**
2013	326	272	150	105	23	6	0	1	0	41	104	243	**1269**
2014	160	143	82	77	20	1	0	0	0	0	46	172	**700**
2015	160	85	63	42	47	0	0	0	0	0	97	254	**747**
2016	240	81	96	45	30	0	0	0	0	0	70	198	**760**
2017	244	158	83	31	40	3	0	0	0	1	38	149	**747**
2018	111	169	136	58	48	1	0	0	0	1	48	195	**767**
2019	216	290	161	48	69	2	0	0	2	14	88	232	**1121**
2020	233	194	178	96	3	0	0	0	0	6	133	245	**1088**
2021	251	190	234	92	40	5	0	0	1	48	72	306	**1239**
2022	270	241	192	104	71	6	0	0	0	16	218	305	**1422**
2023	336	336	306	183	108	29	0	0	3	18	106	210	**1635**
2024	295	257	227	139	61	13	0	1	4	17	154	237	**1404**

20-Yr-Avg (Jan 2005-Dec 2024)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Avg.	246.7	215.3	176.4	104.5	49.9	8.3	0.5	0.1	1.0	19.3	105.5	252.0	**1179.4**
St.Dev.	64.8	65.9	66.6	44.3	26.8	8.6	2.0	0.3	1.5	15.5	48.1	52.7	**287.6**
Min.	111.4	80.7	62.7	31.2	2.7	0.0	0.0	0.0	0.0	0.0	37.7	149.3	**700.3**
Max.	367.3	335.7	307.3	183.0	108.4	28.9	9.0	1.2	4.0	48.1	218.3	342.4	**1634.9**

II. Calculations to Define Our Average-Temperature Year

The simple average of the 20-year period (January 2005 through December 2024) was used to represent the Average Year total and the individual monthly values for HDD. In this proceeding, the standard deviation has been calculated using an approach that compensates for the annual HDD values for the years 2014-2018 in SDG&E's service territory being dramatically lower than in any preceding year going back to 1972[2]. A regression with a dummy variable for the years 2014-2018 has been used to estimate a shift in the level of annual HDD that occurred beginning in 2014. A dummy variable takes the value one for some observations to indicate the presence of an effect or membership in a group and zero for the remaining observations. Estimating the effect of the dummy variable gives an estimate of that effect or the impact of membership in that group. A dummy variable is used here to estimate the average effect on annual HDD of a given year having membership in the group of years 2014-2018. The dataset is SDG&E system-wide annual HDD for the years 2005-2024. The regression equation is:

$$HDD_t = \alpha + \beta * t + \beta_{2014-2018} * D_{2014-2018} + \varepsilon$$

where $D_{2014-2018}$ is a dummy variable for the years 2014-2018 and $\beta_{2014-2018}$ is the corresponding dummy coefficient. This regression equation estimates average HDD over the period 2005-2024 controlling for time trends in HDD and the warm weather regime of years 2014-2018. It's important to note that p-value for the estimate of $\beta_{2014-2018}$ is virtually zero, indicating an extremely low probability that membership in the group of years 2014-2018 had no effect on annual HDDs. Please see Table 3 below for the full regression output.

Table 3

Dummy Regression for Calculation of Heating Degree-Day Standard Deviation

Regression Statistics	
Multiple R	0.897742518
R Square	0.805941629
Adjusted R Square	0.783111233
Standard Error	133.9412539
Observations	20

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1266627.316	633313.6582	35.30125404	8.85983E-07
Residual	17	304984.4116	17940.2595		
Total	19	1571611.728			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1301.713846	62.89719567	20.69589641	1.70995E-13
Time	2.282615385	5.253608211	0.43448527	0.669400746
Regime Dummy	-584.9652308	69.96049455	-8.361365004	1.98979E-07

[2] The same approach to control warm weather regime from 2014 to 2018 when estimating standard deviation was used in CAP 2024.

The dummy variable's estimated effect, $\beta_{2014-2018}$, is subtracted from the actual annual HDD data for years 2014-2018 to adjust the data to remove the level shift. The standard deviation has been calculated to be 127.4 using this adjusted dataset. This adjusted standard deviation has been used to design the Cold Years based on a "1-in-10" and "1-in-35" chance, $\boldsymbol{c}$, that the respective annual "Cold Year" $\boldsymbol{hdd_c}$ value would be exceeded. A probability model for the annual HDD is based on a t-Distribution with N-1 degrees of freedom, where N is the number of years of HDD data we use, μ is the average of the last 20 years of HDD, and S_{20} is the average of the standard deviations of the 20 most recent 20-year periods:

$U = (HDD_y - \mu)/S_{20}$, has a t-Distribution with N-1 degrees of freedom.

III. Calculating the Cold-Temperature Year Weather Designs

Cold Year HDD Weather Designs

For SDG&E, cold-temperature-year HDD weather designs are developed with a 1-in-35-year chance of occurrence. In terms of probabilities this can be expressed as the following for a "1-in-35" cold-year HDD value in equation 1 and a "1-in-10" cold-year HDD value in equation 2, with Annual HDD as the random variable:

(1) Prob { Annual HDD > "1-in-35" Cold-Yr HDD } = 1/35 = 0.0286

(2) Prob { Annual HDD > "1-in-10" Cold-Yr HDD } = 1/10 = 0.1000

An area of 0.0286 under one tail of the T-Distribution translates to 2.025 standard deviations *above* an average-year based on a t-statistic with 19 degrees of freedom. Using the standard deviation calculated as described earlier, 127.4 HDD, these equations yield values of about 1,437 HDD for a "1-in-35" cold year and 1,348 as the number of HDDs for a "1-in-10" cold year (an area of 0.1000 under one tail of the T-Distribution translates to 1.328 standard deviations *above* an average-year based on a t-statistic with 19 degrees of freedom). For example, the "1-in-35" cold-year HDD is calculated as follows:

(3) Cold-year HDD = 1,437, which equals approximately

1,179 average-year HDDs + 2.025 * 127.4

Table 4 below shows monthly HDD figures for "1-in-35" cold year, "1-in-10" cold year and, average year temperature designs. The monthly average-temperature-year HDDs are calculated from weighted monthly HDDs from 2005 to 2024, as shown as the bottom of Table 2, above. For example, the average-year December value of 251.9 HDD equals the simple average of the 20 December HDD figures from 2005 to 2024. SDG&E calculates the cold-temperature-year monthly HDD values using the same shape of the average-year HDDs. For example, since 21.4 percent (251.9 / 1179) of average-temperature-year HDDs occurred in December, the estimated number of HDDs during

December for a cold-year is equal to 1,437 HDDs multiplied by 21.4 percent, or 307.0 HDDs.

Table 4

Calendar Month Heating Degree-Day Designs

	Cold		Average	Hot	
	1-in-35 Design	1-in-10 Design		1-in-10 Design	1-in-35 Design
January	300.5	281.9	246.6	211.2	192.6
February	262.3	246.1	215.2	184.4	168.1
March	215.0	201.6	176.4	151.1	137.8
April	127.3	119.4	104.4	89.5	81.6
May	60.7	57.0	49.8	42.7	38.9
June	10.1	9.5	8.3	7.1	6.5
July	0.6	0.6	0.5	0.4	0.4
August	0.2	0.2	0.1	0.1	0.1
September	1.2	1.2	1.0	0.9	0.8
October	23.5	22.1	19.3	16.5	15.1
November	128.5	120.5	105.4	90.3	82.4
December	307.0	288.0	251.9	215.8	196.8
Total	**1,437**	**1,348**	**1,179**	**1,010**	**921**

IV. Adjusting Forecasted HDDs for a Climate-Change Trend

SDG&E incorporates a climate-change warming trend that gradually reduces HDDs by 6 HDDs per year over the forecast period. The annual reduction is based on the latest twenty-year trend in 20-year-averaged HDDs. That is, they are based on the observed trend in changes starting with average HDDs for years 1986-2005, then 1987-2006, 1988-2007...and ending with the average HDDs for years 2005-2024.

Table 5 below shows system HDDs, rolling 20-year averaged HDDs, and the annual changes in those rolling 20-year averages. The actual average annual change is -6.1 HDDs for the most recent twenty of the 20-year averages (with ending years from 2005 through 2024). A simple “ordinary least squares” regression-fitted time trend (using Microsoft Excel’s “LINEST” function) was applied to those same annual changes, resulting in a fitted estimation of -9.6 HDDs per year. However, after CGR 2022, which incorporated a tread of -6 HDD per year, HDDs of 3 consecutive years from 2022 to 2024 are colder than average years, it was decided to decrease average-year and cold-year forecasted HDD’s by 6 HDDs per year based on average change of the last 20 years, which is the same tread as that in CGR 2022 and CGR 2024, starting with the first forecast year of 2025.

Table 5

Average Annual Changes in 20-Year Averaged Heating-Degree Days

	Regression Fitted trend	Actual
20 Year: (2005-2024)	-9.6	**-6.0**

Year	SDG&E System HDDs	20-year averaged HDDs	Annual change in 20-year averaged HDDs
1981	961		
1982	1346		
1983	1126		
1984	1126		
1985	1402		
1986	1027		
1987	1404		
1988	1272		
1989	1258		
1990	1322		
1991	1316	1252.3	
1992	1007	1232.0	-20.3
1993	1105	1212.4	-19.6
1994	1467	1215.0	2.6
1995	1078	1182.9	-32.1
1996	1154	1182.6	-0.3
1997	1156	1188.0	5.4
1998	1576	1210.5	22.5
1999	1606	1228.8	18.3
2000	1322	1251.4	22.6
2001	1540	1280.4	29.0
2002	1479	1287.0	6.6
2003	1268	1294.1	7.1
2004	1248	1300.2	6.1
2005	1126	1286.4	-13.8
2006	1373	1303.7	17.3
2007	1448	1305.9	2.2
2008	1385	1311.6	5.6
2009	1265	1311.9	0.4
2010	1407	1316.2	4.2
2011	1427	1321.8	5.6
2012	1261	1334.4	12.7
2013	1269	1342.6	8.2
2014	700	1304.3	-38.3
2015	747	1287.7	-16.6
2016	760	1268.0	-19.7
2017	747	1247.6	-20.4
2018	767	1207.1	-40.5
2019	1121	1182.9	-24.3
2020	1088	1171.2	-11.7
2021	1239	1156.1	-15.0
2022	1422	1153.3	-2.8
2023	1635	1171.7	18.4
2024	1404	1179.4	7.8

Below tables 6.1 – 6.3 show the complete monthly weather design:

Table 6.1

Calendar Month Heating Degree-Day Designs with Climate-Change Trend

	Cold		Average	Hot	
	1-in-35 Design	**1-in-10 Design**		**1-in-10 Design**	**1-in-35 Design**
Jan-2024	300.5	281.9	246.6	211.2	192.6
Feb-2024	262.3	246.1	215.2	184.4	168.1
Mar-2024	215.0	201.6	176.4	151.1	137.8
Apr-2024	127.3	119.4	104.4	89.5	81.6
May-2024	60.7	57.0	49.8	42.7	38.9
Jun-2024	10.1	9.5	8.3	7.1	6.5
Jul-2024	0.6	0.6	0.5	0.4	0.4
Aug-2024	0.2	0.2	0.1	0.1	0.1
Sep-2024	1.2	1.2	1.0	0.9	0.8
Oct-2024	23.5	22.1	19.3	16.5	15.1
Nov-2024	128.5	120.5	105.4	90.3	82.4
Dec-2024	307.0	288.0	251.9	215.8	196.8
Jan-2025	299.3	280.7	245.3	210.0	191.4
Feb-2025	261.2	245.0	214.1	183.3	167.0
Mar-2025	214.1	200.7	175.5	150.2	136.9
Apr-2025	126.8	118.9	103.9	88.9	81.0
May-2025	60.5	56.7	49.6	42.4	38.7
Jun-2025	10.1	9.4	8.2	7.1	6.4
Jul-2025	0.6	0.6	0.5	0.4	0.4
Aug-2025	0.2	0.2	0.1	0.1	0.1
Sep-2025	1.2	1.2	1.0	0.9	0.8
Oct-2025	23.4	22.0	19.2	16.4	15.0
Nov-2025	128.0	120.0	104.9	89.8	81.8
Dec-2025	305.7	286.7	250.6	214.5	195.5
Jan-2026	298.0	279.4	244.1	208.7	190.1
Feb-2026	260.1	243.9	213.0	182.2	165.9
Mar-2026	213.2	199.8	174.6	149.3	136.0
Apr-2026	126.2	118.3	103.4	88.4	80.5
May-2026	60.2	56.5	49.3	42.2	38.4
Jun-2026	10.0	9.4	8.2	7.0	6.4
Jul-2026	0.6	0.6	0.5	0.4	0.4
Aug-2026	0.2	0.2	0.1	0.1	0.1
Sep-2026	1.2	1.2	1.0	0.9	0.8
Oct-2026	23.3	21.9	19.1	16.3	14.9
Nov-2026	127.4	119.5	104.4	89.2	81.3
Dec-2026	304.4	285.4	249.3	213.2	194.2

Table 6.2

Calendar Month Heating Degree-Day Designs with Climate-Change Trend

	Cold		Average	Hot	
	1-in-35 Design	1-in-10 Design		1-in-10 Design	1-in-35 Design
Jan-2027	296.8	278.2	242.8	207.5	188.9
Feb-2027	259.0	242.8	211.9	181.1	164.8
Mar-2027	212.3	199.0	173.7	148.4	135.1
Apr-2027	125.7	117.8	102.8	87.9	80.0
May-2027	60.0	56.2	49.1	41.9	38.2
Jun-2027	10.0	9.4	8.2	7.0	6.4
Jul-2027	0.6	0.6	0.5	0.4	0.4
Aug-2027	0.2	0.2	0.1	0.1	0.1
Sep-2027	1.2	1.2	1.0	0.9	0.8
Oct-2027	23.2	21.8	19.0	16.2	14.8
Nov-2027	126.9	118.9	103.8	88.7	80.7
Dec-2027	303.2	284.1	248.0	211.9	192.9
Jan-2028	295.5	276.9	241.6	206.2	187.6
Feb-2028	257.9	241.7	210.8	180.0	163.7
Mar-2028	211.4	198.1	172.8	147.5	134.2
Apr-2028	125.2	117.3	102.3	87.3	79.5
May-2028	59.7	56.0	48.8	41.7	37.9
Jun-2028	9.9	9.3	8.1	6.9	6.3
Jul-2028	0.6	0.6	0.5	0.4	0.4
Aug-2028	0.2	0.2	0.1	0.1	0.1
Sep-2028	1.2	1.2	1.0	0.9	0.8
Oct-2028	23.1	21.7	18.9	16.2	14.7
Nov-2028	126.3	118.4	103.3	88.2	80.2
Dec-2028	301.9	282.9	246.8	210.6	191.6
Jan-2029	294.3	275.6	240.3	205.0	186.3
Feb-2029	256.8	240.6	209.7	178.9	162.6
Mar-2029	210.5	197.2	171.9	146.6	133.3
Apr-2029	124.6	116.7	101.8	86.8	78.9
May-2029	59.5	55.7	48.6	41.4	37.7
Jun-2029	9.9	9.3	8.1	6.9	6.3
Jul-2029	0.6	0.5	0.5	0.4	0.4
Aug-2029	0.2	0.2	0.1	0.1	0.1
Sep-2029	1.2	1.1	1.0	0.9	0.8
Oct-2029	23.0	21.6	18.8	16.1	14.6
Nov-2029	125.8	117.9	102.7	87.6	79.7
Dec-2029	300.6	281.6	245.5	209.4	190.4

Table 6.3

Calendar Month Heating Degree-Day Designs with Climate-Change Trend

	Cold		Average	Hot	
	1-in-35 Design	1-in-10 Design		1-in-10 Design	1-in-35 Design
Jan-2030	293.0	274.4	239.0	203.7	185.1
Feb-2030	255.7	239.5	208.6	177.8	161.6
Mar-2030	209.6	196.3	171.0	145.7	132.4
Apr-2030	124.1	116.2	101.2	86.3	78.4
May-2030	59.2	55.5	48.3	41.2	37.4
Jun-2030	9.9	9.2	8.0	6.9	6.2
Jul-2030	0.6	0.5	0.5	0.4	0.4
Aug-2030	0.2	0.2	0.1	0.1	0.1
Sep-2030	1.2	1.1	1.0	0.8	0.8
Oct-2030	22.9	21.5	18.7	16.0	14.5
Nov-2030	125.3	117.3	102.2	87.1	79.1
Dec-2030	299.3	280.3	244.2	208.1	189.1
Jan-2031	291.8	273.1	237.8	202.4	183.8
Feb-2031	254.6	238.4	207.6	176.7	160.5
Mar-2031	208.7	195.4	170.1	144.8	131.5
Apr-2031	123.6	115.7	100.7	85.7	77.9
May-2031	59.0	55.2	48.1	40.9	37.2
Jun-2031	9.8	9.2	8.0	6.8	6.2
Jul-2031	0.6	0.5	0.5	0.4	0.4
Aug-2031	0.2	0.2	0.1	0.1	0.1
Sep-2031	1.2	1.1	1.0	0.8	0.8
Oct-2031	22.9	21.4	18.6	15.9	14.4
Nov-2031	124.7	116.8	101.7	86.6	78.6
Dec-2031	298.0	279.0	242.9	206.8	187.8
Jan-2032	290.5	271.9	236.5	201.2	182.6
Feb-2032	253.6	237.3	206.5	175.6	159.4
Mar-2032	207.8	194.5	169.2	143.9	130.6
Apr-2032	123.0	115.1	100.2	85.2	77.3
May-2032	58.7	55.0	47.8	40.7	36.9
Jun-2032	9.8	9.1	8.0	6.8	6.1
Jul-2032	0.6	0.5	0.5	0.4	0.4
Aug-2032	0.2	0.2	0.1	0.1	0.1
Sep-2032	1.2	1.1	1.0	0.8	0.8
Oct-2032	22.8	21.3	18.5	15.8	14.3
Nov-2032	124.2	116.2	101.1	86.0	78.1
Dec-2032	296.7	277.7	241.6	205.5	186.5

V. Calculating the Peak-Day Design Temperature

SDG&E's 1-in-35 year Peak-Day design temperature of 43.6 degrees Fahrenheit, denoted "Deg-F," is determined from a statistical analysis of observed annual minimum daily system average temperatures constructed from daily temperature recordings from the three U.S. Weather Bureau weather stations discussed above. Since we have a time series of daily data by year, the following notation will be used for the remainder of this discussion:

(1) $AVG_{y,d}$ = system average value of Temperature for calendar year "y" and day "d".

The calendar year, y, can range from 1972 through 2024, while the day, d, can range from 1 to 365, for non-leap years, or from 1 to 366 for leap years. The "upper" value for the day, d, thus depends on the calendar year, y, and will be denoted by n(y)=365, or 366, respectively, when y is a non-leap year or a leap year.

For each calendar year, we calculate the following statistic from our series of daily system average temperatures defined in equation (1) above:

(2) $$MinAVG_y = \min_{d=1}^{n(y)}\{ AVG_{y,d} \}, \text{ for } y=1972, 1973, \ldots, 2024.$$

(The notation used in equation 2 means "For a particular year, y, list all the daily values of system average temperature for that year, then pick the smallest one.")

The resulting minimum annual temperatures are shown in Table 7, below. Most of the minimum temperatures occur in the months of December, January, or February; for a few calendar years the minimums occurred in March or November.

The statistical methods we use to analyze this data employ software developed to fit three generic probability models: the Generalized Extreme Value (GEV) model, the Double-Exponential or GUMBEL (EV1) model and a 2-Parameter Students' T-Distribution (T-Dist) model. [The GEV and EV1 models have the same mathematical specification as those implemented in a DOS-based executable-only computer code that was developed by Richard L. Lehman and described in a paper published in the Proceedings of the Eighth Conference on Applied Climatology, January 17-22, 1993, Anaheim, California, pp. 270-273, by the American Meteorological Society, Boston, MA., with the title "Two Software Products for Extreme Value Analysis: System Overviews of ANYEX and DDEX." At the time he wrote the paper, Dr. Lehman was with the Climate Analysis Center, National Weather Service/NOAA in Washington, D.C., zip code 20233.] The Statistical Analysis System (SAS) procedure for nonlinear statistical model estimation (PROC MODEL) was used to do the calculations. Further, the calculation procedures were implemented to fit the probability models to observed *maximums* of data, like heating degrees. By recognizing that:

$$- MinAVG_y = - \min_{d=1}^{n(y)}\{AVG_{y,d}\} = \max_{d=1}^{n(y)}\{ -AVG_{y,d}\}, \text{ for } y=1972, \ldots, 2024;$$

this same software, when applied to the *negative* of the minimum temperature data, yields appropriate probability model estimation results.

The calculations done to fit any one of the three probability models chooses the parameter values that provide the "best fit" of the parametric probability model's calculated cumulative distribution function (CDF) to the empirical cumulative distribution function (ECDF). Note that the ECDF is constructed based on the variable "-$MinAVG_y$" (which is a *maximum* over a set of *negative* temperatures) with values of the variable $MinAVG_y$ that are the same as shown in Table 7, below.

In Table 7, the data for -$MinAVG_y$ are shown after they have been sorted from "lowest" to "highest" value. The ascending *ordinal* value is shown in the column labeled "RANK" and the empirical cumulative distribution function is calculated and shown in the next column. The formula used to calculate this function is:

$$ECDF = (RANK - \alpha)/[MaxRANK + (1 - 2\,\alpha)],$$

where the parameter "α" (shown as *alpha* in Table 8.1 and 8.2) is a "small" positive value (usually less than ½) that is used to bound the ECDF away from 0 and 1.

Of the three probability models considered (GEV, EV1, and T_Dist) the results obtained for the T_Dist model were selected since the fit to the ECDF was better than that of either the GEV model or the EV1 model. (Although convergence to stable parameter estimates is occasionally a problem with fitting a GEV model to the ECDF, the T_Dist model had no problems with convergence of the iterative procedure to estimate parameters.)

The T_Dist model used here is a three-parameter probability model where the variable $z = (-MinAVG_y - \gamma) / \theta$, for each year, y, is presumed to follow a T_Dist with location parameter, γ, and scale parameter, θ, and a third parameter, ν, that represents the number of degrees of freedom. For a given number of years of data, N, then ν=N-2.

The following mathematical expression specifies the T_Dist model we fit to the data for "-$MinAVG_y$ " shown in Table 7, below.

(3) $ECDF(-MinAVG_y) = Prob\ \{ -T < -MinAVG_y \} = T\_Dist\{z; \gamma, \theta, \nu=N-2\}$,

where "T_Dist{ . }" is the cumulative probability distribution function for Student's T-Distribution[3], and

[3] A common mathematical expression for Student's T-Distribution is provided at http://en.wikipedia.org/wiki/Student%27s_t-distribution; with a probability density function

$$f(t) = \frac{\Gamma(\frac{\nu+1}{2})}{\sqrt{\nu\pi}\,\Gamma(\frac{\nu}{2})} \left(1 + \frac{t^2}{\nu}\right)^{-\frac{\nu+1}{2}},$$

(4) $z = (-\text{MinAVG}_y - \gamma) / \theta$, for each year, y, and

the parameters "γ" and "θ" are estimated for this model for given degrees of freedom ν=N-2. The estimated values for γ and θ are shown in Table 8.1 and 8.2 along with the fitted values of the model CDF (the column: "Fitted" Model CDF).

Now, to calculate a *peak-day design temperature*, TPDD_δ, with a specified likelihood, δ, that a value less than TPDD_δ would be observed, we use the equation below:

(5) $\delta = \text{Prob}\ \{ T \leq \text{TPDD}_\delta \}$, which is equivalent to

(6) $\delta = \text{Prob}\ \{ [(-T - \gamma) / \theta] \geq [(-\text{TPDD}_\delta - \gamma) / \theta] \}, = \text{Prob}\ \{ [(-T - \gamma) / \theta] \geq [z_\delta] \}$,

where $z_\delta = [(-\text{TPDD}_\delta - \gamma) / \theta]$. In terms of our probability model,

(7) $\delta = 1 - \text{T\_Dist}\{ z_\delta; \gamma, \theta, \nu\text{=N-2}\}$,

which yields the following equation for z_δ,

(7') $z_\delta = \{ \text{TINV\_Dist}\{ (1-\delta); \gamma, \theta, \nu\text{=N-2}\}$, where "TINV_Dist{ . }" is the inverse function of the T_Dist{ . } function[4]. The implied equation for TPDD_δ is:

(8) $\text{TPDD}_\delta = - [\gamma + (z_\delta)(\theta)]$.

To calculate the minimum daily (system average) temperature to define our extreme weather event, we specify that this COLDEST-Day be one where the temperature would be lower with a "1-in-35" likelihood. This criterion translates into two equations to be solved based on equations (7) and (8) above:

(9) solve for "z_δ" from equation (7') above with $(1-\delta) = (1 - 1/35) = 1 - 0.0286$,

(10) solve for "TPDD_δ" from $\text{TPDD}_\delta = - [\gamma + (z_\delta)(\theta)]$.

The value of $z_\delta = 1.947$ and $\text{TPDD}_\delta = - [\gamma + (z_\delta)(\theta)] = 43.6$ degrees Fahrenheit, with values for "ν=N-2"; along with "γ" and "θ" in Table 8.1 and 8.2 , below.

SDG&E's "1-in-10" peak-day design temperature of 45.0 degrees Fahrenheit, is calculated in a methodologically similar way as for the 43.6 degree "1-in-35" peak day temperature. The criteria specified in equation (9) above for a "1-in-35" likelihood would be replaced by a "1-in-10" likelihood.

(9') solve for "z_δ" from equation (7') above with $(1-\delta) = (1 - 1/10) = 1 - 0.1000$,

which yields a "z_δ" value of $z_\delta = 1.299$ and, $\text{TPDD}_\delta = - [\gamma + (z_\delta)(\theta)] = 45.0$ with values for "ν=N-2"; along with "γ" and "θ" in Table 8.1 and 8.2 , below.

such that $\text{T\_Dist}\{z; \gamma, \theta, \nu\text{=N-2}\}=\int f(t)\,dt$, from $t=-\infty$ to $t=z$. Also, the notation $\Gamma(.)$ is known in mathematics as the GAMMA function; see http://www.wikipedia.org/wiki/Gamma_function for a description. Also, see *Statistical Theory*, 3rd Ed., B.W. Lindgren, MacMillian Pub. Inc, 1976, pp. 336-337.

[4] Computer software packages such as SAS and EXCEL have implemented statistical and mathematical functions to readily calculate values for T_Dist{ . } and TINV_Dist{ . } as defined above.

A plot of the cumulative distribution function for $MinAVG_y$ based on "ν=N-2", the fitted model parameters, "γ" and "θ" with values in Table 8.1 and 8.2 , below, is shown in Figure 1.

Table 7

YEAR	MINAVG	Month(MinAvg)
1972	46.8333	Jan
1973	46.3333	Jan
1974	44.1667	Dec
1975	44.3333	Jan
1976	44.8333	Jan
1977	50.8333	Mar
1978	42.8333	Dec
1979	45.1667	Jan
1980	53.6667	Jan
1981	49.6667	Jan
1982	48.5000	Dec
1983	50.8333	Jan
1984	48.0000	Dec
1985	45.5000	Dec
1986	49.8333	Feb
1987	41.3333	Dec
1988	45.1667	Dec
1989	45.0000	Jan
1990	43.5000	Feb
1991	48.3333	Mar
1992	47.0000	Dec
1993	46.8333	Jan
1994	47.8333	Nov
1995	51.1667	Dec
1996	48.6667	Feb
1997	48.8333	Dec
1998	46.8333	Dec
1999	48.6667	Jan
2000	50.3333	Mar
2001	47.5000	Jan
2002	45.5000	Jan
2003	49.0000	Dec
2004	47.8333	Nov
2005	48.0000	Jan
2006	48.6667	Mar
2007	43.1667	Jan
2008	49.0000	Dec
2009	48.5000	Feb
2010	47.8333	Dec
2011	48.8333	Dec
2012	48.1667	Dec
2013	44.1667	Jan
2014	47.6667	Dec
2015	47.6667	Jan
2016	50.1667	Feb
2017	51.0000	Jan
2018	49.6667	Feb
2019	48.1667	Feb
2020	48.3333	Feb
2021	47.8333	Dec
2022	47.5000	Feb
2023	48.0000	Mar
2024	47.6667	Jan

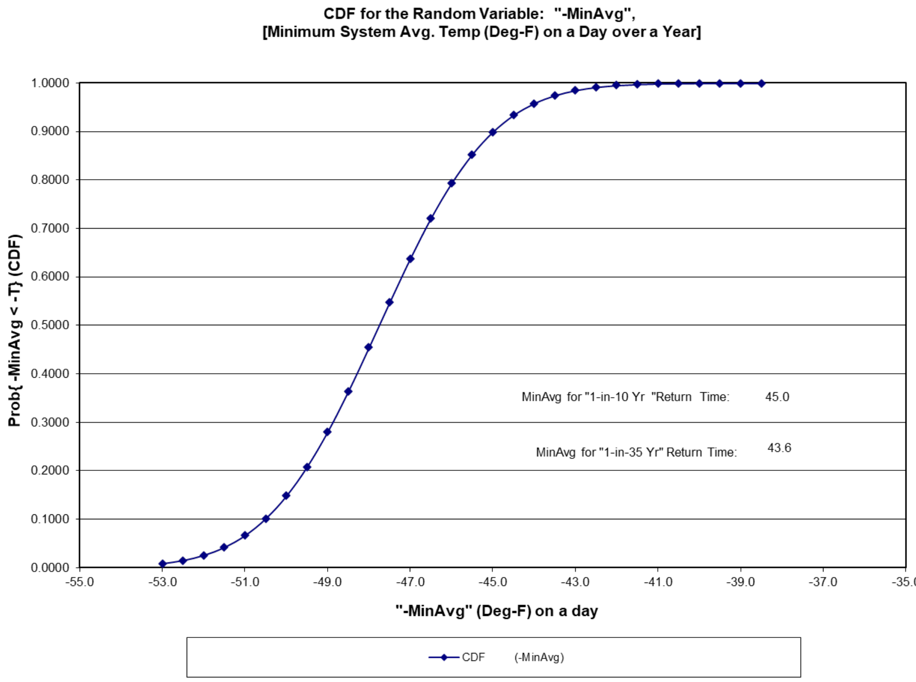
Table 8.1 (alpha=0.375)

Year	-MinAvg	Month(-MinAvg)	Rank	Empirical CDF	Model - [(-MinAvg - γ)/θ]	Model - Fitted CDF
1980	-53.6667	Jan	1	0.0117	-2.5620	0.0067
1995	-51.1667	Dec	2	0.0305	-1.5132	0.0682
2017	-51.0000	Jan	3	0.0493	-1.4433	0.0775
1977	-50.8333	Mar	4	0.0681	-1.3734	0.0878
1983	-50.8333	Jan	5	0.0869	-1.3734	0.0878
2000	-50.3333	Mar	6	0.1056	-1.1636	0.1250
2016	-50.1667	Feb	7	0.1244	-1.0937	0.1396
1986	-49.8333	Feb	8	0.1432	-0.9538	0.1723
1981	-49.6667	Jan	9	0.1620	-0.8839	0.1904
2018	-49.6667	Feb	10	0.1808	-0.8839	0.1904
2003	-49.0000	Dec	11	0.1995	-0.6042	0.2742
2008	-49.0000	Dec	12	0.2183	-0.6042	0.2742
1997	-48.8333	Dec	13	0.2371	-0.5343	0.2977
2011	-48.8333	Dec	14	0.2559	-0.5343	0.2977
1996	-48.6667	Feb	15	0.2746	-0.4644	0.3222
1999	-48.6667	Jan	16	0.2934	-0.4644	0.3222
2006	-48.6667	Mar	17	0.3122	-0.4644	0.3222
1982	-48.5000	Dec	18	0.3310	-0.3945	0.3474
2009	-48.5000	Feb	19	0.3498	-0.3945	0.3474
1991	-48.3333	Mar	20	0.3685	-0.3245	0.3734
2020	-48.3333	Feb	21	0.3873	-0.3245	0.3734
2012	-48.1667	Dec	22	0.4061	-0.2546	0.4000
2019	-48.1667	Feb	23	0.4249	-0.2546	0.4000
1984	-48.0000	Dec	24	0.4437	-0.1847	0.4271
2005	-48.0000	Jan	25	0.4624	-0.1847	0.4271
2023	-48.0000	Mar	26	0.4812	-0.1847	0.4271
1994	-47.8333	Nov	27	0.5000	-0.1148	0.4545
2004	-47.8333	Nov	28	0.5188	-0.1148	0.4545
2010	-47.8333	Dec	29	0.5376	-0.1148	0.4545
2021	-47.8333	Dec	30	0.5563	-0.1148	0.4545
2014	-47.6667	Dec	31	0.5751	-0.0449	0.4822
2015	-47.6667	Jan	32	0.5939	-0.0449	0.4822
2024	-47.6667	Jan	33	0.6127	-0.0449	0.4822
2001	-47.5000	Jan	34	0.6315	0.0251	0.5099
2022	-47.5000	Feb	35	0.6502	0.0251	0.5099
1992	-47.0000	Dec	36	0.6690	0.2348	0.5924
1972	-46.8333	Jan	37	0.6878	0.3048	0.6191
1993	-46.8333	Jan	38	0.7066	0.3048	0.6191
1998	-46.8333	Dec	39	0.7254	0.3048	0.6191
1973	-46.3333	Jan	40	0.7441	0.5145	0.6954
1985	-45.5000	Dec	41	0.7629	0.8641	0.8042
2002	-45.5000	Jan	42	0.7817	0.8641	0.8042
1979	-45.1667	Jan	43	0.8005	1.0040	0.8399
1988	-45.1667	Dec	44	0.8192	1.0040	0.8399
1989	-45.0000	Jan	45	0.8380	1.0739	0.8560
1976	-44.8333	Jan	46	0.8568	1.1438	0.8710
1975	-44.3333	Jan	47	0.8756	1.3536	0.9091
1974	-44.1667	Dec	48	0.8944	1.4235	0.9197
2013	-44.1667	Jan	49	0.9131	1.4235	0.9197
1990	-43.5000	Feb	50	0.9319	1.7032	0.9527
2007	-43.1667	Jan	51	0.9507	1.8430	0.9644

1978	-42.8333	Dec	52	0.9695	1.9829	0.9736
1987	-41.3333	Dec	53	0.9883	2.6121	0.9941

"Gamma" (Fitted) =	**-47.75**
"Theta" (Fitted) =	**2.13**
Deg. Freedom=	**51**

Figure 1



CDF for the Random Variable: "-MinAvg",
[Minimum System Avg. Temp (Deg-F) on a Day over a Year]
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
Prob{ -MinAvg < -T} (CDF)
MinAvg for "1-in-10 Yr "Return Time: 45.0
MinAvg for "1-in-35 Yr" Return Time: 43.6
-55.0
-53.0
-51.0
-49.0
-47.0
-45.0
-43.0
-41.0
-39.0
-37.0
-35.0
"-MinAvg" (Deg-F) on a day
CDF (-MinAvg)

VI. Estimating the Uncertainty in the Peak-Day Design Temperature

The calculated peak-day design temperatures in section V above also have a statistical uncertainty associated with them. The estimated measures of uncertainty recommended for our use are calculated from the fitted model for the probability distribution and are believed to be reasonable, although rough, approximations.

The basic approach used the estimated parameters for the probability distribution (see the results provided in Table 8.1 and 8.2, above) to calculate the fitted temperatures as a function of the empirical CDF listed in Table 8.1 and 8.2. These fitted temperatures are then "compared" with the observed temperatures by calculating the difference = "observed" – "fitted" values. The full set of differences are then separated into the lower third (L), the middle third (M) and the upper third (U) of the distribution. Finally, calculate values of the root-mean-square error (RMSE) of the differences in each third of the distribution, along with the entire set of differences overall. The data in Table 9, below, show the temperature data and the resulting RMSE values.

The formula below is used to calculate the RMSE for a specified set of "N" data differences:

$$\text{RMSE} = \text{SQRT}\left\{ \left(\sum_{i=1, \ldots, N} e[\,i\,]^{2} \right) / \, (N-2) \right\},$$

where e[i] = *observed* less *fitted* value of temperature, T[i]. The number of estimated parameters (3 for the GEV model, 2 for the T-Dist and EV1 models) is subtracted from the respective number of data differences, N, in the denominator of the RMSE expression.

Since both the "1-in-35" and "1-in-10" peak-day temperature values are in the lower third quantile of the fitted distribution, the calculated standard error for these estimates is 0.79 Deg-F.

Table 9

Quantile: (Lower, Middle, Upper 3rd's)	Observed $T_{[i]}$ Temp. Ranked	Fitted Value of $T_{[i]}$	Residual $e_{[i]}$: Obs'd. less Fitted Value of $T_{[i]}$	Square of $e_{[i]}$:
U	53.6667	52.7245	0.9421	0.8876
U	51.1667	51.8305	-0.6639	0.4407
U	51.0000	51.3345	-0.3345	0.1119
U	50.8333	50.9765	-0.1431	0.0205
U	50.8333	50.6902	0.1431	0.0205
U	50.3333	50.4484	-0.1150	0.0132
U	50.1667	50.2367	-0.0701	0.0049
U	49.8333	50.0470	-0.2137	0.0457
U	49.6667	49.8739	-0.2073	0.0430
U	49.6667	49.7138	-0.0472	0.0022
U	49.0000	49.5642	-0.5642	0.3183
U	49.0000	49.4230	-0.4230	0.1789
U	48.8333	49.2889	-0.4555	0.2075
U	48.8333	49.1606	-0.3273	0.1071
U	48.6667	49.0373	-0.3707	0.1374
U	48.6667	48.9183	-0.2516	0.0633
U	48.6667	48.8028	-0.1361	0.0185
U	48.5000	48.6904	-0.1904	0.0362
M	48.5000	48.5805	-0.0805	0.0065
M	48.3333	48.4729	-0.1396	0.0195
M	48.3333	48.3671	-0.0338	0.0011
M	48.1667	48.2628	-0.0961	0.0092
M	48.1667	48.1598	0.0069	0.0000
M	48.0000	48.0577	-0.0577	0.0033
M	48.0000	47.9563	0.0437	0.0019
M	48.0000	47.8554	0.1446	0.0209
M	47.8333	47.7547	0.0787	0.0062
M	47.8333	47.6540	0.1793	0.0322
M	47.8333	47.5531	0.2803	0.0785
M	47.8333	47.4517	0.3816	0.1457
M	47.6667	47.3496	0.3171	0.1005
M	47.6667	47.2465	0.4201	0.1765
M	47.6667	47.1423	0.5244	0.2750
M	47.5000	47.0365	0.4635	0.2149
M	47.5000	46.9288	0.5712	0.3262
L	47.0000	46.8190	0.1810	0.0328
L	46.8333	46.7066	0.1268	0.0161
L	46.8333	46.5911	0.2422	0.0587
L	46.8333	46.4720	0.3613	0.1305
L	46.3333	46.3487	-0.0154	0.0002
L	45.5000	46.2205	-0.7205	0.5191
L	45.5000	46.0864	-0.5864	0.3438
L	45.1667	45.9452	-0.7785	0.6061
L	45.1667	45.7955	-0.6288	0.3954
L	45.0000	45.6354	-0.6354	0.4038
L	44.8333	45.4623	-0.6290	0.3956
L	44.3333	45.2726	-0.9393	0.8822
L	44.1667	45.0610	-0.8943	0.7998
L	44.1667	44.8191	-0.6524	0.4257
L	43.5000	44.5329	-1.0329	1.0668
L	43.1667	44.1748	-1.0082	1.0164
L	42.8333	43.6788	-0.8455	0.7149
L	41.3333	42.7848	-1.4515	2.1068

Overall RMSE (e[i]):	**0.5238**	**°F**
Upper 3rd RMSE (e[i]):	**0.4075**	**°F**
Middle 3rd RMSE (e[i]):	**0.3075**	**°F**
Lower 3rd RMSE (e[i]):	**0.7872**	**°F**

VII. The Relationship between Annual Likelihoods for Peak-Day Temperatures and "Expected Return Time"

The event whose probability distribution we've modeled is the likelihood that the minimum daily temperature over a calendar year is less than a specified value. And, in particular, we've used this probability model to infer the value of a temperature, our *peak-day design temperature* ($TPDD_\delta$), that corresponds to a pre-defined likelihood, δ, that the observed minimum temperature is less than or equal to this design temperature.

(1) δ = Prob{ Minimum Daily Temperature over the Year < $TPDD_\delta$ }.

For some applications, it is useful to think of how this specified likelihood (or "risk level" δ) relates to the expected number of years until this Peak-Day event would first occur. This expected number of years is what is meant by the *return period*. The results stated below are found in the book: ***Statistics of Extremes***, E.J. Gumbel, Columbia University Press, 1958, on pages 21-25.

(2) E[#Yrs for Peak-Day Event to Occur] = $1 / \delta$,

1 / Prob{ Minimum Daily Temperature over the Year < $TPDD_\delta$ }.

For our peak-day design temperature (43.6°F) associated with a 1-in-35 annual likelihood, the return period is 35 years (δ=1/35). For the 45.0°F peak-day design temperature, the return period is 10 years (δ=1/10). Occasionally, a less precise terminology is used. For example, the 43.6°F peak-day design temperature may be referred to as a "1-in-35 year cold day"; and the 45.0°F peak-day design temperature may be referred to as a "1-in-10 year cold day."

The probability model for the *return period*, as a random variable, is a geometric (discrete) distribution with positive integer values for the *return period*. The parameter δ = Prob{ Minimum Daily Temperature over the Year < $TPDD_\delta$ }.

(3) Prob{ *return period* = r } = $(1 - \delta)^{(r-1)}\, \delta$, for r = 1, 2, 3, . . .

The expected value of the *return period* is already given in (2) above; the variance of the *return period* is:

(4) Var[*return period*] = $(\text{E[} \textit{return period} \text{]})^2 \times (1 - (1 / \text{E [} \textit{return period} \text{]}))$,

(4') Var[*return period*] = $(\text{E[} \textit{return period} \text{]}) \times (\text{E [} \textit{return period} \text{] - 1})$.

Equations (4) and (4') indicate that the standard deviation (square root of the variance) of the *return period* is nearly equal to its expected value. Thus, there is substantial variability about the expected value—a *return period* is not very precise.