Weather Normalization

Building: AZ0000FF
PM ID: 1299729
Address: WEST AJO ROAD
City: TUCSON
State: Arizona
Zip Code: 85713
Country: United States
Type: Office
Gross Sq.Ft: 13511 Sq. Ft.

Weather station ID: KTUS

For simplicity, using the 65F as heating and cooling break even point for the current calculation, further detailed calculation of the break-even point can be found in this document: http://esl.tamu.edu/docs/terp/2003/ESL-PA-03-07-03.pdf

Using PM (Natural Gas) Modified

Check the method with one example building

1 User Enters energy data into Portfolio Manager *(only step required by user)*

- Monthly bills in increments of 65 days or less are required for weather normalization because energy use is compared to monthly weather data. For this reason, it may not be available for fuels that are delivered in bulk.
- Normalization is based on the most recent 24 calendar months of data. If 24 calendar months of data are not available, the most recent 12 months are used.

2 Portfolio Manager splits energy data into whole calendar months

- Data is apportioned to calendar months based on the average energy use per day.
  For example, if a bill runs from January 10 through February 9, it covers 31 days: 22 in January and 9 in February. Of the total bill, 22/31 (71%) is assigned to January and 9/31 (29%) is assigned to February.

Using 2013 and 2014 gas consumption

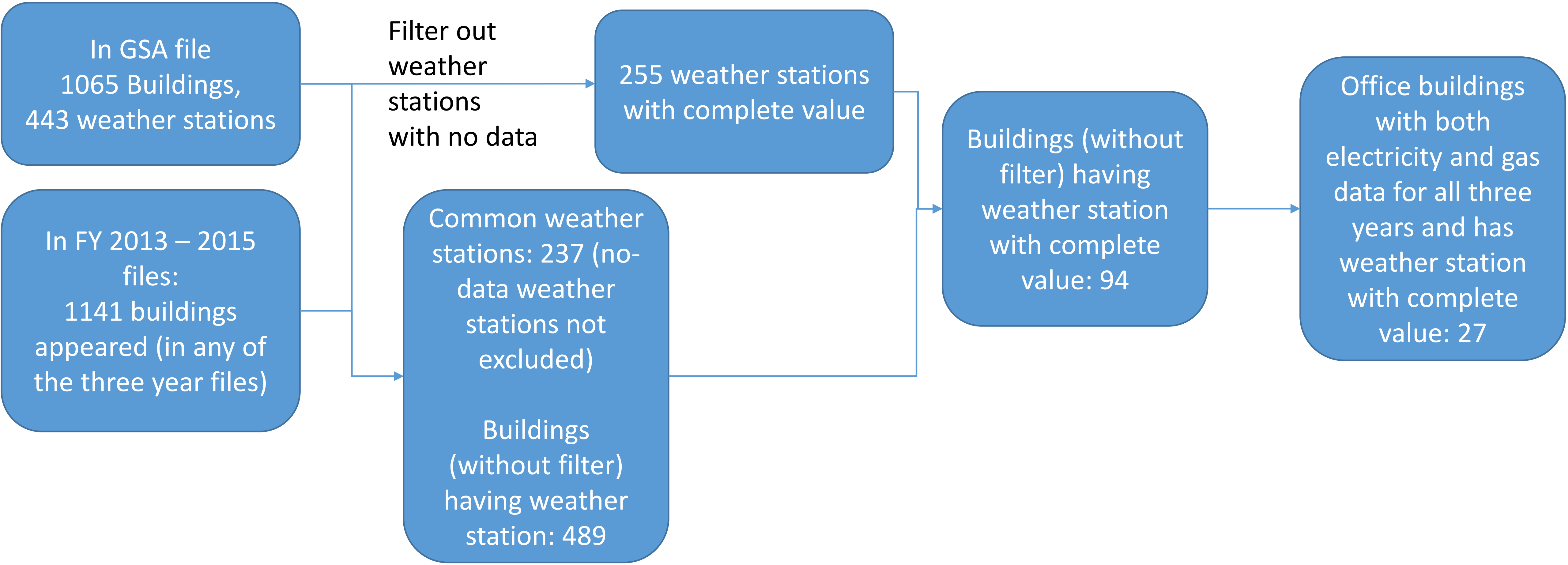
Building: AZ0000FF
PM ID: 1299729
Address: WEST AJO ROAD
City: TUCSON
State: Arizona
Zip Code: 85713
Country: United States
Type: Office
Gross Sq.Ft: 13511 Sq. Ft.

eui_gas	month	year
4.397501	1	2013
3.992371	2	2013
0.574548	3	2013
0.081026	4	2013
0.088392	5	2013
0.088392	6	2013
0.095758	7	2013
0.081026	8	2013
0.088392	9	2013
0.095758	10	2013
0.316738	11	2013
3.543045	12	2013
2.010917	1	2014
1.156462	2	2014
0.228346	3	2014
0.235712	4	2014
0.103124	5	2014
0.096517	6	2014
0.088468	7	2014
0.095758	8	2014
0.088468	9	2014
0.088392	10	2014
0.817626	11	2014
2.430779	12	2014

3 Portfolio Manager plots energy use and actual temperature for each fuel

- The ***actual*** temperature for each of the 24 calendar months is retrieved from the daily weather station.
- A plot is generated with energy on the vertical axis and temperature on the horizontal axis (***Figure 5***).
- Separate plots are created for each fuel type in the building.

Get weather data



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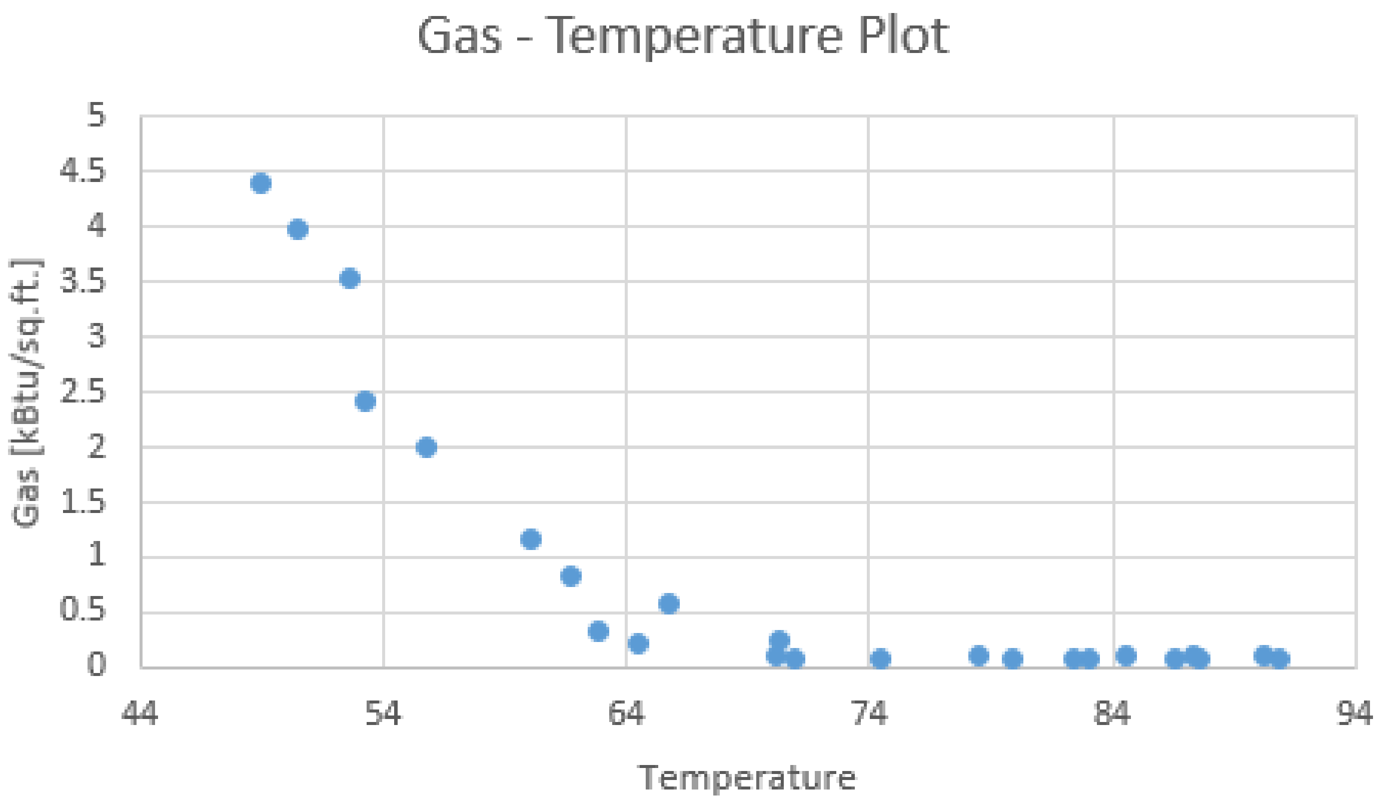
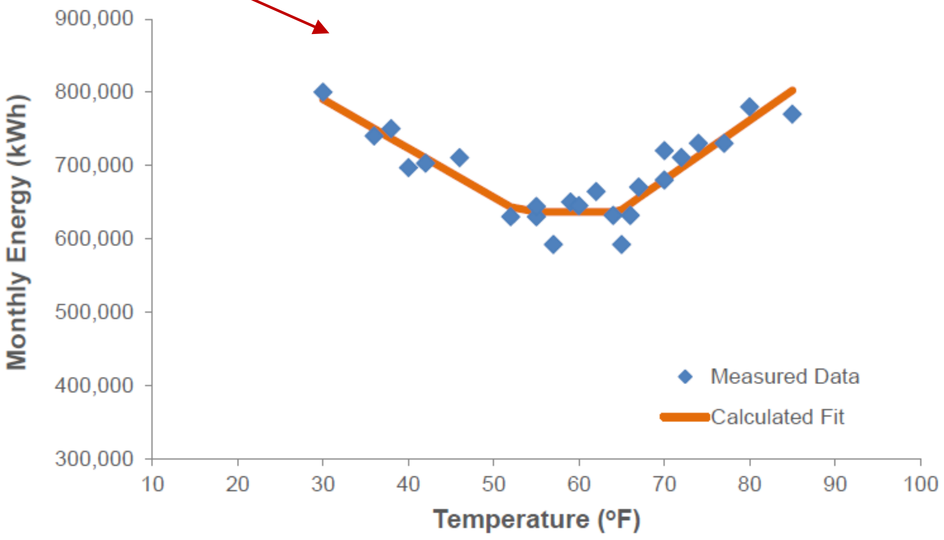
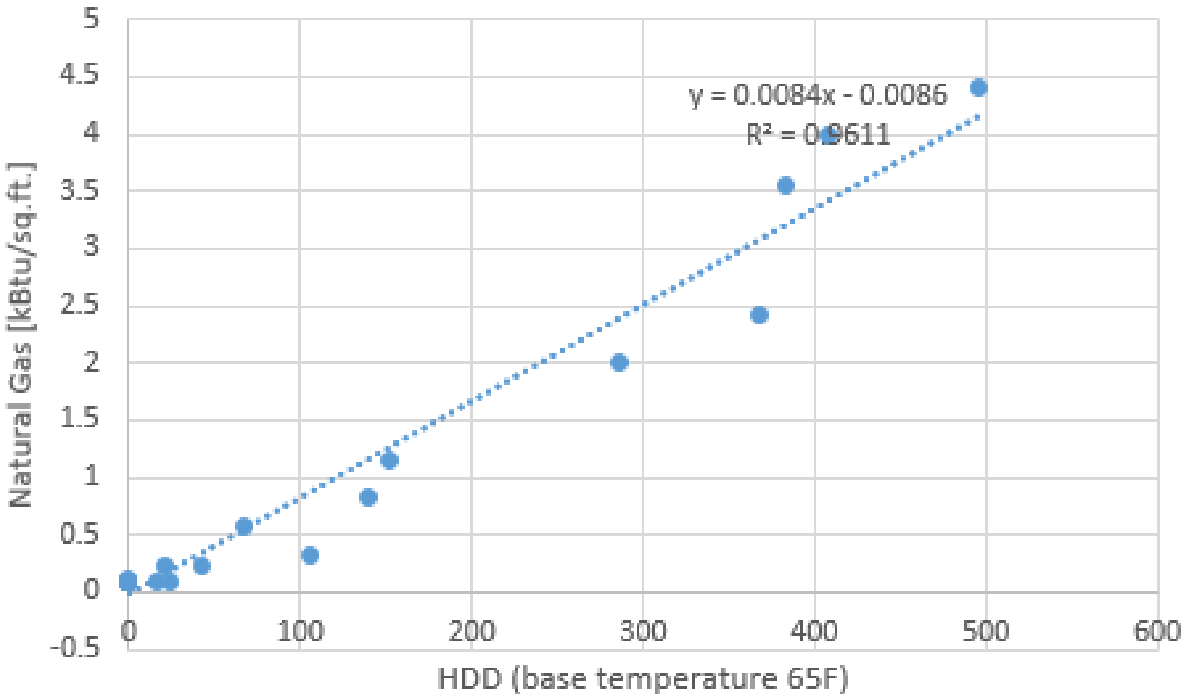


Figure 5 – Example Plot and Fit for 24 Months of Actual Energy and Weather Data



4 Portfolio Manager calculates the relationships between energy and temperature

- For each individual fuel type, a series of linear regressions is performed to determine the equation of the best fit line for the building, based on the solution with the highest correlation (R^2).
- Different fits are explored to account for how a fuel is used in a particular building. A fuel may be used for heating, cooling, or a combination of heating and cooling. A fuel used for heating only is expected to have a graph that has a sloped line at cold temperatures and remains flat during warm temperatures. The opposite is true for cooling-only fuels. Fuels used for both heating and cooling will have opposite slopes at cold and warm temperatures. The regression process reviews all potential profiles and adjusts the "change" points where the curve shifts, in order to find the solution with the highest R^2.
- It is possible to have no calculated fit, meaning a building's energy does not vary significantly as temperature changes. This may be true for buildings that use electricity for only the base load, buildings that have limited heating or cooling loads, or buildings with high internal loads like data centers and hospitals. EPA requires a minimum R^2 that varies based on the type of fit, ranging from 0.4 for simpler fits to 0.7 for more complex fits.



$y = -0.0084x - 0.0086$
$R^2 = 0.9611$

KTUS (HDD_base65F)	eui_gas [kBtu/sq.ft]	month	year
496.1168829	4.397500851	1	2013
408.2710199	3.992370957	2	2013
67.49870189	0.57454785	3	2013
23.70471398	0.081025979	4	2013
0	0.088391977	5	2013
0	0.088391977	6	2013
0	0.095757975	7	2013
0	0.081025979	8	2013
0	0.088391977	9	2013
16.91576529	0.095757975	10	2013
105.3421934	0.316737917	11	2013
383.3107218	3.543045074	12	2013
286.3560448	2.010917475	1	2014
152.0582946	1.156461698	2	2014
42.18807968	0.22834594	3	2014
21.50722218	0.235711938	4	2014
0	0.103123973	5	2014
0	0.096517356	6	2014
0	0.088467915	7	2014
0	0.095757975	8	2014
0	0.088467915	9	2014
0	0.088391977	10	2014
139.7070646	0.817625786	11	2014
367.1278752	2.430779365	12	2014

There was a mis-understanding in the previous version, I should use HDD, not temperature for x in the regression model calculation

Get the average (normal) climate year temperature of the station:
USW00023160 32.1314 -110.9553 776.9 AZ TUCSON INTL AP 72274 TRADITIONAL

Automating this step of retrieving climate normal needs to convert the 4-character weather station ID to UCDC weather station ID, need to find a lookup table for this

From the ftp retrieve the monthly temperature normal:
ftp://ftp.ncdc.noaa.gov/pub/data/normals/1981-2010/products/temperature/mly-htdd-normal.txt

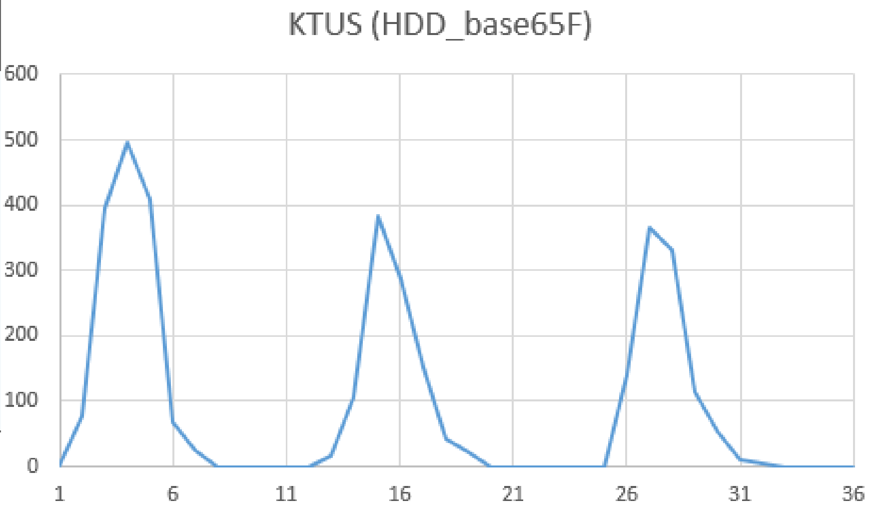
Source: ftp://ftp.ncdc.noaa.gov/pub/data/normals/1981-2010/products/temperature/mly-htdd-normal.txt					unit
			raw record	USW00023160 383S 273S 179S 60S 5S -7777S 0S 0S -7777S 24S 182C 405C	
Month	Temperature	Tag	unit	whole degrees Fahrenheit for heating and cooling degree days (except high	
Jan	383	S		precision files while are in hundredths of degrees Fahrenheit).	
Feb	273	S			
Mar	179	S	C	complete (all 30 years used)	
Apr	60	S	S	standard (no more than 5 years missing and no more than 3 consecutive	
May	5	S		years missing among the sufficiently complete years)	
Jun	-7777	S	R	representative (observed record utilized incomplete, but value was scaled	
Jul	0	S		or based on filled values to be representative of the full period of record)	
Aug	0	S	P	provisional (at least 10 years used, but not sufficiently complete to be	
Sep	-7777	S		labeled as standard or representative). Also used for parameter values on	
Oct	24	S		February 29 as well as for interpolated daily precipitation, snowfall, and	
Nov	182	C		snow depth percentiles.	
Dec	405	C	Q	quasi-normal (at least 2 years per month, but not sufficiently complete to	
				be labeled as provisional or any other higher flag code. The associated	
				value was computed using a pseudonormals approach or derived from monthly	
				pseudonormals.	

ftp://ftp.ncdc.noaa.gov/pub/data/normals/1981-2010/station-inventories/temp-inventory.txt

5 Portfolio Manager computes a normalization ratio for each fuel type

- For each fuel type, this is a ratio of the expected energy for the average (normal) climate year to the expected energy of the current year (12 month period selected).
- The expected energy values are computed using the relationship from Step 4, and solving for energy using the average (normal) climate temperatures and the actual daily temperatures, respectively. The expected values represent the energy a building would use if it exactly followed the regression equation.

  For example, if the current year is very hot, a building might be expected to use twice as much energy than under average (normal) climate conditions. The normalization ratio would be ½. The actual energy would be multiplied by ½ to determine what would have been used if it had not been so hot.

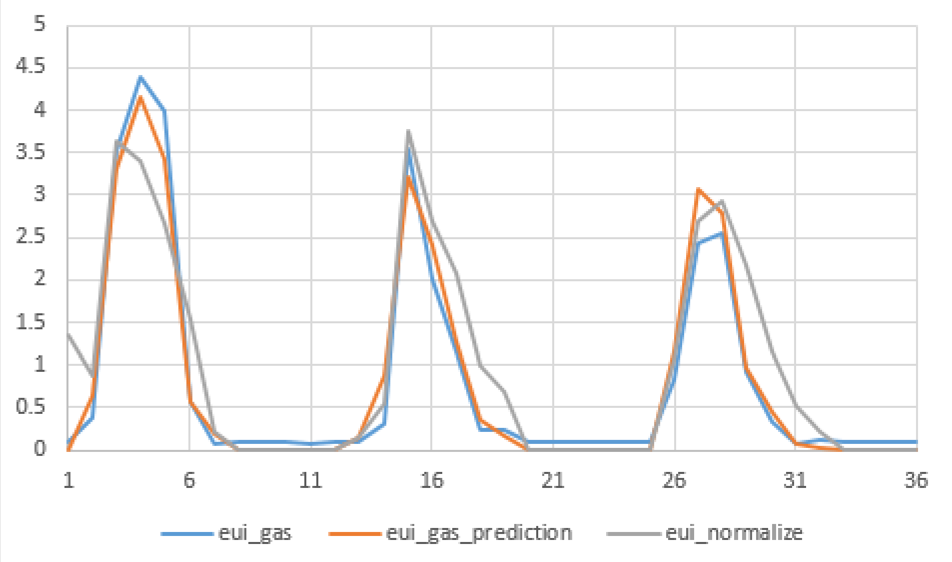


Calculation with equation: Y = 0.0084x - 0.0086

eui_normalize = eui_gas x ratio

ratio = eui_gas_norm_prediction / eui_gas_norm_prediction

eui_gas	month	year	KTUS (HDD_base65F)	eui_gas_prediction	HDD normal	eui_gas_norm_prediction	normalization ratio	eui_normalize
0.088392	10	2012	2.536249638	0.012704497	24	0.193	15.19147123	1.342804174
0.3683	11	2012	77.73789517	0.644398319	182	1.5202	2.359099883	0.86885626
3.522846	12	2012	393.238232	3.294601149	405	3.3934	1.029988107	3.628489002
4.397501	1	2013	496.1168829	4.158781816	383	3.2086	0.771524004	3.392777466
3.992371	2	2013	408.2710199	3.420876567	273	2.2846	0.667840524	2.666267113
0.574548	3	2013	67.49870189	0.558389096	179	1.495	2.677344545	1.538262552
0.081026	4	2013	23.70471398	0.190519597	60	0.4954	2.600257436	0.210688404
0.088392	5	2013	0	0	5	0.0334	0	0
0.088392	6	2013	0	0	0	0	0	0
0.095758	7	2013	0	0	0	0	0	0
0.081026	8	2013	0	0	0	0	0	0
0.088392	9	2013	0	0	0	0	0	0
0.095758	10	2013	16.91576529	0.133492428	24	0.193	1.445774883	0.138444475
0.316738	11	2013	105.3421934	0.876274425	182	1.5202	1.734844652	0.549491082
3.543045	12	2013	383.3107218	3.211210063	405	3.3934	1.056735602	3.744061871
2.010917	1	2014	286.3560448	2.396790776	383	3.2086	1.338706754	2.692028805
1.156462	2	2014	152.0582946	1.268689675	273	2.2846	1.800755571	2.082504845
0.228346	3	2014	42.18807968	0.345779869	179	1.495	4.323559967	0.987267366



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Gross Sq.Ft: 13511 Sq. Ft.

Weather station ID: KTUS

Using PM (Electricity)

Check the method with one example building

1 User Enters energy data into Portfolio Manager *(only step required by user)*

- Monthly bills in increments of 65 days or less are required for weather normalization because energy use is compared to monthly weather data. For this reason, it may not be available for fuels that are delivered in bulk.
- Normalization is based on the most recent 24 calendar months of data. If 24 calendar months of data are not available, the most recent 12 months are used.

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- Data is apportioned to calendar months based on the average energy use per day.

  For example, if a bill runs from January 10 through February 9, it covers 31 days: 22 in January and 9 in February. Of the total bill, 22/31 (71%) is assigned to January and 9/31 (29%) is assigned to February.

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PM ID: 1299729
Address: WEST AJO ROAD
City: TUCSON
State: Arizona
Zip Code: 85713
Country: United States
Type: Office
Gross Sq.Ft: 13511 Sq. Ft.

Using 2013 and 2014 electricity consumption

eui_elec [kBtu/sq.ft]	month	year
2.606160906	1	2013
2.606160906	2	2013
2.808188883	3	2013
3.212244838	4	2013
4.767860262	5	2013
6.242664496	6	2013
5.596174969	7	2013
5.778000148	8	2013
4.727454667	9	2013
2.606160906	10	2013
2.48494412	11	2013
2.404132929	12	2013
2.222307749	1	2014
2.020279772	2	2014
1.899062986	3	2014
2.889000074	4	2014
3.979951151	5	2014
5.980028125	6	2014
6.121447709	7	2014
5.858811339	8	2014
4.889077048	9	2014
3.232447635	10	2014
2.525349715	11	2014
2.707174895	12	2014

3 Portfolio Manager plots energy use and actual temperature for each fuel

- The ***actual*** temperature for each of the 24 calendar months is retrieved from the daily weather station.
- A plot is generated with energy on the vertical axis and temperature on the horizontal axis (***Figure 5***).
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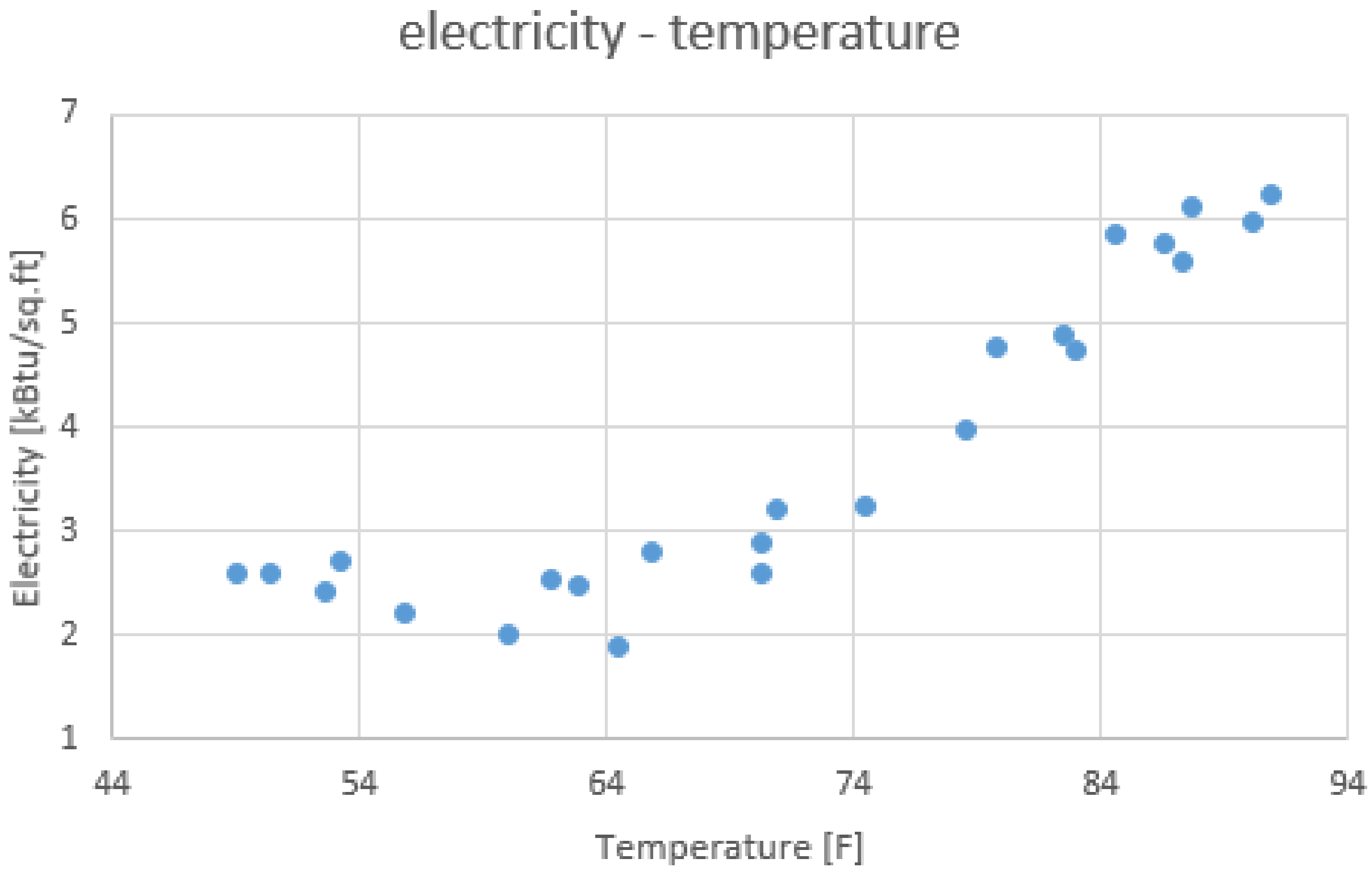
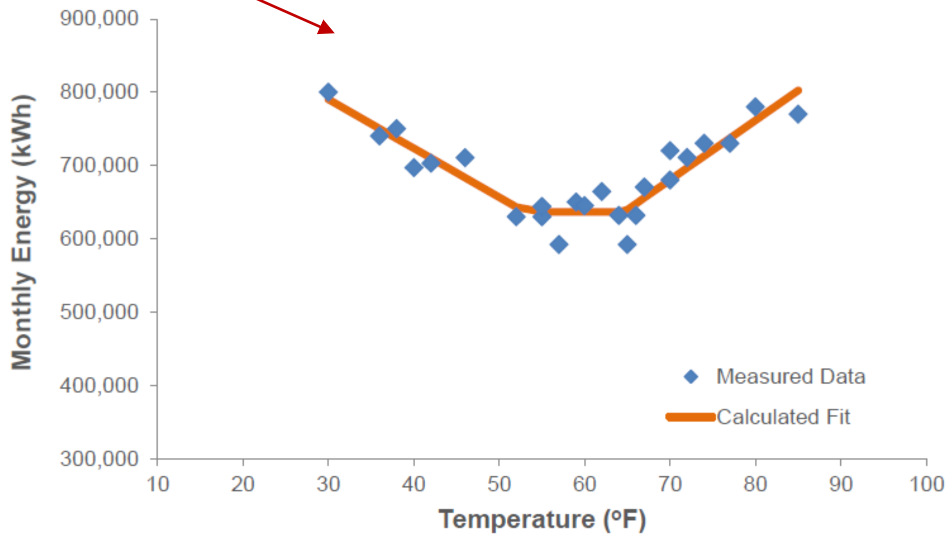


Figure 5 – Example Plot and Fit for 24 Months of Actual Energy and Weather Data



4 Portfolio Manager calculates the relationships between energy and temperature

- For each individual fuel type, a series of linear regressions is performed to determine the equation of the best fit line for the building, based on the solution with the highest correlation (R^2).
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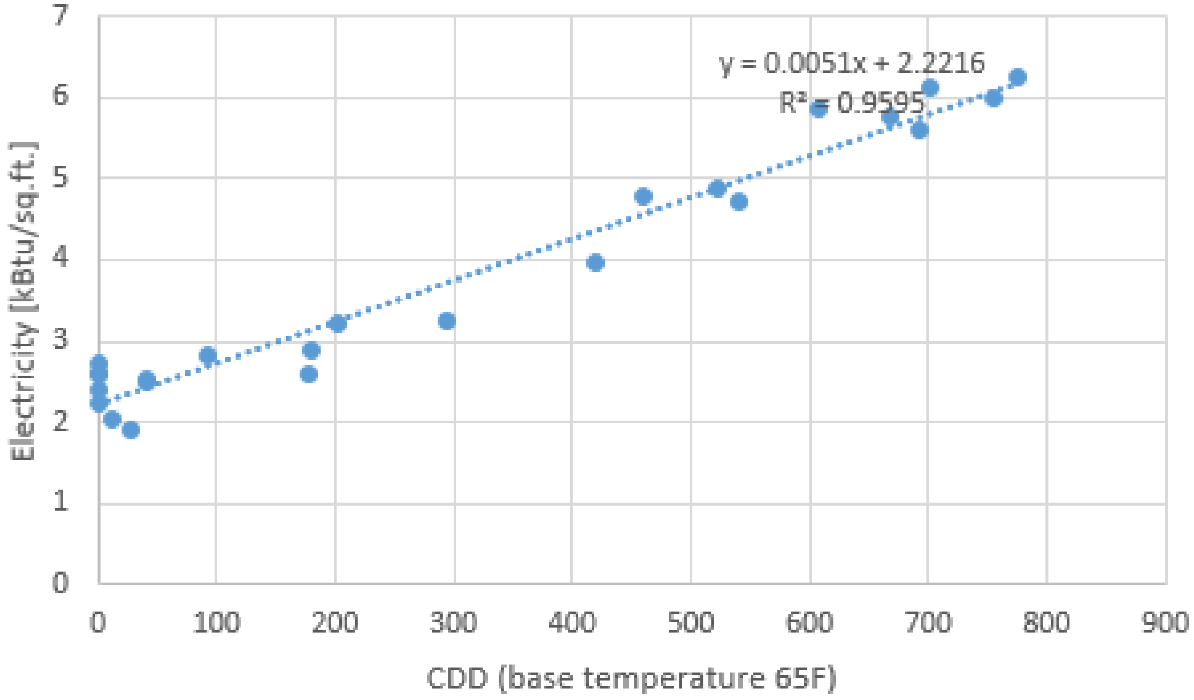

$$y = 0.0051x + 2.2216$$
$$R^2 = 0.9595$$

KTUS (CDD_base65F)	eui_elec [kBtu/sq.ft]	KTUS (Temperature)	month	year
0	2.606160906	48.99622958	1	2013
0	2.606160906	50.41889215	2	2013
92.49643103	2.808188883	65.80637836	3	2013
202.0732406	3.212244838	70.94561755	4	2013
459.673275	4.767860262	79.82817016	5	2013
775.0961936	6.242664496	90.83653979	6	2013
691.5686668	5.596174969	87.30866667	7	2013
668.721722	5.778000148	86.57166845	8	2013
540.2454537	4.727454667	83.00818179	9	2013
178.5256689	2.606160906	70.2132227	10	2013
39.96000147	2.48494412	62.8205936	11	2013
0	2.404132929	52.63513801	12	2013
1.196319103	2.222307749	55.80129917	1	2014
12.66687489	2.020279772	60.02173501	2	2014
26.95674562	1.899062986	64.50866664	3	2014
180.1026595	2.889000074	70.28651458	4	2014
419.3408548	3.979951151	78.52712435	5	2014
756.0490837	5.980028125	90.20163612	6	2014
701.4688915	6.121447709	87.62802876	7	2014
607.1507864	5.858811339	84.58550924	8	2014
523.0236214	4.889077048	82.43412071	9	2014
293.2586996	3.232447635	74.45995805	10	2014
41.77007103	2.525349715	61.73543355	11	2014
0.952499072	2.707174895	53.18789109	12	2014

Get the average (normal) climate year temperature of the station:
USW00023160 32.1314 -110.9553 776.9 AZ TUCSON INTL AP 72274 TRADITIONAL

From the ftp retrieve the monthly temperature normal:
ftp://ftp.ncdc.noaa.gov/pub/data/normals/1981-2010/products/temperature/mly-cldd-normal.txt

Automating this step of retrieving climate normal needs to convert the 4-character weather station ID to UCDC weather station ID, need to find a lookup table for this

Source: ftp://ftp.ncdc.noaa.gov/pub/data/normals/1981-2010/products/temperature/mly-htdd-normal.txt					unit
			raw record	USW00023160 1S 3S 29S 121S 348S 594S 683S 631S 497S 212S 27C -7777C	
Month	Temperature	Tag	unit	whole degrees Fahrenheit for heating and cooling degree days (except high	
Jan	1	S		precision files while are in hundredths of degrees Fahrenheit).	
Feb	3	S			
Mar	29	S	C	complete (all 30 years used)	
Apr	121	S	S	standard (no more than 5 years missing and no more than 3 consecutive	
May	348	S		years missing among the sufficiently complete years)	
Jun	594	S	R	representative (observed record utilized incomplete, but value was scaled	
Jul	683	S		or based on filled values to be representative of the full period of record)	
Aug	631	S	P	provisional (at least 10 years used, but not sufficiently complete to be	
Sep	497	S		labeled as standard or representative). Also used for parameter values on	
Oct	212	S		February 29 as well as for interpolated daily precipitation, snowfall, and	
Nov	27	C		snow depth percentiles.	
Dec	-7777	C	Q	quasi-normal (at least 2 years per month, but not sufficiently complete to	
				be labeled as provisional or any other higher flag code. The associated	
				value was computed using a pseudonormals approach or derived from monthly	
				pseudonormals.	

ftp://ftp.ncdc.noaa.gov/pub/data/normals/1981-2010/station-inventories/temp-inventory.txt

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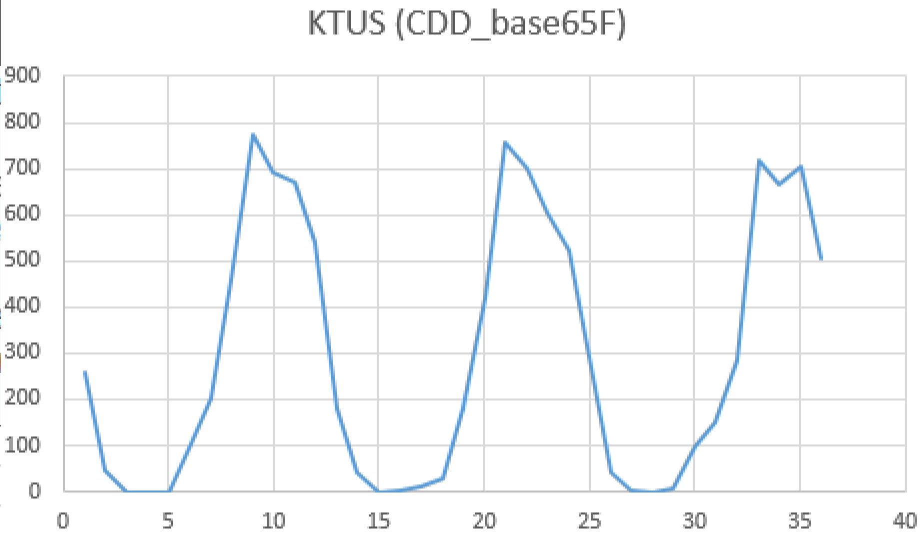

Calculation with equation: Y = 0.0051x + 2.2216

eui_elec	month	year	KTUS (HDI	eui_gas_p	CDD norm	eui_gas_n	normaliza	eui_normalize
3.959748	10	2012	258.7266	3.541106	212	3.3028	0.932703	3.693269
3.798126	11	2012	44.42757	2.448181	27	2.3593	0.963695	3.660236
3.333462	12	2012	0	2.2216	0	2.2216	1	3.333462
2.606161	1	2013	0	2.2216	1	2.2267	1.002296	2.612144
2.606161	2	2013	0	2.2216	3	2.2369	1.006887	2.624109
2.808189	3	2013	92.49643	2.693332	29	2.3695	0.879765	2.470547
3.212245	4	2013	202.0732	3.252174	121	2.8387	0.872862	2.803848
4.76786	5	2013	459.6733	4.565934	348	3.9964	0.875265	4.173139
6.242664	6	2013	775.0962	6.174591	594	5.251	0.850421	5.308891
5.596175	7	2013	691.5687	5.7486	683	5.7049	0.992398	5.553633
5.778	8	2013	668.7217	5.632081	631	5.4397	0.965842	5.580635
4.727455	9	2013	540.2455	4.976852	497	4.7563	0.955684	4.517955
2.606161	10	2013	178.5257	3.132081	212	3.3028	1.054507	2.748214
2.484944	11	2013	39.96	2.425396	27	2.3593	0.972748	2.417225
2.404133	12	2013	0	2.2216	0	2.2216	1	2.404133
2.222308	1	2014	1.196319	2.227701	1	2.2267	0.999551	2.221309
2.02028	2	2014	12.66687	2.286201	3	2.2369	0.978435	1.976713
1.899063	3	2014	26.95675	2.359079	29	2.3695	1.004417	1.907452
2.889	4	2014	180.1027	3.140124	121	2.8387	0.904009	2.611682
3.979951	5	2014	419.3409	4.360238	348	3.9964	0.916555	3.647846