Ryerson University
Faculty of Engineering and Architectural Science
BL8207-Building Performance Assessment, Prof. Vera Straka

Energy Cost versus Weather
Normalization of Energy Use

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November 17, 2009

Why to normalize the use of energy

1) What may happen if only bills are used?

You've got the client based on the promise about Electricity bill reduction from installation of your product (Fig.A)

One year after installation you've got a letter from the client claiming you in fraud based on the following diagram (Fig.B)

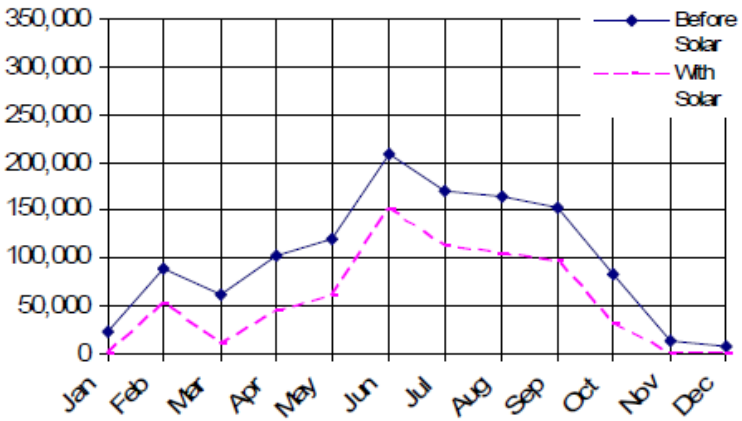


Fig.A. Monthly bills before (2004) and after installation (2005), as promised (Avina, J., n.d.)

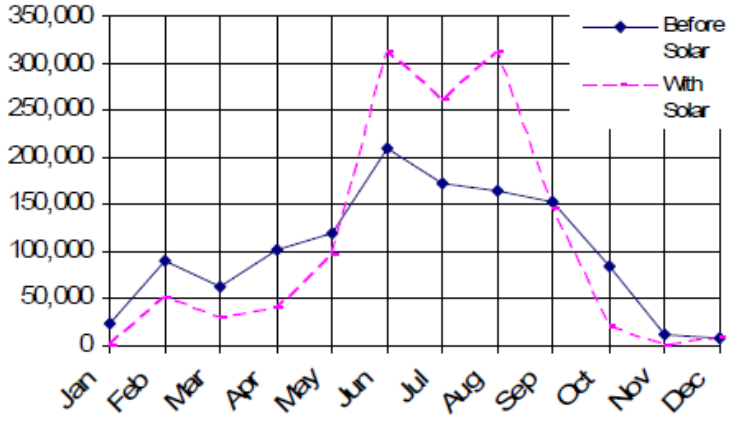


Fig.B. Monthly bills before and after installation, as measured (Avina, J., n.d.)

Why to normalize the use of energy

2) Was it your fault? The weather?

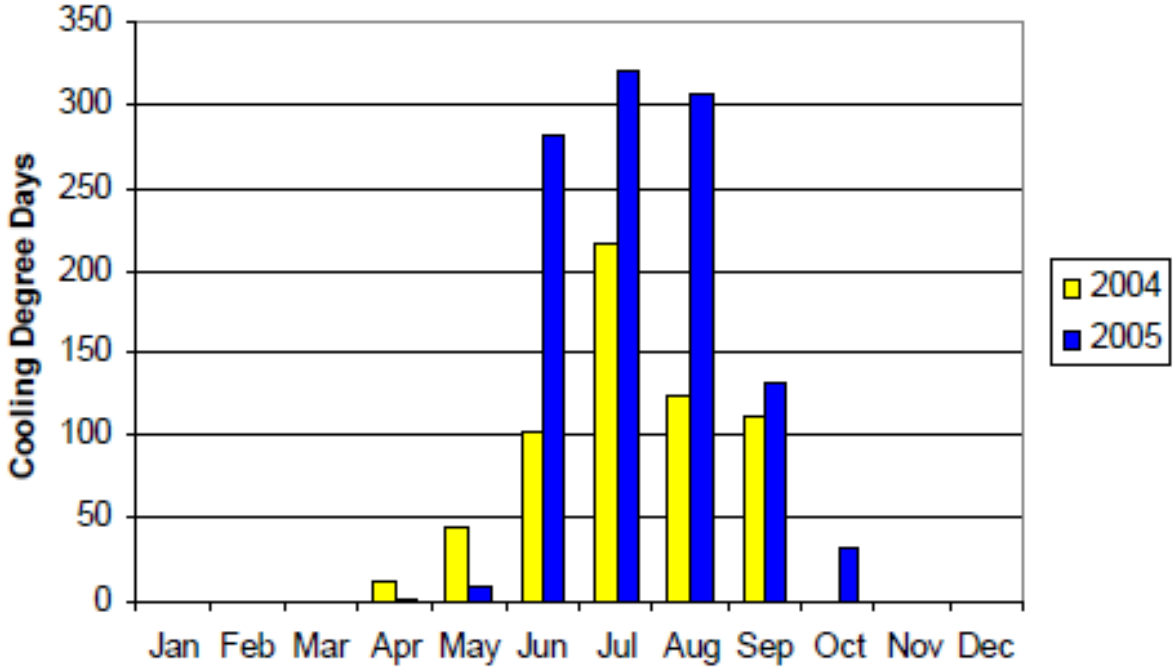
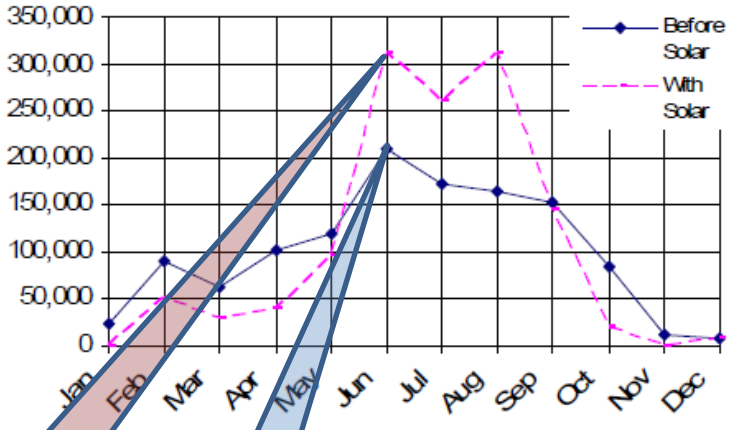
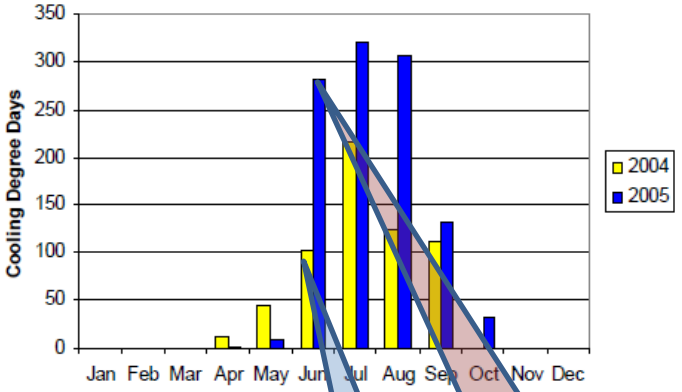


Fig. C. Cooling Degree-Days for the years before (2004) and after installation (2005) (Avina, J., n.d.)

Why to normalize the use of energy

3) Quick answer to the client





310 $ 'After' in Jun, 2005

210 $ 'Before' in Jun, 2004

2.10 $/D-day
'Before' in Jun, 2004

1.11 $/D-day
'After' in Jun, 2005

280 CDD 'After' in Jun, 2005

100 CDD 'Before' in Jun, 2004

How to normalize the use of energy

4) Useful Assumption

An average **energy consumption (*E*)** for **heating** or **cooling** the building during particular number of days is **proportional** to the **sum** of differences between Daily Outdoor Mean Temperature and Some Base Temperature ($T_{outdoor} - T_{base}$) for given number of days

$$E = \text{Coef} * \sum (T_{outdoor} - T_{base}),$$

where - T_{base} = 18ºC for Canada (In the UK, the most readily available heating degree days come with a base temperature of 15.5°C; in the US, it's 65°F(18.3 18ºC))

What does Industry Suggest?

Common (and simple) Normalization Procedure Outline (*Degree Days,* n.d. and Avina, J., n.d.)

1. Collect weather data for the pre-retrofit and post-retrofit periods. Climatic Data from http://www.climate.weatheroffice.ec.gc.ca work well.
2. Weather data need to be processed in order to get Heating Degree Days (***HDD***) or Cooling Degree Days (***CDD***). Most likely you have monthly bills, and you may need to do a little Excel exercise.
3. Process **pre-retrofit bill data** in order to determine how much did you pay (or use) per day. Excel can help.
4. Put processed **pre-retrofit bill data** against processed **weather data** in the same scatter graph. Determine the **Best Fit Line** (regression line or simply linear approximation of scattered data) and its quality (R^2 - value). Industry suggest if $R^2 > 0.7$ you may rely upon it.
5. Use this line to try **post-retrofit bill data**.

Normalization Procedure

1) Weather data collection (Environment Canada, 2009)

Environment Canada | Environnement Canada | Canada

National Climate Data and Information Archive
www.climate.weatheroffice.ec.gc.ca

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Notices:

We are pleased to announce the release of a new feature, Historical Radar to our site. The Historical Radar feature allows users to view historical radar images from 2007 to present at the national, regional and local levels. It can be accessed by clicking the "Historical Radar" link on the left menu bar.

As of July 24, 2008 changes were made in how data are accessed at 25 stations. Please click here for further details.

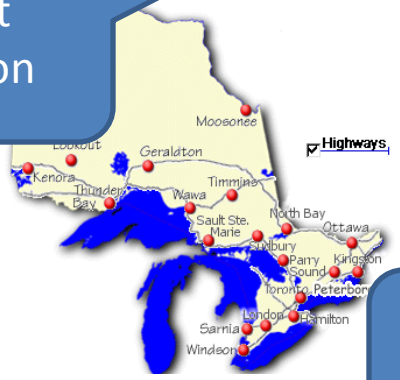
To display climate data directly from the database, first specify a date, data interval and select a location on the map. For locations not available on the map, click on customized search.

Province: ONTARIO Go

City: TORONTO Go

Customized Search

Search options:
Month: Nov
Day: 14
Year: 2009
Interval: Daily



Select Location

Select Type of Data

Daily Data Report for November 2009

Notes on Data Quality.

TORONTO LESTER B. PEARSON INT'L A
ONTARIO
Latitude: 43° 40.800' N Longitude: 79° 37.800' W Elevation: 173.40 m
Climate ID: 6158733 WMO ID: 71624 TC ID: YYZ

Previous Month | November | 2009 | Go

Daily Data Report for November 2009

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10's Deg	Spd of Max Gust km/h
01†	10.7	4.1	7.4	10.6	0.0	0.0	0.0	0.0		28	32
02†	10.4	1.1	5.8	12.2	0.0	1.6	0.0	1.6			<31
03†	8.9	0.9	4.9	13.1	0.0	T	0.0	T		33	50
04†	6.2	-1.2	2.5	15.5	0.0	1.8	0.0	1.8			<31
05†	7.5	1.3	4.4	13.6	0.0	1.6	0.0	1.6		32	69
06†	4.9	-1.1	1.9	16.1	0.0	0.0	0.0	0.0			<31
07†	16.1	4.5	10.3	7.7	0.0	0.0	0.0	0.0		21	41
08†	18.1	4.7	11.4	6.6	0.0	0.0	0.0	0.0			<31
09†	19.1	3.9	11.5	6.5	0.0	0.0	0.0	0.0			<31
10†	13.5	3.3	8.4	9.6	0.0	0.0	0.0	0.0			<31
11†	9.0	-0.5	4.3	13.7	0.0	0.0					1
12†	9.6	-1.8	3.9	14.1	0.0	0.0					1
13†	11.1	-1.5	4.8	13.2	0.0	0.0					1
14											
Sum				152.5*	0.0*	5.0*					
Avg	11.2*	1.4*	6.3*								
Xtrm	19.1*	-1.8*									

Previous Month | November | 2009 | Go

Legend
[empty] = No data available
M = Missing
E = Estimated
A = Accumulated
C = Precipitation occurred, amount uncertain
L = Precipitation may or may not have occurred
F = Accumulated and estimated
N = Temperature missing but known to be > 0

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Customizable Cha...
Monthly Data (2009
Bulk Data (2009) [CSV] [XML]

Download Bulk Data

Normalization Procedure

1) Weather data collection (Environment Canada, 2009)

Monthly Data Report for 2007

Notes on Data Quality.

TORONTO LESTER B. PEARSON INT'L A
ONTARIO

Latitude: 43° 40.800' N Longitude: 79° 37.800' W Elevation: 173.40 m

Climate ID: 6158733 WMO ID: 71624 TC ID: YYZ

Previous Year 2007 Go Next Year

Monthly Data Report for 2007

Month	Mean Max Temp °C	Mean Temp °C	Mean Min Temp °C	Extr Max Temp °C	Extr Min Temp °C	Total Rain mm	Total Snow cm	Total Precip mm	Snow Grnd Last Day cm	Dir of Max Gust 10's Deg	Spd of Max Gust km/h
Jan	0.6	-2.9	-6.3	11.9	-17.5	23.4	15.8	38.6	7	26	78
Feb	-4.6	-8.4	-12.2	4.3	-21.0	T	27.2	24.6	11	32	76
Mar	4.9	0.4	-4.1	20.3	-22.1	18.8	13.3	33.4	0	30*	70*
Apr	10.5	6.1	1.7	25.4	-7.2	58.4	2.4	60.8	0	27*	95*
May	20.3	14.3	8.3	31.0	2.4	73.6	0.0	73.6	0	33	59
Jun	26.9	20.8	14.6	34.4	6.2	43.2	0.0	43.2	0	24	96
Jul	27.0	21.3	15.6	34.4	11.2	47.4	0.0	47.4	0	22S	59S
Aug	28.1	22.4	16.7	34.8	9.7	20.8	0.0	20.8	0	32	70
Sep	24.3	18.4	12.4	34.4	5.1S	28.6	0.0	28.6	0	23	70
Oct	19.0	14.2	9.4	31.6	-0.8	41.2	0.0	41.2	0	30	78
Nov	6.6	2.6	-1.5	15.7	-9.9	73.6	11.0	87.8	0	27	80
Dec	0.6	-2.3	-5.3	7.9	-13.2	49.2	44.4	92.7	2	29	74
Sum						**478.2**	**114.1**	**592.7**			
Avg	**13.7**	**8.9**	**4.1**								
Xtrm				**34.8**	**-22.1**					**29**	**96***

Previous Year 2007 Go Next Year

Legend
[empty] = No data available
M = Missing
E = Estimated
B = More than one occurrence and estimated
* = The value displayed is based on incomplete data
S = More than one occurrence

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Normalization Procedure

2) Weather data processing

Heating Degree Days (HDD) (Environment Canada, 2009)

Heating degree-days for a given day are the number of Celsius degrees that the mean temperature is below 18°C. If the temperature is equal to or greater than 18°C, then the number will be zero. For example, a day with a mean temperature of 15.5°C has 2.5 heating degree-days; a day with a mean temperature of 20.5°C has zero degree-days. Heating degree-days are used primarily to estimate the heating requirements of buildings.

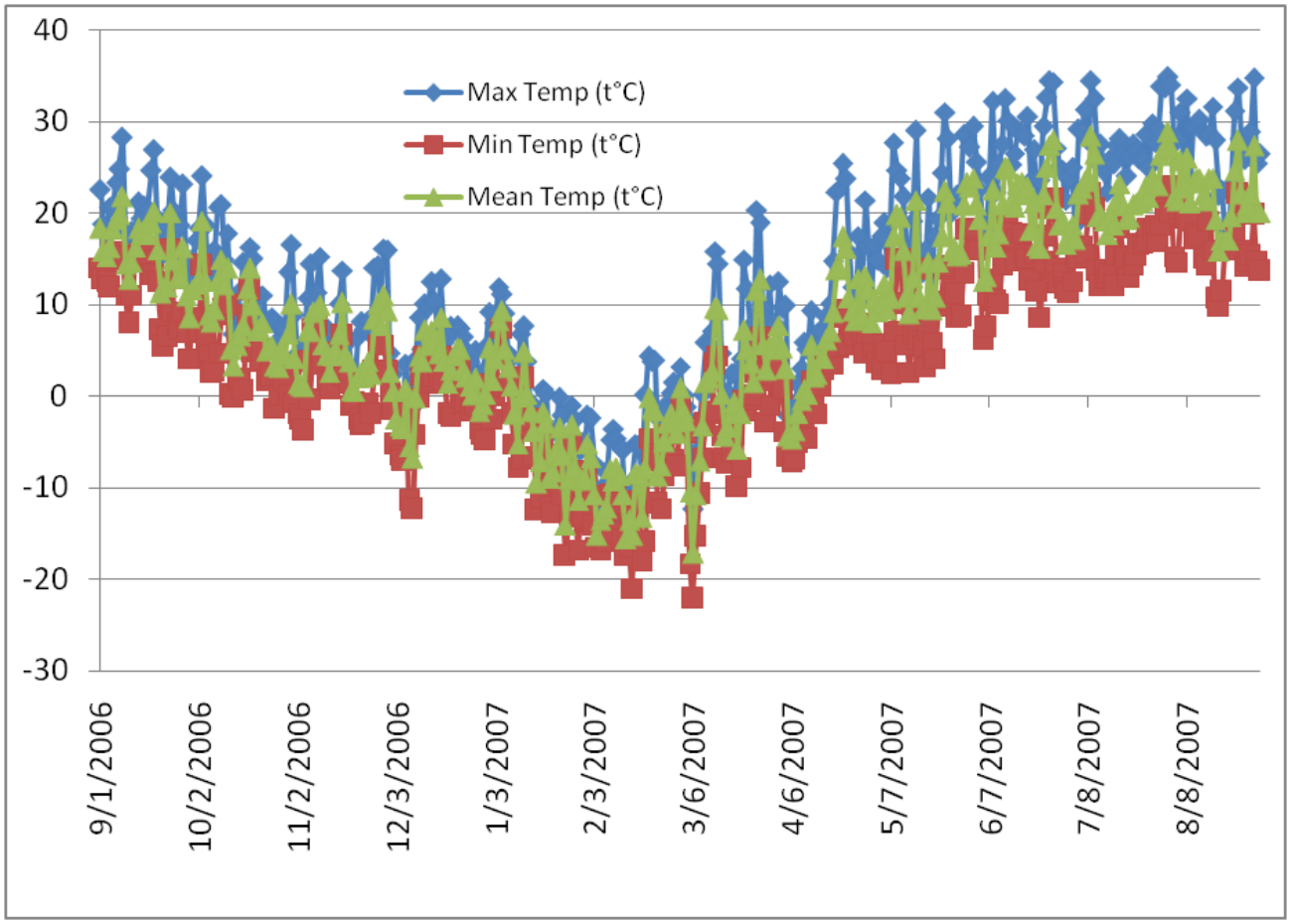
Cooling Degree Days (CDD) (Environment Canada, 2009)

Cooling degree-days for a given day are the number of Celsius degrees that the mean temperature is above 18°C. If the temperature is equal to or less than 18°C, then the number will be zero. For example, a day with a mean temperature of 20.5°C has 2.5 cooling degree-days; a day with a mean temperature of 15.5°C has zero degree-days. Cooling degree-days are used primarily to estimate the air-conditioning requirements of buildings.

Normalization Procedure

2) Weather data processing

Max/Min/Mean Temperature Sept.2006 – Aug.2007

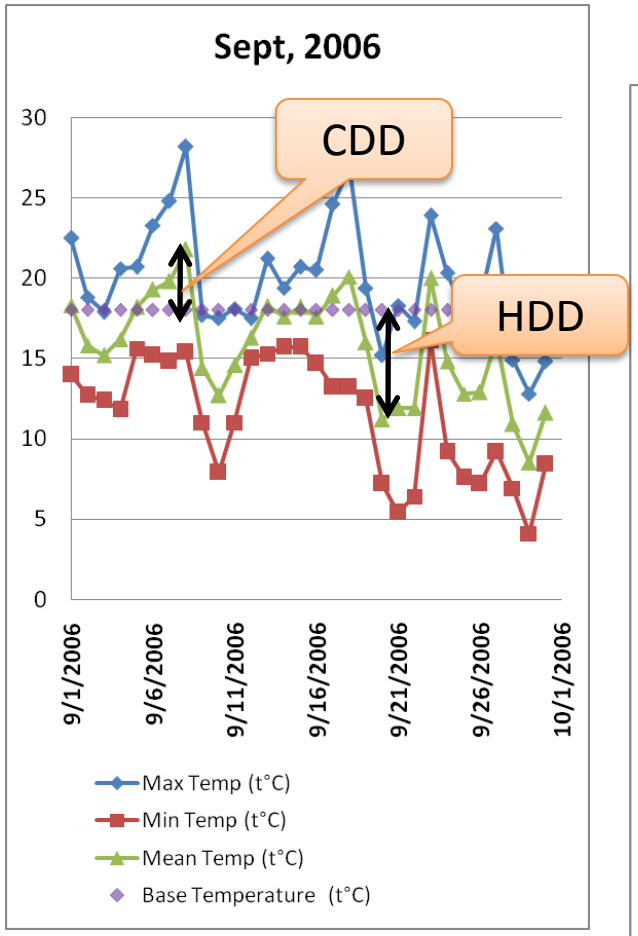


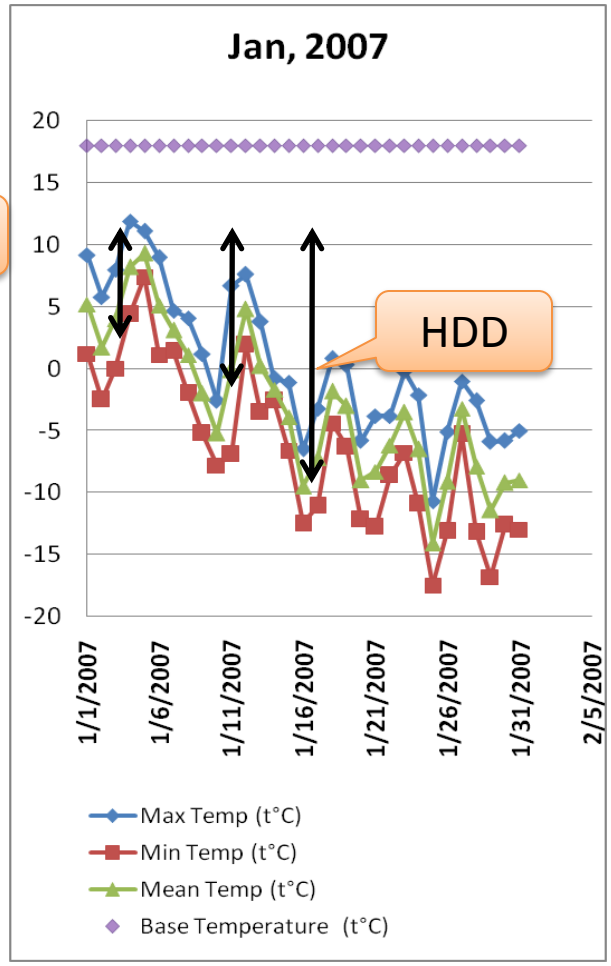
Toronto Lester B. Pearson Int'l Airport

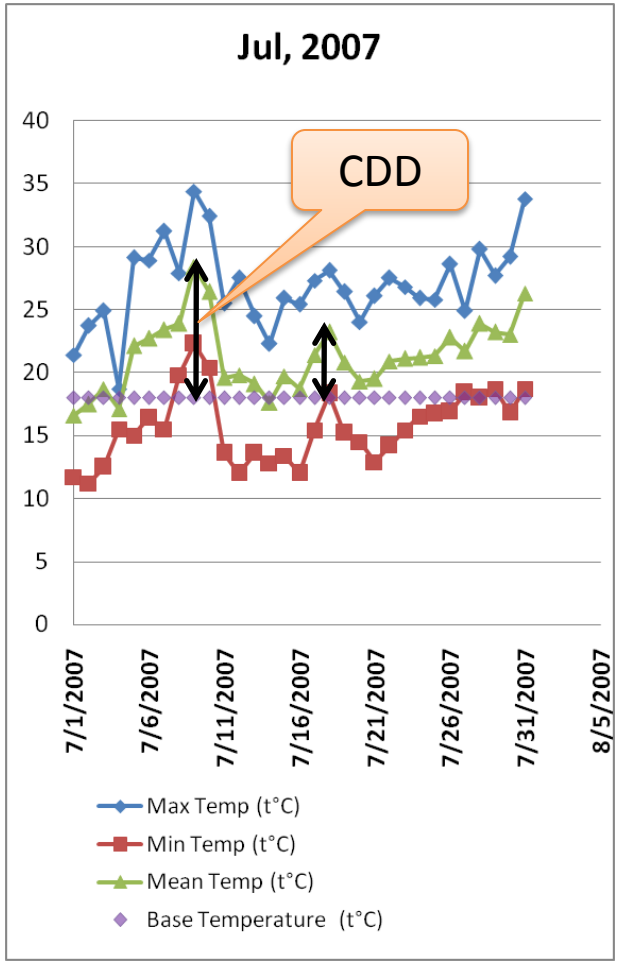
Normalization Procedure

2) Weather data processing

Max/Min/Mean Temperature







Normalization Procedure

2) Weather data processing

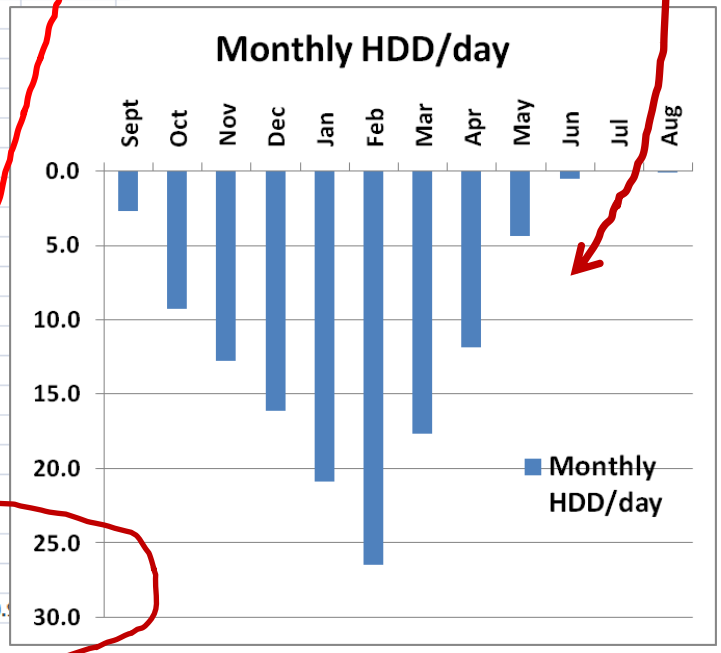
	A	B	C	D	E	F	G	H	I	J	K
1	Date/Time	Year	Month	Day	Max Temp (t°C)	Min Temp (t°C)	Mean Temp (t°C)	Heat Deg Days (Â°C)	Cool Deg Days (Â°C)		HDD
2	9/1/2006	2006	9	1	22.5	14	18.3	0	0.3		
3	9/2/2006	2006	9	2	18.8	12.7	15.8	2.2			
4	9/3/2006	2006	9	3	17.9	12.4	15.2	2.8			
5	9/4/2006	2006	9	4	20.6	11.8	16.2	1.8			
6	9/5/2006	2006	9	5	20.7	15.6	18.2	0			
7	9/6/2006	2006	9	6	23.3	15.2	19.3	0			
8					24.8	14.8	19.8	0			
9					28.2	15.4	21.8	0	3.8		
10					17.7	11	14.4	3.6	0		
11					17.5	7.9	12.7	5.3	0		
12						11	14.6	3.4	0		
13					17.5		16.3	1.7	0		
14	9/13/2006	2006	9	13	21.2	15.3	18.3	0	0.3		
15	9/14/2006	2006	9	14	19.4	15.7	17.6	0.4	0		
16	9/15/2006	2006	9	15	20.7	15.7	18.2	0	0.2		
17	9/16/2006	2006	9	16	20.5	14.7	17.6	0.4	0		
18	9/17/2006	2006	9	17	24.6	13.2	18.9	0	0.9		
19	9/18/2006	2006	9	18	26.9	13.2	20.1	0	2.1		
20	9/19/2006	2006	9	19	19.4	12.5	16	2	0		
21	9/20/2006	2006	9	20	15.2	7.2	11.2	6.8	0		
22	9/21/2006	2006	9	21	18.3	5.4	11.9	6.1	0		
23	9/22/2006	2006	9	22	17.3	6.4	11.9	6.1	0		
24	9/23/2006	2006	9	23	23.9	16.1	20	0	2		
25	9/24/2006	2006	9	24	20.3	9.2	14.8	3.2	0		
26	9/25/2006	2006						5.2	0		
27	9/26/2006	2006						5.1	0		
28	9/27/2006	2006						1.8	0		
29	9/28/2006	2006							0		
30	9/29/2006	2006									
31	9/30/2006	2006						6.4	0		
32										Sept	80.9
33	10/1/2006	2006	10	1	17	7.4	12.2	5.8			

	A	B	C	D	E	F
1			HDD	Monthly HDD/day	Monthly Gas, m3	Monthly Gas/day
2	Sept	30	80.9	2.7	0	0.00
3	Oct	31	288.3	9.3	1505	48.55
4	Nov	30	382.2	12.7	5704	190.13
5	Dec	31	500.5	16.1	9397	303.13
6	Jan	31	647.1	20.9	12407	400.23
7	Feb	28	740.1	26.4	11921	425.75
8	Mar	31	546.7	17.6	9009	290.61
			.4	11.9	6426	214.20
			136.4	4.4	2115	68.23
			16.5	0.6	580	19.33
			3.2	0.1	244	7.87
			5.2	0.2	152	4.90
14						

HDD=Tbase-Tmean
Tbase= 18°C

HDD
days in a month .

Sum of HDD



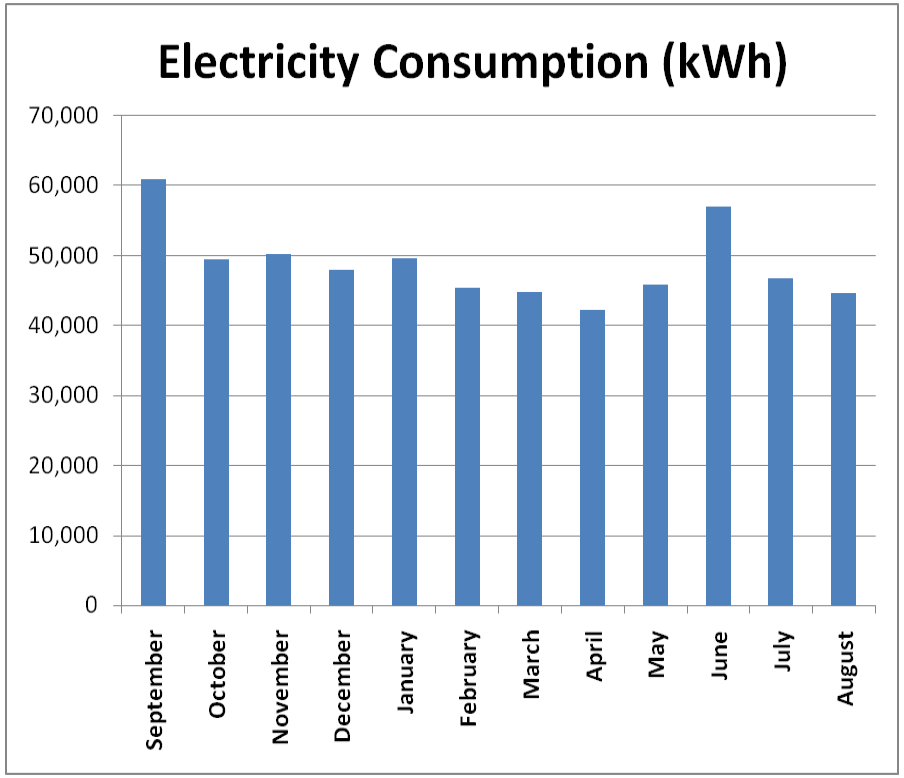
Normalization Procedure. Example

3) Pre-retrofit bill data processing

A North York School:

Electricity consumed within period from Sept.2006 through Aug.2007

Actual Energy Consumption 2006/2007 - Electricity						
Year	Month	Consumption (kWh)	Consumption (MJ)	Consumption (MJ/sq.m)	Number of Students	Consumption (MJ/students)
2006	September	61,018	219,665	58.11	300	732.22
2006	October	49,488	178,157	47.13	300	593.86
2006	November	50,274	180,986	47.88	300	603.29
2006	December	47,953	172,631	45.67	300	575.44
2007	January	49,650	178,740	47.29	300	595.80
2007	February	45,416	163,498	43.25	300	544.99
2007	March	44,765	161,154	42.63	300	537.18
2007	April	42,263	152,147	40.25	300	507.16
2007	May	45,915	165,294	43.73	300	550.98
2007	June	56,975	205,110	54.26	300	683.70
2007	July	46,795	168,462	44.57	300	561.54
2007	August	44,657	160,765	42.53	300	535.88
Total		585,169	2,106,608	557.30	300	7022.03

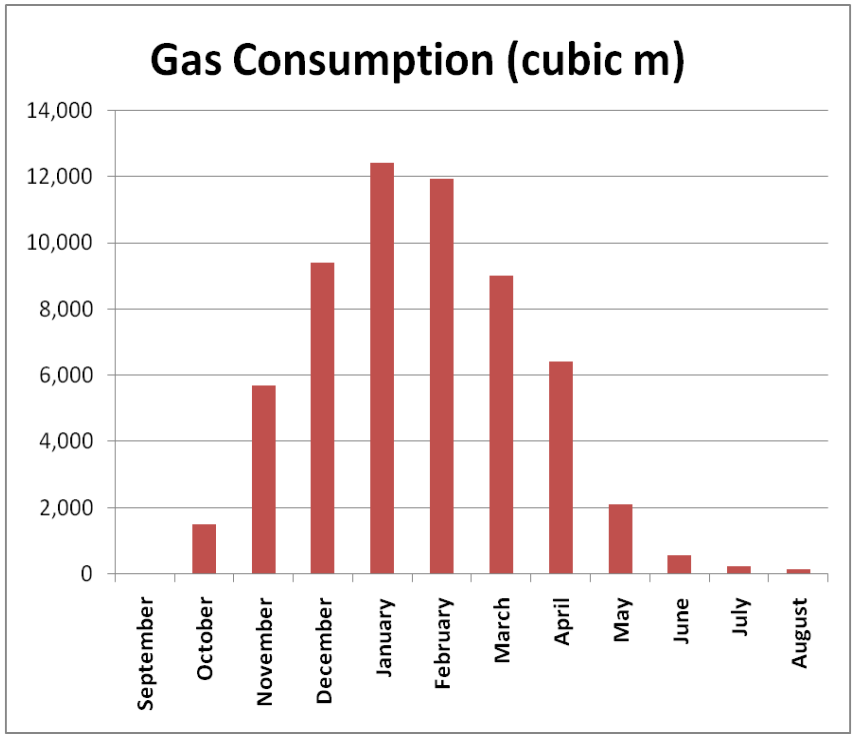


Normalization Procedure. Example

3) Pre-retrofit bill data processing

A North York School:
Gas consumed within period from Sept.2006 through Aug.2007

Actual Energy Consumption 2006/2007 - Gas						
Year	Month	Consumption (cubic m)	Consumption (MJ)	Consumption (MJ/sq.m)	Number of Students	Consumption (MJ/students)
2006	September	0	0	0.00	300	0.00
2006	October	1,505	57,190	15.13	300	190.63
2006	November	5,704	216,752	57.34	300	722.51
2006	December	9,397	357,086	94.47	300	1190.29
2007	January	12,407	471,466	124.73	300	1571.55
2007	February	11,921	452,998	119.84	300	1509.99
2007	March	9,009	342,342	90.57	300	1141.14
2007	April	6,426	244,188	64.60	300	813.96
2007	May	2,115	80,370	21.26	300	267.90
2007	June	580	22,040	5.83	300	73.47
2007	July	244	9,272	2.45	300	30.91
2007	August	152	5,776	1.53	300	19.25
Total		59,460	2,259,480	597.75	300	7531.60



Normalization Procedure. Example

4) Best Fit Line for Bill Data versus D-days data

	A	B	C	D	E	F	G
1			HDD	Monthly HDD/day	Monthly Gas, m3	Monthly Gas/day	
2	Sept	30	80.9	2.7	0	0.00	
3	Oct	31	288.3	9.3	1505	48.55	
4	Nov	30	382.2	12.7	5704	190.13	
5	Dec	31	500.5	16.1	9397	303.13	
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12	Jul	31	3.2	0.1	244	7.87	
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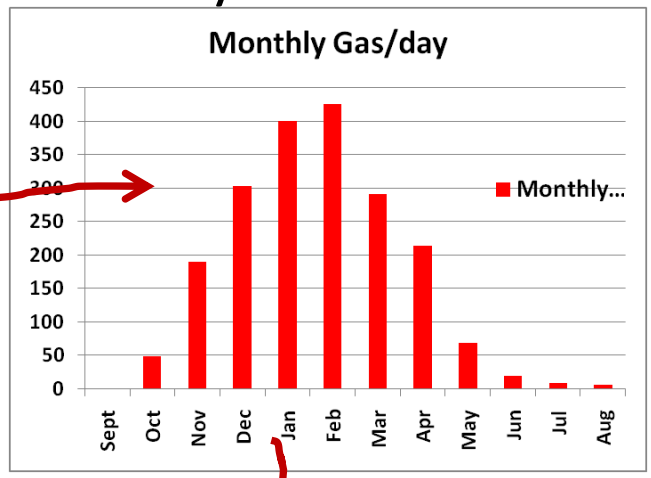
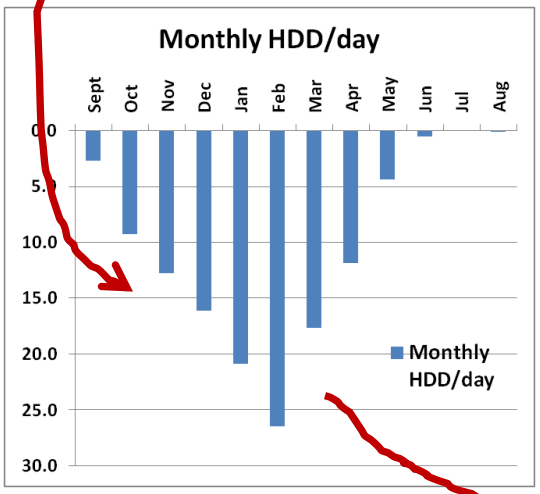
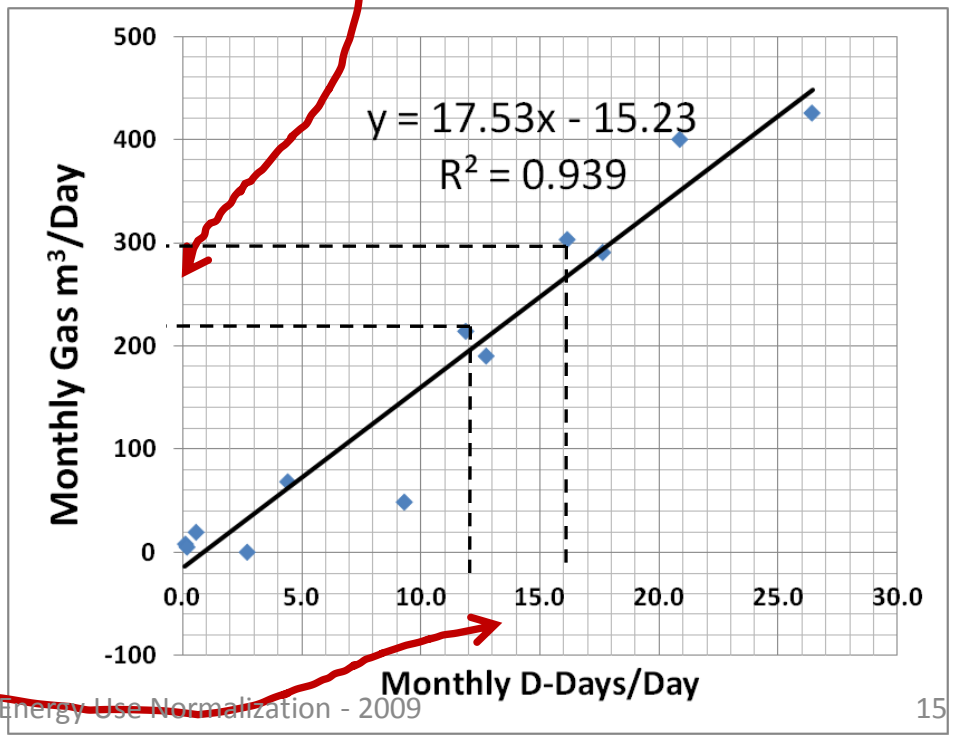
14							



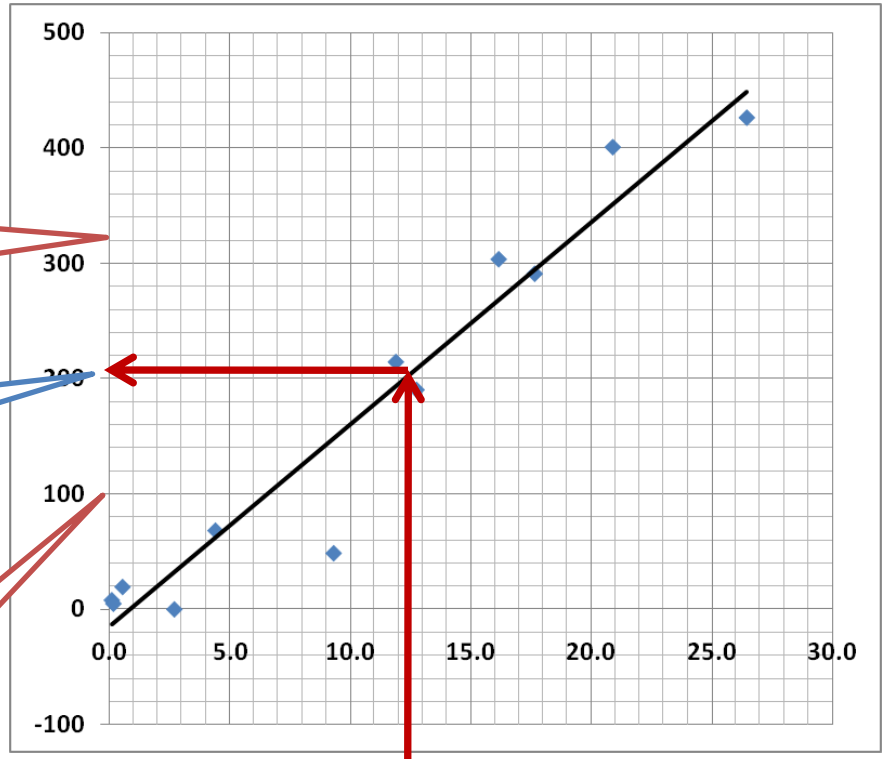




Normalization Procedure. Example

5) How to use the **Baseline** for normalization

E_{base}= **17.53** x ***HDD-15.23***



Actual **Consumption** after **'Bad' Retrofit**

'Would be' Consumption as before Retrofit

Actual **Consumption** after **Good Retrofit**

New Weather Data

Some Problems with degree-day-based methods

(*Degree Days,* n.d.)

The base temperature problem

Different buildings have different base temperatures.
In the UK, for example, a base temperature is 15.5°C.
Buildings are typically heated to a temperature of around 19°C.
Some heat comes from other sources such (the people and equipment in the building.
These sources contribute to an "average internal heat gain" that is typically worth around 3.5°C.

Different buildings are heated to different temperatures.

Average internal heat gain varies greatly from building to building.

The meter reading problem

If you're taking those meter readings manually, you will need to take them at midnight, and you will often need to take them on weekends.

The "ideal" temperature problem

Use of both heating and air conditioning

Poor HVAC control can often result in a building being heated at the same time as it is being cooled - not very energy efficient at all!

'Heat Island' and other local site effects

Conclusions

There is no perfect solution

Use degree days wisely (e.g. *Degree Days,* n.d.)

References

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Thank You !!!

Questions????