High-Rise Residential Building Weather Sensitivity for British Columbia

Case Studies outside Vancouver and Burnaby

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BC Hydro Customer Information Management—Load Analysis
BC Hydro, Burnaby, British Columbia

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Context and Important Findings

Audience: Managers, analysts and forecasters concerned with effect of increasing numbers of high-rise residential buildings on the weather sensitivity of BC Hydro's distribution system.

BC Hydro Context

- There is sparse quantitative knowledge about weather sensitivity of high-rise residential buildings; Need to know relationship between weather-driven consumption and height
- Over and underestimating relationship between consumption and weather events (in terms of degree-days) has costs in BC Hydro's business model
- More accurate consumption forecasting is beneficial financially for BC Hydro

Important Findings

- Weather-driven electrical energy consumption in a sample of 35 electrically heated residential high-rise buildings outside of Vancouver/Burnaby often is stable with height (69%), sometimes decreases with height (28%), or rarely increases with height (3%).
- Analyses of weather sensitivity of electrical heating is confounded by natural gas heating of building common areas. This heat infiltrates suites that also have electrical baseboard heaters.
- When gas heating data is available for a building the relative proportions of gas and electric heating can be estimated, as can the efficiency of the gas heating system.
- Missing gas data can be inferred if: (1) weather sensitivity of electric energy consumption is known and (2) a reasonable assumption is made about a building enclosure's thermal transmissivity.
- Rehabilitation of building enclosures of gas/electric buildings reduces the proportion of gas consumed but increases the proportion of electricity consumed.

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High-Rise Residential Building Weather Sensitivity for BC

Introduction to case studies outside Vancouver/Burnaby

Load analysis accuracy may improve with better understanding of high-rise (tall) building weather sensitivity in the context of the heating degree-day climate of BC's urban centres. BC Hydro's working definition of a tall building is at least 12 storeys with at least 80 apartment suites. Most of the buildings in this study stand alone—lone pines rather than part of a pine forest—in contrast to buildings in Vancouver/Burnaby. This project used BC Hydro's electrical energy consumption data set from Apr 2004 to Sep 2009 for purely apartment buildings. RDH Building Engineering Ltd. kindly supplied thermal modeling results and spreadsheet analyses for several buildings.

Analyses of weather sensitivity in this report are normalized to unit area dimensions unlike our earlier report which used aggregated data (Wahlgren and Bains, 2010). Weather sensitivities are represented by the floor-by-floor steady-state thermal transmittance with dimensions [W / (m^2 · K)].

Gas heating data was available for two case studies, one in Coquitlam, the other in Surrey.

Companion reading:
Wahlgren, R. and Bains, H. (2010) Tall Building Climatology for British Columbia (Residential): Overview and analyses of aggregated data. Available in BC Hydro's online Load Research Library http://bchx/library/ViewAttachment.asp?d=2946

Source: http://nanaimocondo.ca/cameron-island/

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Project and Data Set Specifications (1 of 4)

Project and Data Set Specifications were written by Harinder Bains, Sr. Energy Load Advisor

[The] Excel file contains **256 "tall"** residential apartment buildings. My criterion for a "tall" building is that the building has to be **at least 12 floors** (storeys) high with **at least 80 Apartment Suites**. I picked buildings that are at least 6 years old (based on our building age logic) and those that are quite clean with respect to data quality (pure apartment buildings with common use). Based on these criteria I was able to **obtain 256 buildings** (33,864 Apartment Suites in total) – majority of these buildings are from the Lower Mainland (Metro Vancouver) - breakdown by region/service town is as follows:

"The ASHRAE Technical Committee for Tall Buildings defines *tall buildings* as those higher than 91 m [30 stories]" (Ross, 2004; cited in Ellis and Torcellini, 2005)

Project and Data Set Specifications (2 of 4)

Electrically-heated buildings outside Vancouver/Burnaby
n = 35

Suites are heated by electric baseboard heaters; Common areas (hallways, lobbies) are heated by gas

Lower Mainland (total of 244 buildings)

- Vancouver – 157 buildings
- Burnaby – 50 buildings

} Not used in this study

- Richmond – 9 buildings [7 electric, 2 non-electric]
- Surrey – 9 buildings [9 electric]
- North Vancouver – 6 buildings [2 electric, 4 non-electric]; 1 LEED building was added to original dataset
- Coquitlam – 5 buildings [4 electric, 1 non-electric]
- Abbotsford – 4 buildings [3 electric, 1 non-electric]
- West Vancouver – 3 buildings [3 non-electric]
- Maple Ridge – 1 building [non-electric]

Vancouver Island (total of 11 buildings)

- Victoria – 9 buildings [7 electric, 2 non-electric]
- Nanaimo – 2 buildings [2 electric]

Northern (total of 1 building)

- Prince George – 1 building [non-electric]

The Prince George building was the only non-electric building analyzed in this study. It illustrated the minimal weather sensitivity of electric energy consumption in buildings heated solely by gas.

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Project and Data Set Specifications (3 of 4)

As mentioned above, the minimum number of floors (storeys) is 12 – and the maximum number of floors is 46. I have separated out the common/other use by the following "Floor Number" codes (fake floor numbers are created to capture common use consumption by rate/premise codes):

Floor Number = 90 shows consumption for common use (rate 1111 with premise code of 140)

Floor Number = 91 shows consumption for common use (rate 1220 with premise code of 140)

Floor Number = 92 shows consumption for common use (rate 1220 with premise code of 141)

Floor Number = 93 shows consumption for common use (rate 1200 with premise code of 140)

Floor Number = 94 shows consumption for common use (rate 1200 with premise code of 141)

Floor Number = 95 shows consumption for common use (rate 1210 with premise code of 140)

Floor Number = 96 shows consumption for common use (rate 1210 with premise code of 141)

Floor Number = 97 shows consumption for common use (rate 1211 with premise code of 140)

Floor Number = 98 shows consumption for common use (rate 1212 with premise code of 140/141)

Floor Number = 99 shows consumption for common use (rate 1101 with premise code of 020) – suites that are missing unit numbers (unable to place on Floor)

Project and Data Set Specifications (4 of 4)

The following rate and premise codes are important here:
Rate 1111 – residential common use rate
Rate 1220 – commercial (general under 35 kW) common use rate
Rates 1200/1210/1211 – commercial (general – 35 kW & over) common use rate
Rate 1212 – transformer discount rate
Premise 020 – Apartment Suite
Premise 140 – Apartment Building common use
Premise 141 – Apartment/Business Complex common use
Billing history is summarized, by Floor Number, for each of the 256 buildings. The apartment suite consumption is shown for each floor – by rate code 1101 and premise code 020. The number of apartment suites per floor is indicated by "N" for each month – typically, the N is fairly consistent across time (some months may show it lower by 1 due to no billing). The billing history is provided from April 2004 to September 2009 (5 ½ years). … bring in weather to ***see if there is any relationship between usage and height (floor) of the building.***

In this report, **one storey is equivalent to 3 m (10 ft),** in accordance with the *Fire Reporting Manual* issued by Office of the Fire Commissioner, Ministry of Public Safety and Solicitor General, Government of British Columbia (Source: http://www.pssg.gov.bc.ca/firecom/fire_reporting_manual/pdf/bh.pdf)

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Weather Sensitivity, U-factor, and R-value

- Equivalence of Weather Sensitivity and U-factor (1/R-value)
- Weather Sensitivity and Fourier's Law

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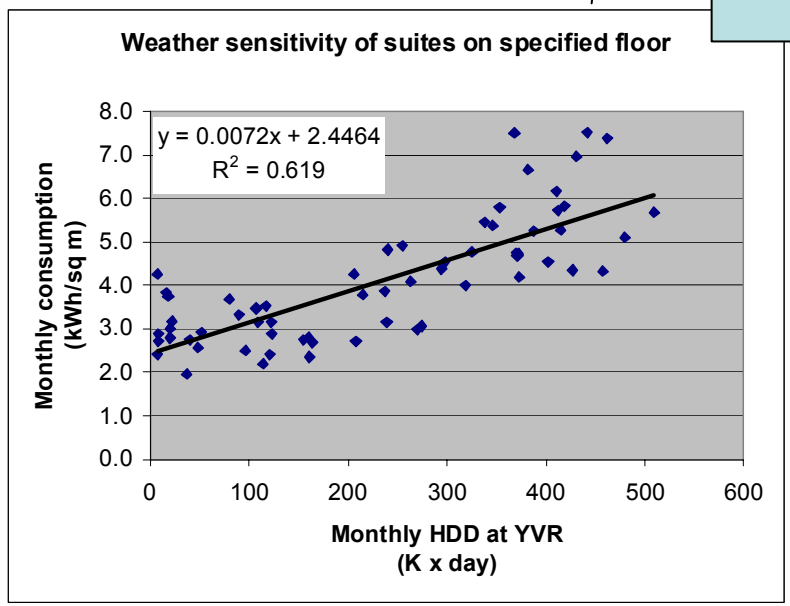
Equivalence of Weather Sensitivity and U-factor (1/R-value)

- Weather sensitivity is based preferably on a common area unit (such as m^2 or ft^2) not a variable area unit like 'suite'
- Weather sensitivity value is slope of linear relationship between energy consumption per unit area and degree days
- Dimensional analysis:
  - Slope = energy intensity / degree day
  - Slope = $(kWh/m^2)/(K \times day)$
  - Slope = $kWh / K \times 24\ h \times m^2$
  - Slope = $(1000/24) \times (W/K \times m^2)$

U-factor units

- U-factor is steady-state thermal transmittance or coefficient of thermal conductivity
- R-value is steady-state thermal resistance of building components; R = 1 / U



We generated a chart like this for every floor of every building in the data set. The slope of the graph is equivalent to the U-factor.

YVR = Vancouver International Airport

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Weather Sensitivity and Fourier's Law (1 of 2)

Fourier's Law: $dq / d\theta = - k A (dt / dx)$; where $dq / d\theta$ is rate of heat flow with unit time θ, k is coefficient of thermal conductivity, A is area transverse to heat flow, dt / dx is temperature gradient

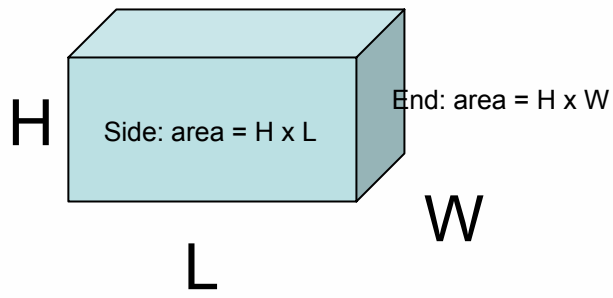
Rewrite as, $q = U A (t_1 – t_2)$

where q is heat transfer rate [W], U is overall heat transfer coefficient representing combined heat transfer coefficients along heat flow path [$W / (m^2 \cdot K)$], A is surface area transverse to heat flow [m^2], t_1 is interior temperature (K) and t_2 is exterior temperature [K]. This equation is from ASHRAE (2005, 3.18; equation 36).

Is it valid to equate weather sensitivity, related to floor area via energy intensity, with overall coefficient of heat transfer U, related to properties of ceilings, walls, doors, or windows?

To answer this, consider that there is a constant relationship between suite floor area and the suite wall area (next slide).

Weather Sensitivity and Fourier's Law (2 of 2)



Corner suite:
Area of suite = W x L
W = Area of suite / L
Area of exterior walls = H x (L + W) = H x (L + (Area of suite / L))

Non-corner suite:
Area of suite = W x L
W = Area of suite / L or L = Area of suite / W
Area of exterior walls = H x W or H x L
Area of exterior walls = H x (Area of suite / L)
or H x (Area of suite /W)

Transforming U-factor from wall area basis to floor area basis

Why do we need to make this transformation?

Reasoning:

- Overall building U-factors are, by definition (Fourier's Law), in terms of gross wall area (GWA)
- Space heat consumption [kWh/m^2] of the building under study was calculated in terms of gross floor area (GFA) by RDH Building Engineering Ltd.
- The chart of Space Heat Consumption against HDD yielded slopes for the gas and electric energy sources
- These slopes represent the weather sensitivity of each heating system in the building (floor area basis)
- Another way of interpreting a slope value is as an energy intensity [kWh/m^2] response to changes in HDD

- The transformation process applied the multiplier, Ratio = GWA/GFA, to reduce the coefficient of thermal conductivity, U. When U is based on wall area, there is a certain energy intensity [kWh/m^2]. When the same amount of energy is spread out over the floor area, the energy intensity is halved (approximately). This effect is modeled by applying the GWA/GFA ratio. Energy intensity based on floor area is compatible with the energy intensity values extracted from the RDH data set (which divided energy by floor area).

Buildings with "square footprint":

Floor area = $L^2 = W^2$

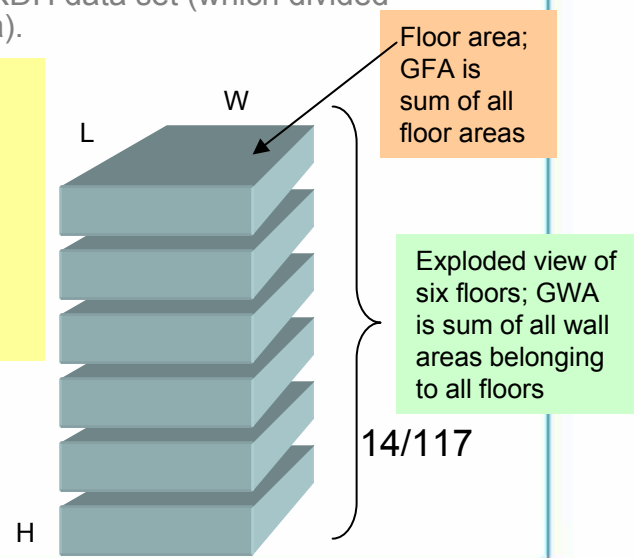
Wall area = 4LH

Ratio: Wall area/Floor area

= $4LH/L^2 = 4H/L$; H = 3 m

Then Ratio = 12 m/L

Ratio = 0.5 if L = W = 24 m



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Special Case Studies for Buildings with Gas Heating Data

- Finding a mean overall building steady-state thermal transmittance (U-factor)
- Special Case Study—Coquitlam
- Special Case Study—Surrey

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Special Case Studies for Buildings with Gas Heating Data

Finding a mean overall building steady-state thermal transmittance (U-factor)

If a building has not been thermally modeled, we need to find a mean U-factor to use in estimating the building's relative proportions of gas and electric heating and gas heating system efficiency. Fortunately, reasonable estimates are possible based on thermal modeling results from nine buildings in BC by RDH Building Engineering Ltd.

Building ID (RDH Building Engineering Ltd., Vancouver, BC)	Pre-rehabilitation overall building enclosure U-factor [W/(m^2 · K)]	Post-rehabilitation overall building enclosure U-factor [W/(m^2 · K)]
7 (built year unknown, Victoria)	1.7	1.4
17 (1990, Vancouver)	2.1	1.6
18 (built 1995, Vancouver)	2.1	1.7
19 (built 1984, Vancouver)	2.0	1.3
32 (built 1985, Burnaby)	2.5	1.6
33 (built 1988, Burnaby)	2.6	1.6
39 (built 2002–2003, Burnaby)	2.8	
41 (built 2001, Burnaby)	2.8	
62 (built 1995, West Vancouver)	2.7	2.2
Mean U-factor	***2.4***	***1.6***
Grand mean U-factor = (2.4 + 1.6)/2 =	***2.0***	

RDH provided rare information from thermal modeling of entire buildings in BC.

U-factors from thermally modeled buildings were kindly provided by Graham Finch, RDH Building Engineering Ltd. , Vancouver, BC.

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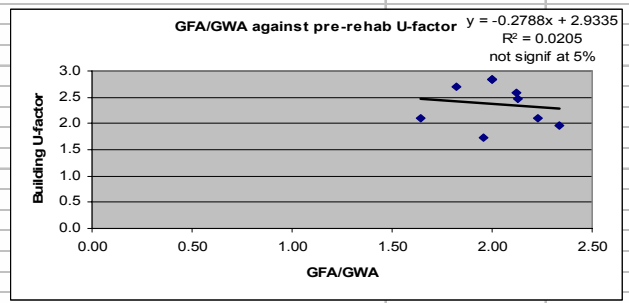
Special Case Studies for Buildings with Gas Heating Data

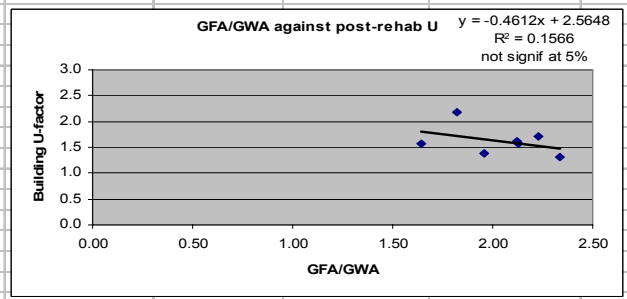
Thermal transmittance (U-factor) was unrelated to the building form ratio (GFA/GWA)

Building Enclosure U-factors

Building ID (RDH Building Engineering Ltd., Vancouver, BC)	Gross Floor Area (GFA, m^2)	Gross Wall Area (GWA, m^2)	GFA/GWA	Pre-rehabilitation overall building enclosure R-value [ft2 F hr/Btu]	Pre-rehabilitation overall building enclosure U-factor [W/(m² · K)]	Post-rehabilitation overall building enclosure R-value [ft2 F hr/Btu]	Post-rehabilitation overall building enclosure U-factor [W/(m² · K)]
7 (built year unknown, Victoria)	8,967	4,581	1.96	3.3	1.7	4.1	1.4
17 (1990, Vancouver)	6,408	3,898	1.64	2.7	2.1	3.6	1.6
18 (built 1995, Vancouver)	13,538	6,079	2.23	2.7	2.1	3.3	1.7
19 (built 1984, Vancouver)	12,063	5,160	2.34	2.9	2.0	4.3	1.3
32 (built 1985, Burnaby)	14,444	6,775	2.13	2.3	2.5	3.6	1.6
33 (built 1988, Burnaby)	16,852	7,943	2.12	2.2	2.6	3.5	1.6
39 (built 2002–2003, Burnaby)	16,218	8,109	2.00	2.0	2.8		
41 (built 2001, Burnaby)	15,753	7,877	2.00	2.0	2.8		
62 (built 1995, West Vancouver)	7,302	4,013	1.82	2.1	2.7	2.6	2.2
Mean U-factor			***2.0***		***2.4***		***1.6***
Grand mean U-factor = (2.4 + 1.6)/2 =						***2.0***	

Conversion of R from IP to SI (multiply by this value):	0.176118352





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Electric Heat

Case Study: HB Building ID # 481474, Coquitlam

Source: http://www.bing.com/maps

Building specifications

- **RDH Building 24**
- Coquitlam
- 137 (144; RDH) Suites, 22 levels (23; RDH)
- Built 1993 (1995; RDH)
- Rehabilitation Feb 2005 to Feb 2006 (RDH)
- Gross Floor Area (GFA) = 13,103 m^2
- Floor Area = 596 m^2
- Gross Wall Area (GWA) = 6,665 m^2

Gas data available

Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

Method "A" for analyzing weather sensitivity of a building for which we have both electricity and gas energy consumption data

Step 1: Estimate overall building enclosure U-factor
This was done as shown on a previous slide. The **mean post-rehab U-factor** models a mix of building stock which was rehabilitated to address moisture damage.

$U = 1.6\ W / (m^2 \cdot K)$

Step 2: Transform U-factor to floor area basis
U (floor area basis) = U (wall area basis) x GWA / GFA
$= [\ 1.6\ W / (m^2 \cdot K)] \times (\ 6{,}665\ m^2 / 13{,}103\ m^2\ )$

$= 0.814\ W / (m^2 \cdot K)$

Step 3: Transform units of U-factor to be (kWh/m^2) / HDD
Note that heating degree-days, HDD = (K · day)

$U = [0.814\ W / (m^2 \cdot K)] \times (24\ h/day)/(1000\ W / kW)$

$= 0.0195\ (kWh/m^2) / HDD$

This result is the composite-fuel weather sensitivity.

Step 4: Find slope of gas consumption weather sensitivity relationship taking into account gas heating system efficiency for this building
Composite-fuel weather sensitivity = Gas slope + Electricity slope

Gas slope = Composite-fuel weather sensitivity – Electricity slope

Gas slope = $0.0195\ (kWh/m^2) / HDD - 0.0058\ (kWh/m^2) / HDD$

$= 0.0137\ (kWh/m^2) / HDD$

Step 5: Find gas heating system efficiency for this building
Gas heating system efficiency

$= [0.0137\ (kWh/m^2) / HDD] / [0.1027\ (kWh/m^2) / HDD]$

= 0.1333 or **13%**

Slope for gas at assumed 100% efficiency. See chart, next slide

Step 6: Determine heating distribution of fuels
Gas = $(0.0137 / 0.0195)\ (kWh/m^2) / HDD$ = **0.70**

Electricity = $(0.0058 / 0.0195)\ (kWh/m^2) / HDD$ = **0.30**

This "electrically-heated" building is 70% heated by gas!

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Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

This chart (adapted from an RDH analysis) shows space heat consumption in response to HDD by type of energy:

- **Electricity—**baseboard heaters convert approximately 100% of electrical energy to heat.
- **Gas**—although furnace efficiency can be fairly high, at 85% according to ASHRAE, once ducting and interactions with the building are accounted for, system efficiency is lower, at 13% for this building.
- **Composite** fuel relationship (Gas @ 13% efficiency and Electricity) reveals the true weather sensitivity of the building.
- Composite slope is, by vector calculation rules, the sum of the electricity and gas (13%) slopes.

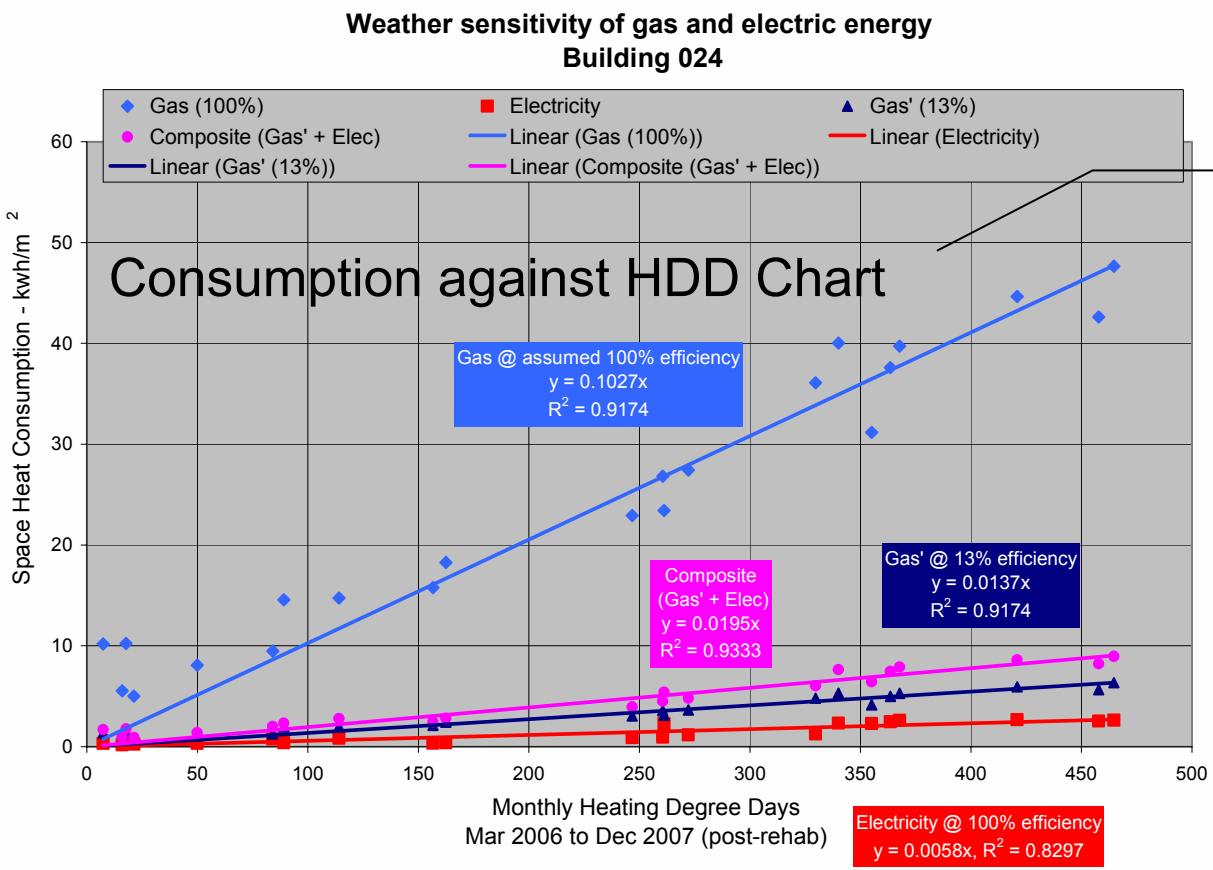

Chart based on data from RDH spreadsheet for Building 024

Step 4 yielded gas slope; Step 5 yielded gas efficiency

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Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Data table for the five charts that follow

Building 024, Coquitlam			GFA (m²) =	13,103	GWA (m^2)	6,665					multiplier for U(total) =	3.33				
			Floor Area =	595	m^2	Ratio: GFA/GWA =	1.97						Method "A"		Method "B"	
Floor	WS Suites	R^2	Floor	Qty of suites	WS Floor	Elec. U, W/(m^2 x K); fab	Elec. U, W/(m^2 x K); wab	RSI, (m^2 x K)/W	R, hr x ft^2 x F/Btu	U(total), W/(m^2 x K), wab	diff = U(gas), W/(m^2 x K), wab		Assume constant U per floor, W/(m^2 x K), wab	alternate result for diff = U(gas), W/(m^2 x K), wab	Gas proportion	Elec proportion
1	1.74	0.76	1	5	8.70	0.609	1.198	1	5	3.992	2.795		1.6	0.402	0.2514141	0.7485859
2	0.70	0.51	2	6	4.20	0.294	0.578	2	10	1.927	1.349		1.6	1.022	0.6386137	0.3613863
3	0.36	0.32	3	7	2.52	0.176	0.347	3	16	1.156	0.810		1.6	1.253	0.7831682	0.2168318
4	0.41	0.67	4	7	2.87	0.201	0.395	3	14	1.317	0.922		1.6	1.205	0.7530527	0.2469473
5	0.51	0.39	5	7	3.55	0.248	0.488	2	12	1.628	1.139		1.6	1.112	0.6948163	0.3051837
6	0.69	0.68	6	7	4.83	0.338	0.665	2	9	2.217	1.552		1.6	0.935	0.5844058	0.4155942
7	0.29	0.22	7	7	2.03	0.142	0.279	4	20	0.932	0.652		1.6	1.321	0.82533	0.17467
8	0.27	0.42	8	7	1.87	0.131	0.257	4	22	0.858	0.601		1.6	1.343	0.8391362	0.1608638
9	0.39	0.52	9	7	2.73	0.191	0.376	3	15	1.253	0.877		1.6	1.224	0.7650989	0.2349011
10	0.35	0.38	10	7	2.45	0.172	0.337	3	17	1.124	0.787		1.6	1.263	0.7891913	0.2108087
11	0.44	0.46	11	7	3.08	0.216	0.424	2	13	1.413	0.989		1.6	1.176	0.7349834	0.2650166
12	0.40	0.52	12	6	2.38	0.166	0.327	3	17	1.090	0.763		1.6	1.273	0.7955795	0.2044205
13	0.47	0.37	13	7	3.28	0.229	0.451	2	13	1.503	1.052		1.6	1.149	0.7181395	0.2818605
14	0.42	0.61	14	7	2.94	0.206	0.405	2	14	1.349	0.944		1.6	1.195	0.7470296	0.2529704
15	0.25	0.22	15	7	1.63	0.114	0.225	4	25	0.749	0.524		1.6	1.375	0.8595261	0.1404739
16	0.25	0.26	16	7	1.74	0.122	0.240	4	24	0.800	0.560		1.6	1.360	0.8500742	0.1499258
17	0.29	0.24	17	5	1.45	0.102	0.200	5	28	0.665	0.466		1.6	1.400	0.8752357	0.1247643
18	0.57	0.65	18	5	2.84	0.199	0.391	3	15	1.304	0.913		1.6	1.209	0.7555167	0.2444833
19	0.35	0.21	19	5	1.75	0.123	0.241	4	24	0.803	0.562		1.6	1.359	0.8494224	0.1505776
20	0.55	0.43	20	5	2.75	0.193	0.379	3	15	1.262	0.883		1.6	1.221	0.763378	0.236622
21	1.01	0.44	21	5	4.93	0.345	0.678	1	8	2.261	1.583		1.6	0.922	0.5760099	0.4239901
22	0.42	0.50	22	5	2.10	0.147	0.289	3	20	0.964	0.675		1.6	1.311	0.8193068	0.1806932
				Building Means		*0.212*	*0.417*			*1.389*	*0.973*		*1.600*	*1.183*	*0.739*	*0.261*
						fab = floor area basis										
						wab = wall area basis										

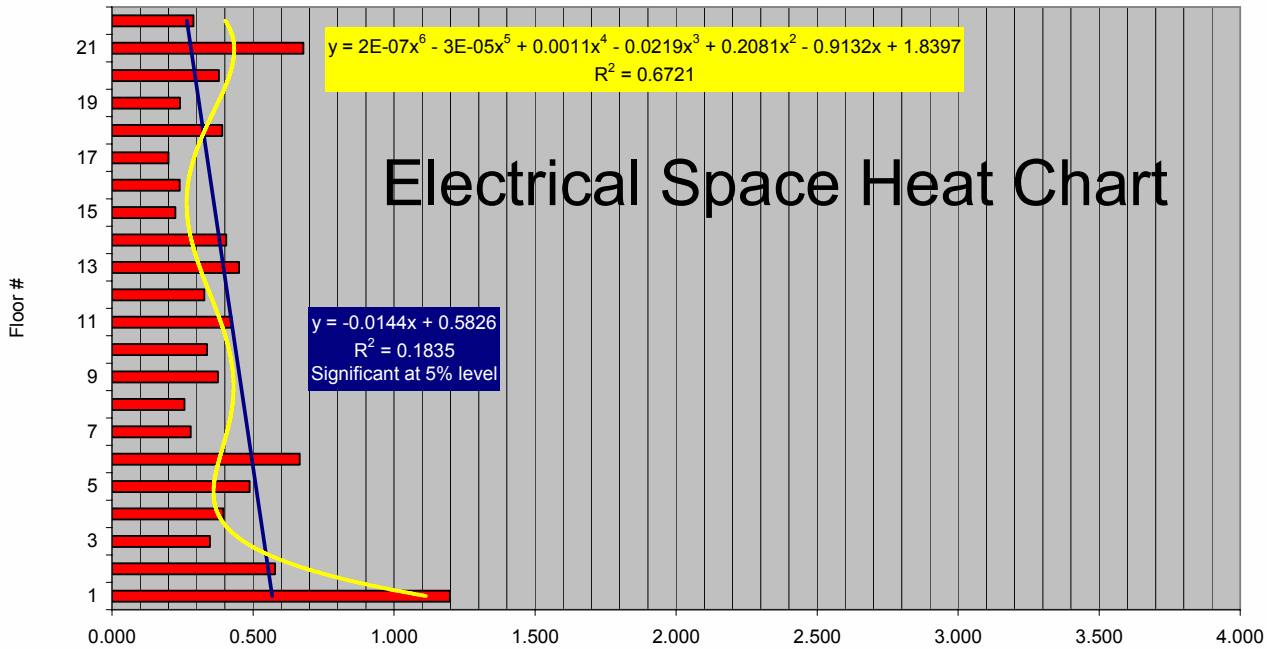
WS = Weather Sensitivity; GFA = Gross Floor Area; GWA = Gross Wall Area; U = Steady-state thermal transmittance; R = R-value = 1/U; RSI = R-value in SI units; U(total) is U or WS related to total heat supplied to floor (storey); U(gas) is WS of gas heating

Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) using only electrical energy data. In this building, baseboard heater heat loss to the outdoors decreases with height in the building. For each floor, electrical energy consumption is presumed to be 30% of total energy consumption. Gas heat provides the balance. If only electrical energy consumption data is available for a building it is still possible to find the relative weather sensitivity of floors (albeit moderated by common area gas heating).

Weather sensitivity (U-factor) by floor
(HB Building ID # 481474, Coquitlam; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
U-factor	1.198	0.578	0.347	0.395	0.488	0.665	0.279	0.257	0.376	0.337	0.424	0.327	0.451	0.405	0.225	0.240	0.200	0.391	0.241	0.379	0.678	0.289

U-factor [W/(m^2 x K)]; wall area basis

Wall area basis

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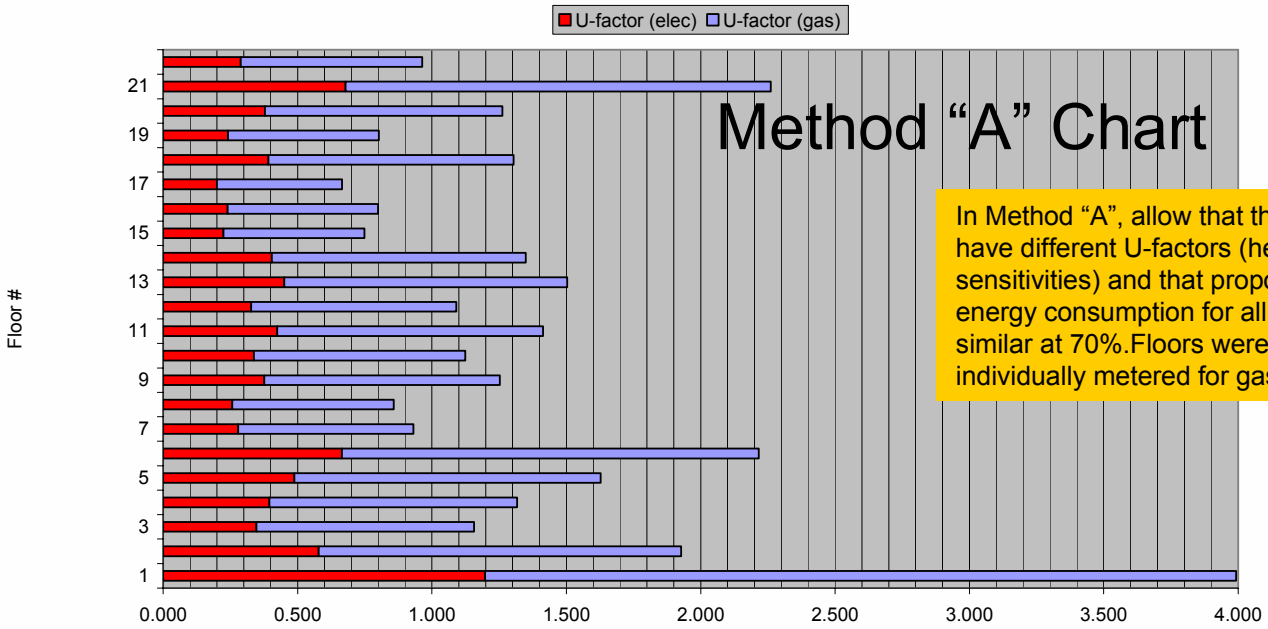
Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) using electrical and gas (13%) energy data. For each floor, electrical energy consumption is presumed to be 30% of total energy consumption. In conjunction with the chart on the next page, an integrated view of gas and electric heating interaction with HDD appears.

Weather sensitivity (U-factor) by floor
(HB Building ID # 481474, Coquitlam; Electric + Gas heat)



Method "A" Chart

In Method "A", allow that the floors may have different U-factors (hence weather sensitivities) and that proportion of gas energy consumption for all floors was similar at 70%.Floors were not individually metered for gas consumption.

Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
U-factor (gas)	2.79	1.34	0.81	0.92	1.13	1.55	0.65	0.60	0.87	0.78	0.98	0.76	1.05	0.94	0.52	0.56	0.46	0.91	0.56	0.88	1.58	0.67
U-factor (elec)	1.19	0.57	0.34	0.39	0.48	0.66	0.27	0.25	0.37	0.33	0.42	0.32	0.45	0.40	0.22	0.24	0.20	0.39	0.24	0.37	0.67	0.28

U-factor [W/(m^2 x K)]; wall area basis

Wall area basis

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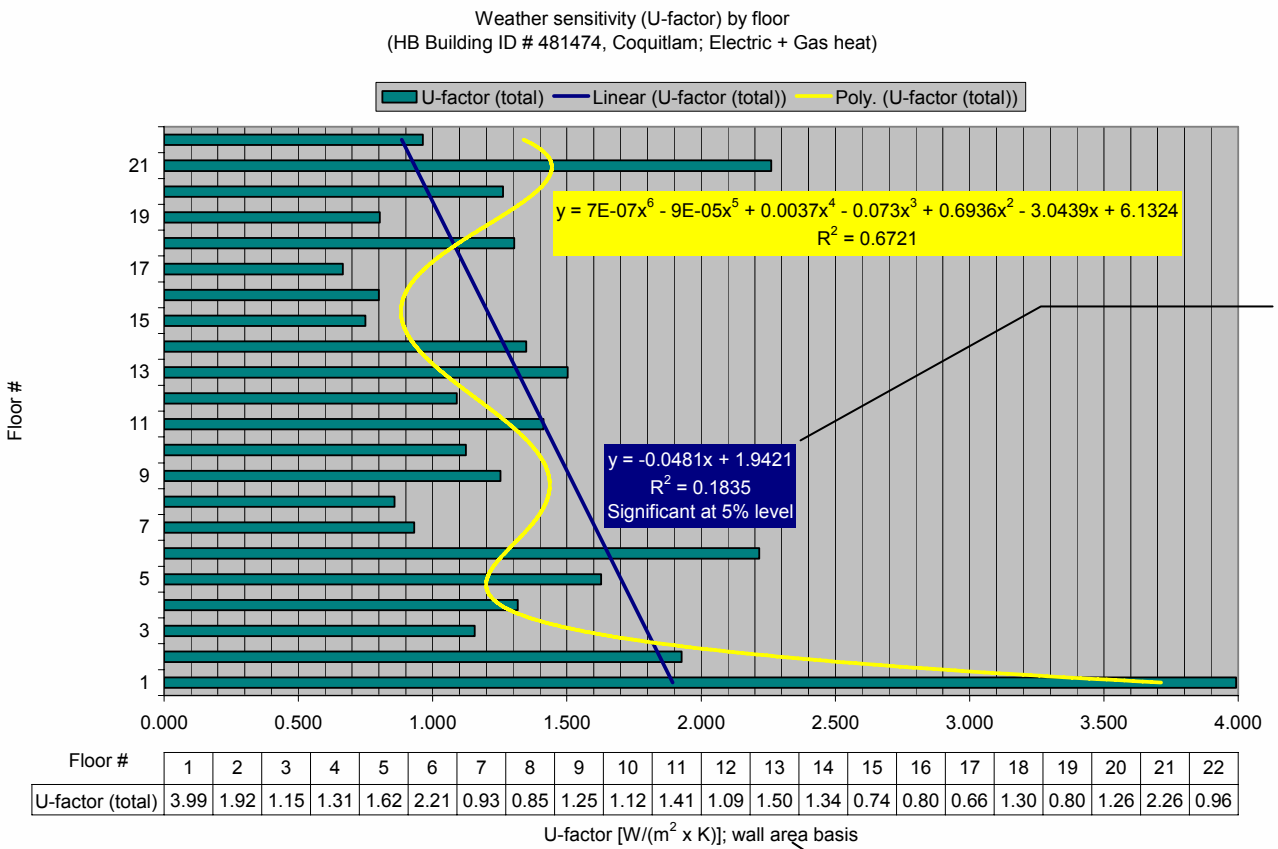
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) using total [gas (13%) + electric] energy data. In this building, total (gas + electric) heat losses to the outdoors decrease with height in the building. In conjunction with the chart on the previous page, an integrated view of gas and electric heating interaction with HDD appears.



Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
U-factor (total)	3.99	1.92	1.15	1.31	1.62	2.21	0.93	0.85	1.25	1.12	1.41	1.09	1.50	1.34	0.74	0.80	0.66	1.30	0.80	1.26	2.26	0.96

Slope and intercept are related to electricity only chart by factor 1/0.3 = 3.33; because of heating distribution of fuels found in Step 6, Method A

Wall area basis

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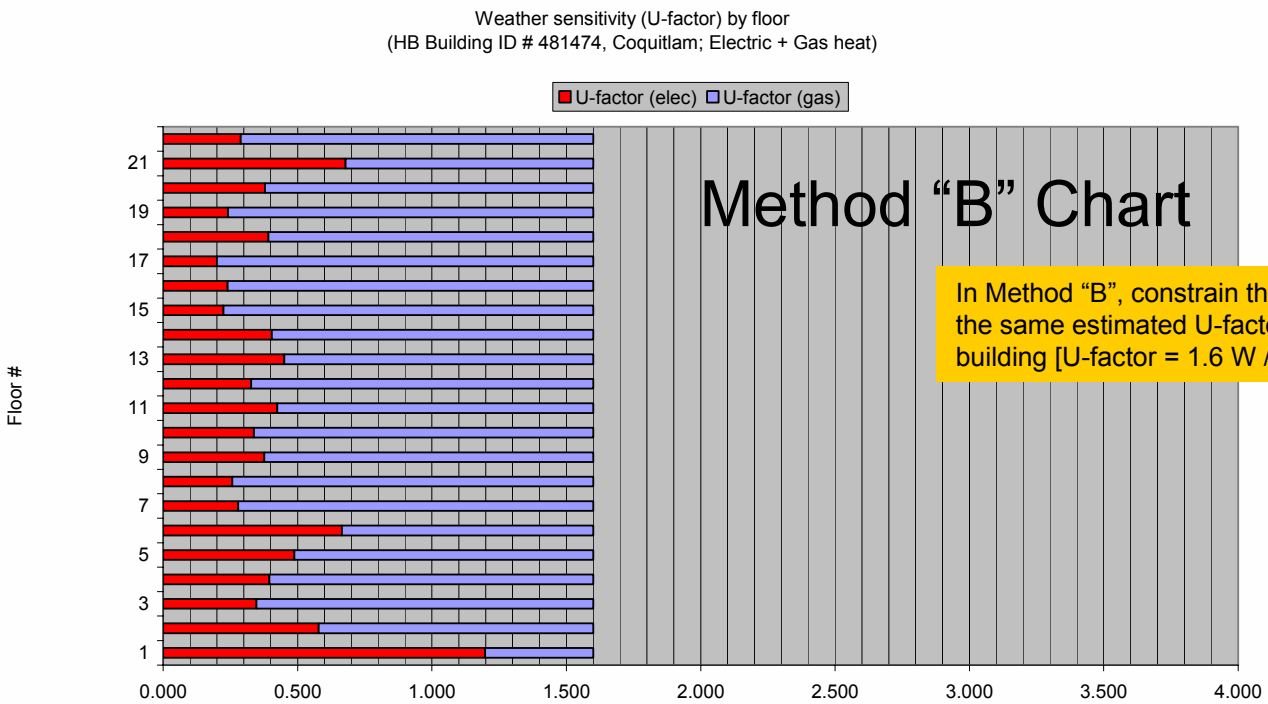
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) equal to the overall enclosure value. For each floor, common area gas consumption depends on variables such as air leakage, operable windows, and ventilation. The electrical consumption is an index of how much additional heat was needed to match aggregated suite thermostat set points given that the building is constantly losing heat to the environment according to the enclosure's steady-state thermal transmittance (U-factor).



In Method "B", constrain the floors to have the same estimated U-factor as the entire building [U-factor = 1.6 W / (m^2 · K)]

Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
U-factor (gas)	0.40	1.02	1.25	1.20	1.11	0.93	1.32	1.34	1.22	1.26	1.17	1.27	1.14	1.19	1.37	1.36	1.40	1.20	1.35	1.22	0.92	1.31
U-factor (elec)	1.19	0.57	0.34	0.39	0.48	0.66	0.27	0.25	0.37	0.33	0.42	0.32	0.45	0.40	0.22	0.24	0.20	0.39	0.24	0.37	0.67	0.28

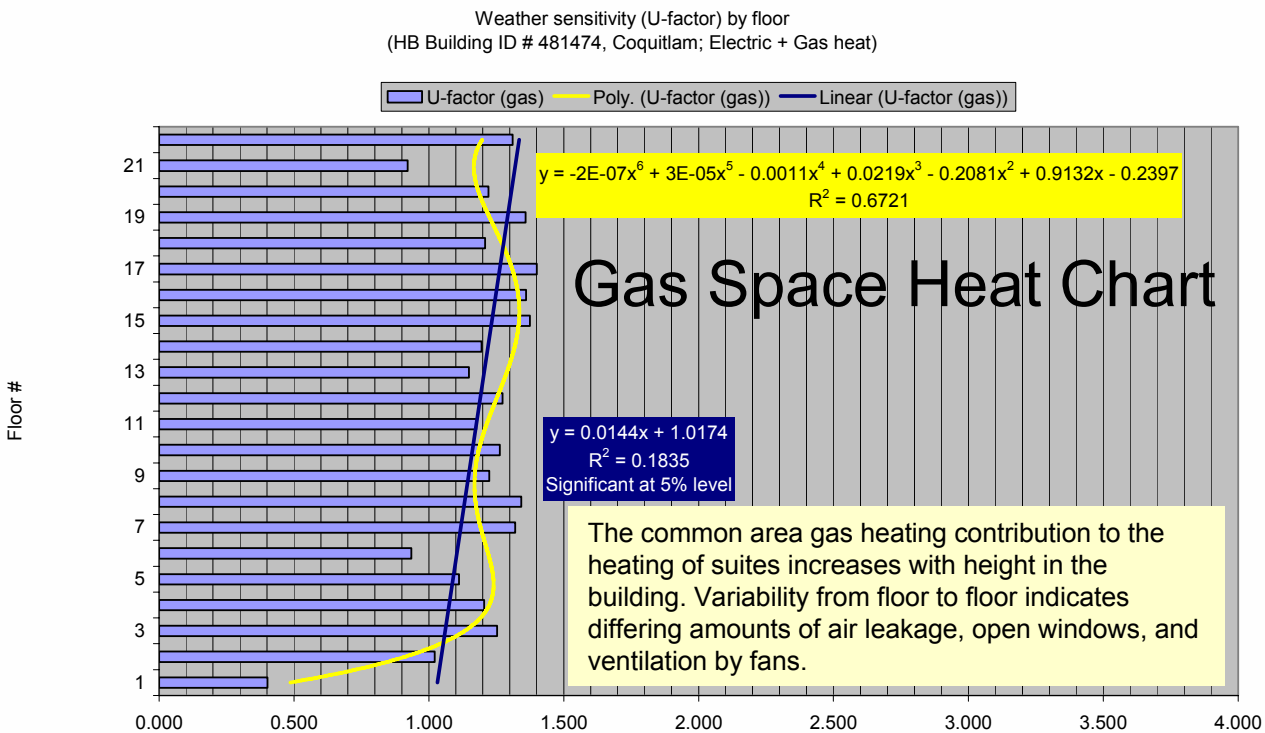
Wall area basis

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) of common area gas energy For each floor, electrical energy consumption is presumed to balance total energy consumption resulting from inhabitants responding to the overall building's steady-state thermal transmittance during a given heating degree-day regime.



Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
U-factor (gas)	0.40	1.02	1.25	1.20	1.11	0.93	1.32	1.34	1.22	1.26	1.17	1.27	1.14	1.19	1.37	1.36	1.40	1.20	1.35	1.22	0.92	1.31

U-factor [W/(m^2 x K)]; wall area basis

Wall area basis

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 481474, Coquitlam (post-rehab)

Electric Heat

Method "B" for analyzing weather sensitivity of a building for which we have both electricity and gas energy consumption data

Step 1: Estimate overall building enclosure U-factor

This was done as shown on a previous slide. The **mean post-rehab U-factor** models a mix of building stock which was rehabilitated to address moisture damage.

U = 1.6 W / (m^2 · K)

Step 2: Transform U-factor to floor area basis

U (floor area basis) = U (wall area basis) x GWA / GFA

= [1.6 W / (m^2 · K)] x (6,665 m^2 / 13,103 m^2)

= 0.814 W / (m^2 · K)

Step 3: Transform units of U-factor to be (kWh/m^2) / HDD

Note that heating degree-days, HDD = (K · day)

U = [0.814 W / (m^2 · K)] x (24 h/day)/(1000 W / kW)

= 0.0195 (kWh/m^2) / HDD

This result is the composite-fuel weather sensitivity.

Step 4: Determine heating distribution of fuels from average proportions of gas and electric U-factors tabulated below Method "B" Chart (see also data table in earlier slide)

Gas = 0.74; Electricity = 0.26

Step 5: Find slope of gas consumption weather sensitivity relationship

Gas slope = 0.74 x composite fuel weather sensitivity

= 0.74 x 0.0195 (kWh/m^2) / HDD

= 0.0144 (kWh/m^2) / HDD

Step 6: Find gas heating system efficiency for this building

Gas heating system efficiency

= [0.0144 (kWh/m^2) / HDD] / [0.1027 (kWh/m^2) / HDD]

= 0.14 or **14%**

Slope for gas at assumed 100% efficiency. See Consumption against HDD Chart

Method "B" Steps 4 and 6 yield results similar to Method "A" Steps 6 and 5 respectively.

BC hydro FOR GENERATIONS

Electric Heat

Case Study: HB Building ID # 25437, Surrey

Source: http://www.bing.com/maps

Building specifications

- **RDH Building 11**
- Surrey
- 126 (128; RDH) Suites, 16 levels
- Built 1993 (1995; RDH)
- Rehabilitation Jan 2001 to Aug 2002 (RDH)
- Gross Floor Area (GFA) = 10,118 m^2 (RDH)
- Floor Area = 632 m^2
- Gross Wall Area (GWA) = 4,134 m^2

Gas data available

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Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

Method "A" for analyzing weather sensitivity of a building for which we have both electricity and gas energy consumption data

Step 1: Estimate overall building enclosure U-factor

This was done as shown on a previous slide. The **mean post-rehab U-factor** models a mix of building stock which was rehabilitated to address moisture damage.

U = 1.6 W / (m^2 · K)

Step 2: Transform U-factor to floor area basis

U (floor area basis) = U (wall area basis) x GWA / GFA

= [1.6 W / (m^2 · K)] x (4,134 m^2 / 10,118 m^2)

= 0.654 W / (m^2 · K)

Step 3: Transform units of U-factor to be (kWh/m^2) / HDD

Note that heating degree-days, HDD = (K · day)

U = [0.654 W / (m^2 · K)] x (24 h/day)/(1000 W / kW)

= 0.0157 (kWh/m^2) / HDD

This result is the composite-fuel weather sensitivity.

Step 4: Find slope of gas consumption weather sensitivity relationship taking into account gas heating system efficiency for this building

Composite-fuel weather sensitivity = Gas slope + Electricity slope

Gas slope = Composite-fuel weather sensitivity – Electricity slope

Gas slope = 0.0157 (kWh/m^2) / HDD – 0.0082 (kWh/m^2) / HDD

= 0.0075 (kWh/m^2) / HDD

Step 5: Find gas heating system efficiency for this building

Gas heating system efficiency

= [0.0075 (kWh/m^2) / HDD] / [0.0079 (kWh/m^2) / HDD]

= 0.95 or **95%**

Slope for gas at assumed 100% efficiency. See chart

Step 6: Determine heating distribution of fuels

Gas = (0.0075 / 0.0157) (kWh/m^2) / HDD = **0.48**

Electricity = (0.0082 / 0.0157) (kWh/m^2) / HDD = **0.52**

This "electrically-heated" building is 48% heated by gas!

BC hydro FOR GENERATIONS

Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

This chart (adapted from an RDH analysis) shows space heat consumption in response to HDD by type of energy:

- **Electricity—**baseboard heaters convert approximately 100% of electrical energy to heat.
- **Gas**—although furnace efficiency can be fairly high, at 85% according to ASHRAE, once ducting and interactions with the building are accounted for, system efficiency must be lower for this building.

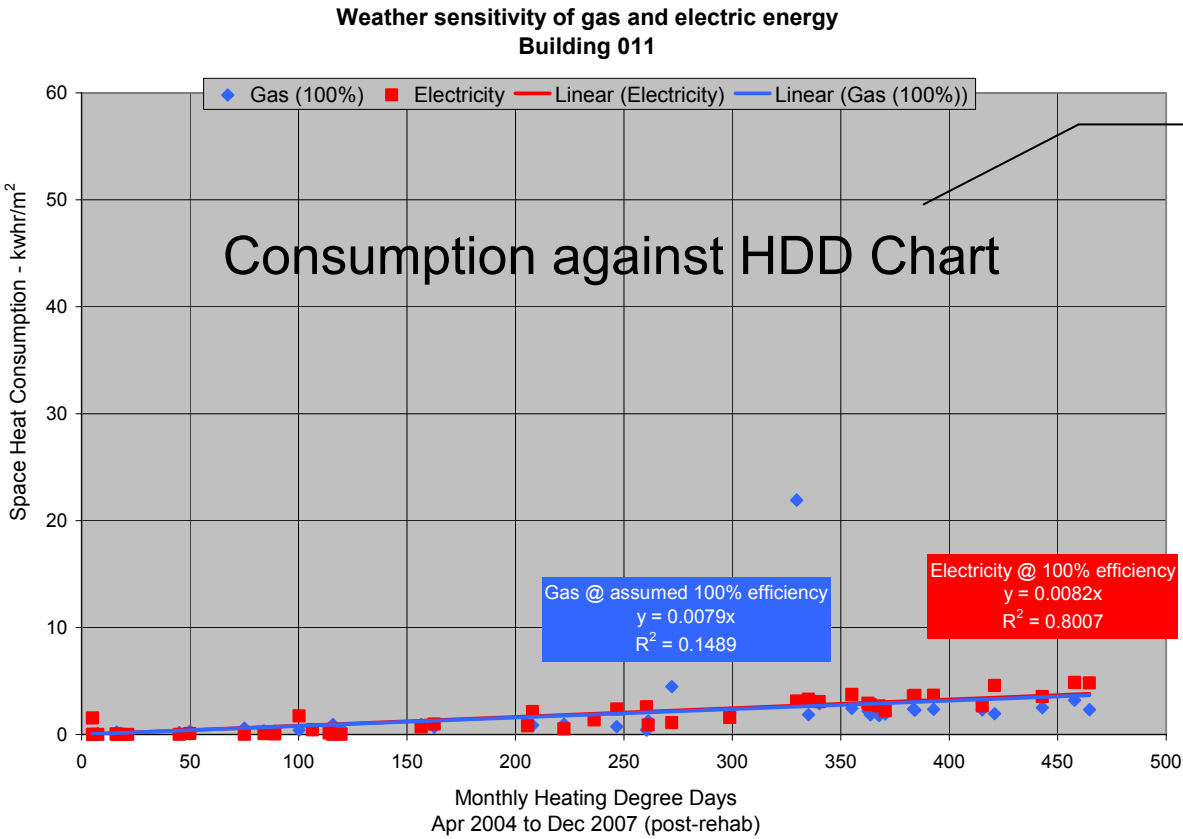

Chart based on data from RDH spreadsheet for Building 011

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Case Study: HB Building ID # 25437, Surrey (post-rehab)

Data table for the five charts that follow

Building 011, Surrey			GFA (m²)=	10,118	GFA (m²)=	4,134											
			Floor Area =	621	m^2	Ratio: GFA/GWA =	2.45			multiplier for U(total) =	1.92						
							Method "A"						Method "B"				
Floor	**WS Suites**	**R^2**	**Floor**	**Qty of suites**	**WS Floor**	**Elec. U, W/(m² x K), fab**	**Elec. U, W/(m² x K), wab**	**RSI, (m² x K)/W**	**R, hr x ft² x F/Btu**	**U(total), W/(m² x K), wab**	**diff = U(gas), W/(m² x K), wab**		**Assume constant U per floor, W/(m² x K), wab**	**alternate result for diff = U(gas), W/(m² x K), wab**	**Gas proportion**	**Elec proportion**	
1	1.13	0.73	1	7	7.91	0.531	1.299	1	4	2.498	1.199		1.6	0.301	0.18814614	0.81185386	
2	1.10	0.75	2	11	12.03	0.807	1.976	1	3	3.800	1.824		1.6	-0.376	-0.2350579	1.23505792	
3	0.72	0.69	3	11	7.89	0.529	1.295	1	4	2.491	1.196		1.6	0.305	0.19047878	0.80952122	
4	0.95	0.74	4	10	9.82	0.659	1.612	1	4	3.100	1.488		1.6	-0.012	-0.0075473	1.00754725	
5	1.01	0.67	5	8	7.67	0.514	1.259	1	5	2.421	1.162		1.6	0.341	0.21310544	0.78689456	
6	0.94	0.71	6	8	7.38	0.495	1.212	1	5	2.330	1.118		1.6	0.388	0.24279224	0.75720776	
7	0.58	0.55	7	8	4.64	0.311	0.762	1	7	1.465	0.703		1.6	0.838	0.52376714	0.47623286	
8	0.35	0.29	8	8	2.78	0.187	0.457	2	12	0.879	0.422		1.6	1.143	0.71425095	0.28574905	
9	0.84	0.77	9	8	6.72	0.451	1.104	1	5	2.122	1.019		1.6	0.496	0.31028344	0.68971656	
10	0.52	0.55	10	8	4.14	0.278	0.681	1	8	1.309	0.628		1.6	0.919	0.57464991	0.42535009	
11	0.71	0.64	11	8	5.68	0.381	0.933	1	6	1.794	0.861		1.6	0.667	0.41702529	0.58297471	
12	0.55	0.63	12	8	4.35	0.292	0.714	1	8	1.374	0.659		1.6	0.886	0.55353169	0.44646831	
13	0.61	0.65	13	8	4.86	0.326	0.798	1	7	1.535	0.737		1.6	0.802	0.50103162	0.49896838	
14	0.54	0.58	14	6	3.10	0.208	0.509	2	11	0.979	0.470		1.6	1.091	0.68173388	0.31826612	
15	0.51	0.59	15	6	2.99	0.201	0.491	2	12	0.944	0.453		1.6	1.109	0.69307053	0.30692947	
16	1.55	0.60	16	4	6.13	0.411	1.007	1	6	1.936	0.929		1.6	0.593	0.37088557	0.62911443	
				Building Means		*0.411*	*1.007*			*1.936*	*0.929*		*1.600*	*0.593*	*0.371*	*0.629*	
						fab = floor area basis											
						wab = wall area basis											

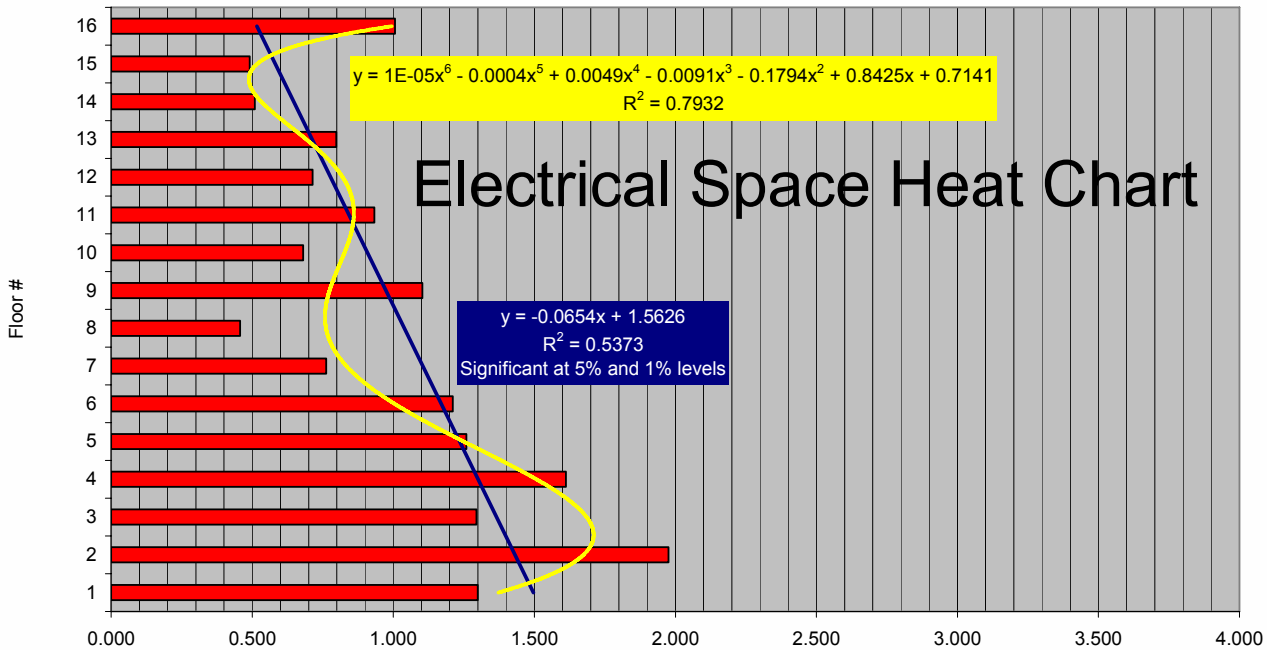
WS = Weather Sensitivity; GFA = Gross Floor Area; GWA = Gross Wall Area; U = Steady-state thermal transmittance; R = R-value = 1/U; RSI = R-value in SI units; U(total) is U or WS related to total heat supplied to floor (storey); U(gas) is WS of gas heating

Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) using only electrical energy data. In this building, baseboard heater heat loss to the outdoors decreases with height in the building. For each floor, electrical energy consumption is a certain proportion of total energy consumption. Gas heat provides the balance. If only electrical energy consumption data is available for a building it is still possible to find the relative weather sensitivity of floors (albeit moderated by common area gas heating).

Weather sensitivity (U-factor) by floor
(HB Building ID # 25437, Surrey; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor	1.299	1.976	1.295	1.612	1.259	1.212	0.762	0.457	1.104	0.681	0.933	0.714	0.798	0.509	0.491	1.007

U-factor [W/(m^2 x K)]

Wall area basis

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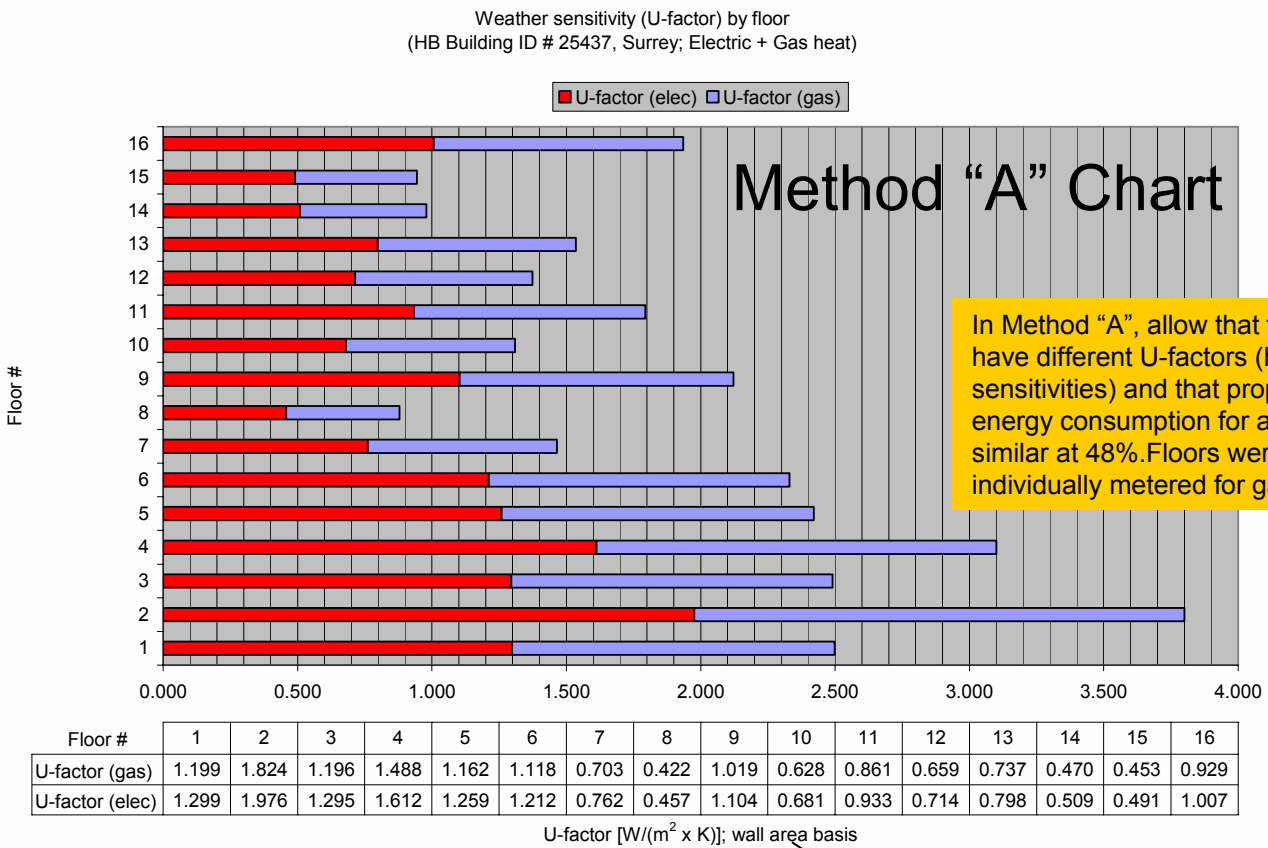
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) using electrical and gas (95%) energy data. For each floor, electrical energy consumption is presumed to be 52% of total energy consumption. In conjunction with the chart on the next page, an integrated view of gas and electric heating interaction with HDD appears.



Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor (gas)	1.199	1.824	1.196	1.488	1.162	1.118	0.703	0.422	1.019	0.628	0.861	0.659	0.737	0.470	0.453	0.929
U-factor (elec)	1.299	1.976	1.295	1.612	1.259	1.212	0.762	0.457	1.104	0.681	0.933	0.714	0.798	0.509	0.491	1.007

In Method "A", allow that the floors may have different U-factors (hence weather sensitivities) and that proportion of gas energy consumption for all floors was similar at 48%.Floors were not individually metered for gas consumption.

Wall area basis

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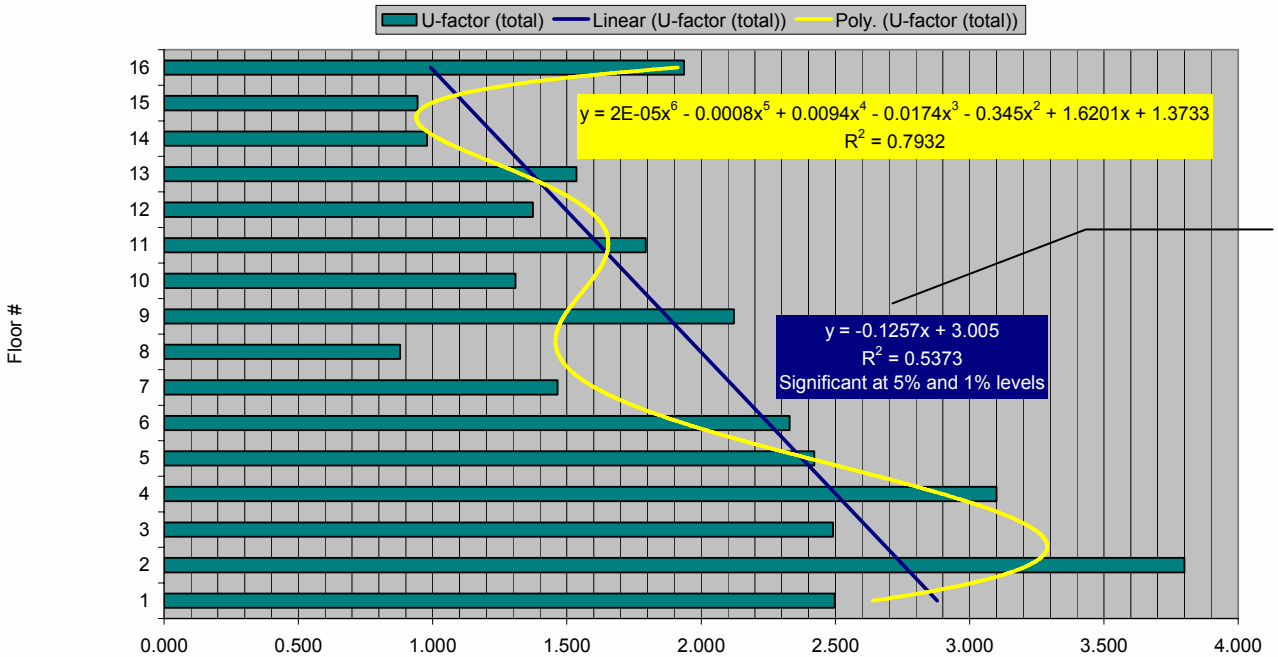
Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) using total [gas (95%) + electric] energy data. In this building, total (gas + electric) heat losses to the outdoors decrease with height in the building. In conjunction with the chart on the previous page, an integrated view of gas and electric heating interaction with HDD appears.

Weather sensitivity (U-factor) by floor
(HB Building ID # 25437, Surrey; Electric + Gas heat)



Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor (total)	2.498	3.800	2.491	3.100	2.421	2.330	1.465	0.879	2.122	1.309	1.794	1.374	1.535	0.979	0.944	1.936

U-factor [W/(m^2 x K)]; wall area basis

Slope and intercept are related to electricity only chart by factor 1/0.52 = 1.92; because of heating distribution of fuels found in Step 6, Method A

Wall area basis

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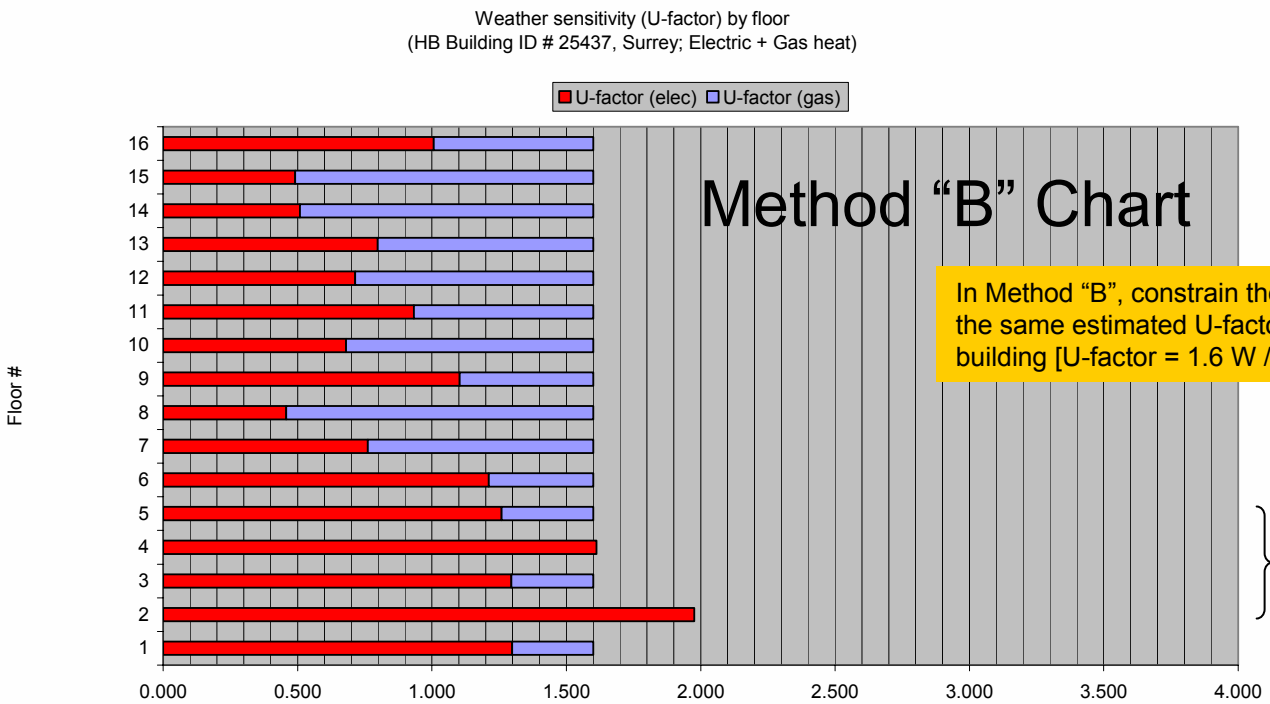
Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) equal to the overall enclosure value. For each floor, common area gas consumption depends on variables such as air leakage, operable windows, and ventilation. The electrical consumption is an index of how much additional heat was needed to match aggregated suite thermostat set points given that the building is constantly losing heat to the environment according to the enclosure's steady-state thermal transmittance (U-factor).



In Method "B", constrain the floors to have the same estimated U-factor as the entire building [U-factor = 1.6 W / (m^2 · K)]

Space heat on floors 2 and 4 is entirely from electricity; no gas heating component

Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor (gas)	0.301	-0.376	0.305	-0.012	0.341	0.388	0.838	1.143	0.496	0.919	0.667	0.886	0.802	1.091	1.109	0.593
U-factor (elec)	1.299	1.976	1.295	1.612	1.259	1.212	0.762	0.457	1.104	0.681	0.933	0.714	0.798	0.509	0.491	1.007

U-factor [W/(m^2 x K)]; wall area basis

Wall area basis

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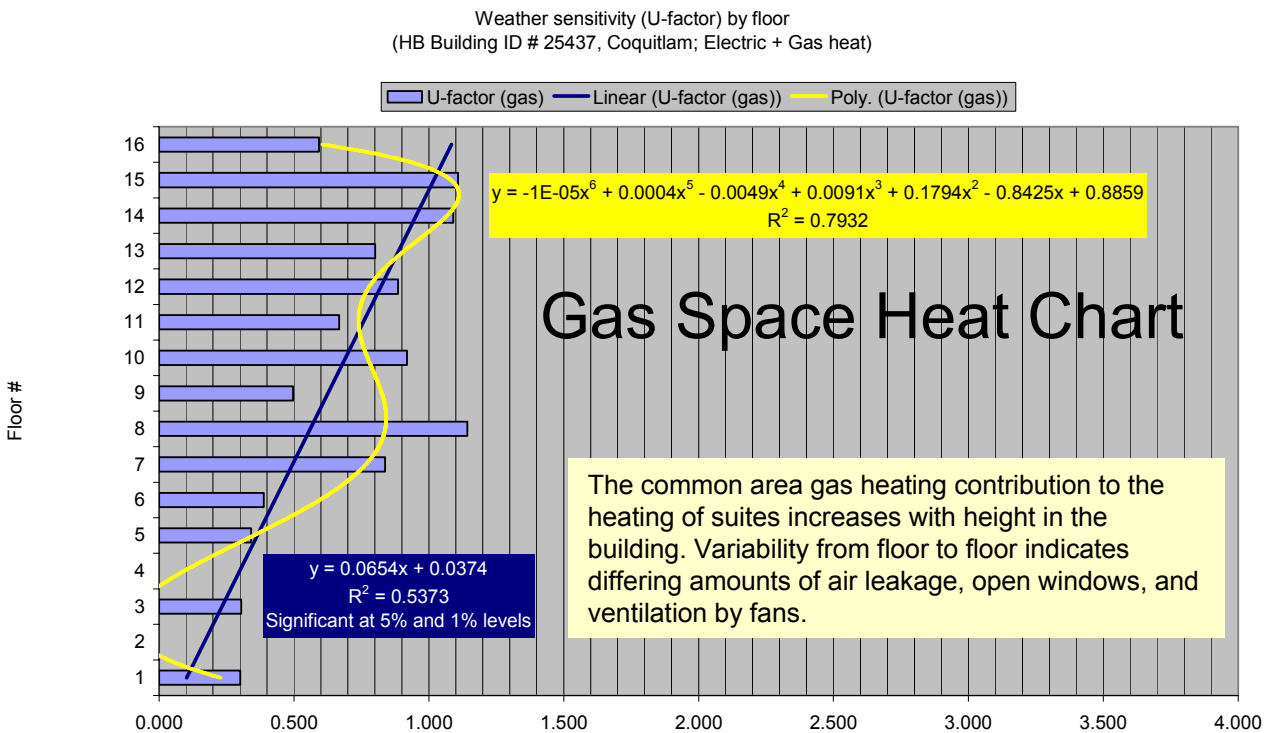
Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

This chart shows floor by floor weather sensitivity (U-factor) of common area gas energy For each floor, electrical energy consumption is presumed to balance total energy consumption resulting from inhabitants responding to the overall building's steady-state thermal transmittance during a given heating degree-day regime.



Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor (gas)	0.301	-0.376	0.305	-0.012	0.341	0.388	0.838	1.143	0.496	0.919	0.667	0.886	0.802	1.091	1.109	0.593

Wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 25437, Surrey (post-rehab)

Electric Heat

Method "B" for analyzing weather sensitivity of a building for which we have both electricity and gas energy consumption data

Step 1: Estimate overall building enclosure U-factor

This was done as shown on a previous slide. The **mean post-rehab U-factor** models a mix of building stock which was rehabilitated to address moisture damage.

$U = 1.6\ W / (m^2 \cdot K)$

Step 2: Transform U-factor to floor area basis

U (floor area basis) = U (wall area basis) x GWA / GFA

$= [\ 1.6\ W / (m^2 \cdot K)] \times (\ 4{,}134\ m^2 / 10{,}118\ m^2\ )$

$= 0.654\ W / (m^2 \cdot K)$

Step 3: Transform units of U-factor to be $(kWh/m^2) / HDD$

Note that heating degree-days, HDD = (K · day)

$U = [0.654\ W / (m^2 \cdot K)] \times (24\ h/day)/(1000\ W / kW)$

$= 0.0157\ (kWh/m^2) / HDD$

This result is the composite-fuel weather sensitivity.

Step 4: Determine heating distribution of fuels from average proportions of gas and electric U-factors tabulated below Method "B" Chart (see also data table in earlier slide)

Gas = 0.37; Electricity = 0.63

Step 5: Find slope of gas consumption weather sensitivity relationship

Gas slope = 0.37 x composite fuel weather sensitivity

$= 0.37 \times 0.0157\ (kWh/m^2) / HDD$

$= 0.0058\ (kWh/m^2) / HDD$

Step 6: Find gas heating system efficiency for this building

Gas heating system efficiency

$= [0.0058\ (kWh/m^2) / HDD] / [0.0079\ (kWh/m^2) / HDD]$

= 0.73 or **73%**

Slope for gas at assumed 100% efficiency. See Consumption against HDD Chart

Method "B" Steps 4 and 6 yield results similar to Method "A" Steps 6 and 5 respectively.

BC hydro FOR GENERATIONS

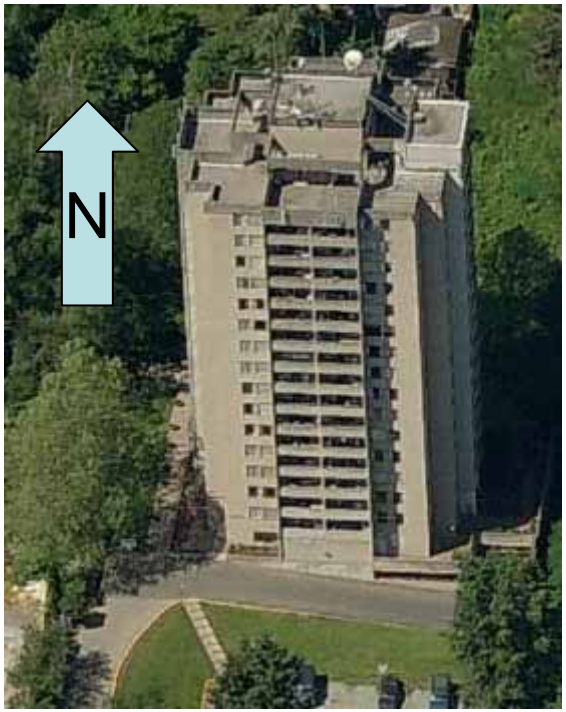
Method for inferring gas data

With the experience of dealing with the Coquitlam and Surrey buildings with gas data it became clear it was possible to estimate gas use in buildings for which gas data was not available. The estimation method relied on making an assumption about the building enclosure's overall U-factor. We used this method only if at least one of the building floors has an electric heater weather sensitivity or U-factor (wall area basis) with an order of magnitude $10^0 \approx 1$. Otherwise, we believed we were risking overstating the contribution of common-area gas to suite heating. Further research is needed to understand better the range of common-area gas contribution to space-heating of suites.

The estimation method is illustrated using electrical consumption data from HB Building ID # 137210, Surrey (next slides).

Electric Heat

Case Study: HB Building ID # 137210, Surrey



Source: http://www.bing.com/maps

Building specifications

- Surrey
- 92 Suites, 16 levels
- Built 1983
- Estimated length from aerial view = 27.5 m
- Estimated width from aerial view = 23m
- Estimated floor area = 633 m^2

BC hydro FOR GENERATIONS

Case Study: HB Building ID # 137210, Surrey

Data table for the four charts that follow

HB Building ID # 137210, Surrey			GFA (m²)=	10,128	GFA (m²)=	4,848											
			Floor Area =	633	m^2	Ratio: GFA/GWA =	2.09			multiplier for U(total) =	not available						
						Method "A"							Method "B"				
Floor	**WS Suites**	**R^2**	**Floor**	**Qty of suites**	**WS Floor**	**Elec. U, W/(m² x K), fab**	**Elec. U, W/(m² x K), wab**	**RSI, (m² x K)/W**	**R, hr x ft² x F/Btu**	**U(total), W/(m² x K), wab**	**diff = U(gas), W/(m² x K), wab**		**Assume constant U per floor, W/(m² x K), wab**	**alternate result for diff = U(gas), W/(m² x K), wab**	**Gas proportion**	**Elec proportion**	
1	2.98	0.86	1	7	20.86	1.373	2.869	0.3	2.0	Not used in this analysis			2	-0.869	-0.4342684	1.43426843	
2	1.82	0.80	2	11	19.91	1.311	2.738	0.4	2.1				2	-0.738	-0.3689286	1.36892856	
3	1.34	0.82	3	11	14.68	0.966	2.019	0.5	2.8				2	-0.019	-0.0092884	1.00928843	
4	1.44	0.84	4	10	14.88	0.979	2.046	0.5	2.8				2	-0.046	-0.0231023	1.02310231	
5	2.06	0.85	5	8	15.64	1.029	2.150	0.5	2.6				2	-0.150	-0.07517	1.07517002	
6	1.25	0.86	6	8	9.81	0.646	1.349	0.7	4.2				2	0.651	0.32545338	0.67454662	
7	0.73	0.66	7	8	5.84	0.384	0.803	1.2	7.1				2	1.197	0.59845985	0.40154015	
8	0.88	0.77	8	8	7.00	0.461	0.963	1.0	5.9				2	1.037	0.51870187	0.48129813	
9	1.51	0.86	9	8	12.08	0.795	1.661	0.6	3.4				2	0.339	0.16941694	0.83058306	
10	0.77	0.59	10	8	6.14	0.404	0.844	1.2	6.7				2	1.156	0.57806197	0.42193803	
11	1.19	0.80	11	8	9.52	0.627	1.309	0.8	4.3				2	0.691	0.34543454	0.65456546	
12	0.85	0.73	12	8	6.72	0.443	0.924	1.1	6.1				2	1.076	0.53776628	0.46223372	
13	0.90	0.70	13	8	7.17	0.472	0.986	1.0	5.8				2	1.014	0.50682568	0.49317432	
14	1.17	0.84	14	6	6.72	0.442	0.924	1.1	6.1				2	1.076	0.53804755	0.46195245	
15	1.11	0.81	15	6	6.51	0.428	0.895	1.1	6.3				2	1.105	0.5524865	0.4475135	
16	1.82	0.86	16	4	7.20	0.474	0.990	1.0	5.7				2	1.010	0.50513801	0.49486199	
				Building Means		*0.702*	*1.467*						*2.000*	*0.533*	*0.267*	*0.733*	
						fab = floor area basis											
						wab = wall area basis											

Mean U-factor (gas) = 0.533 W/(m² · K)

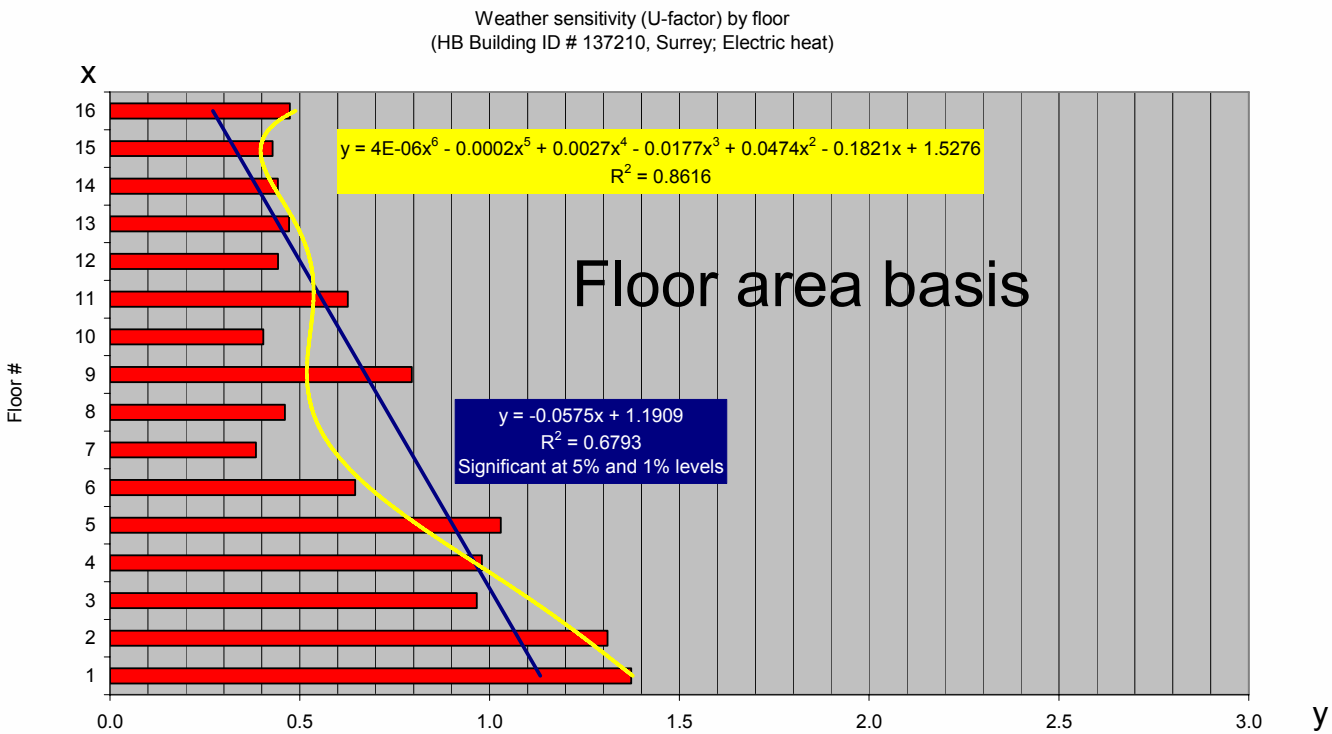
This part of the spreadsheet was used to model the effect of changes in building enclosure U-factor on U(gas) and gas/electric energy consumption proportions

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 137210, Surrey

Electric Heat



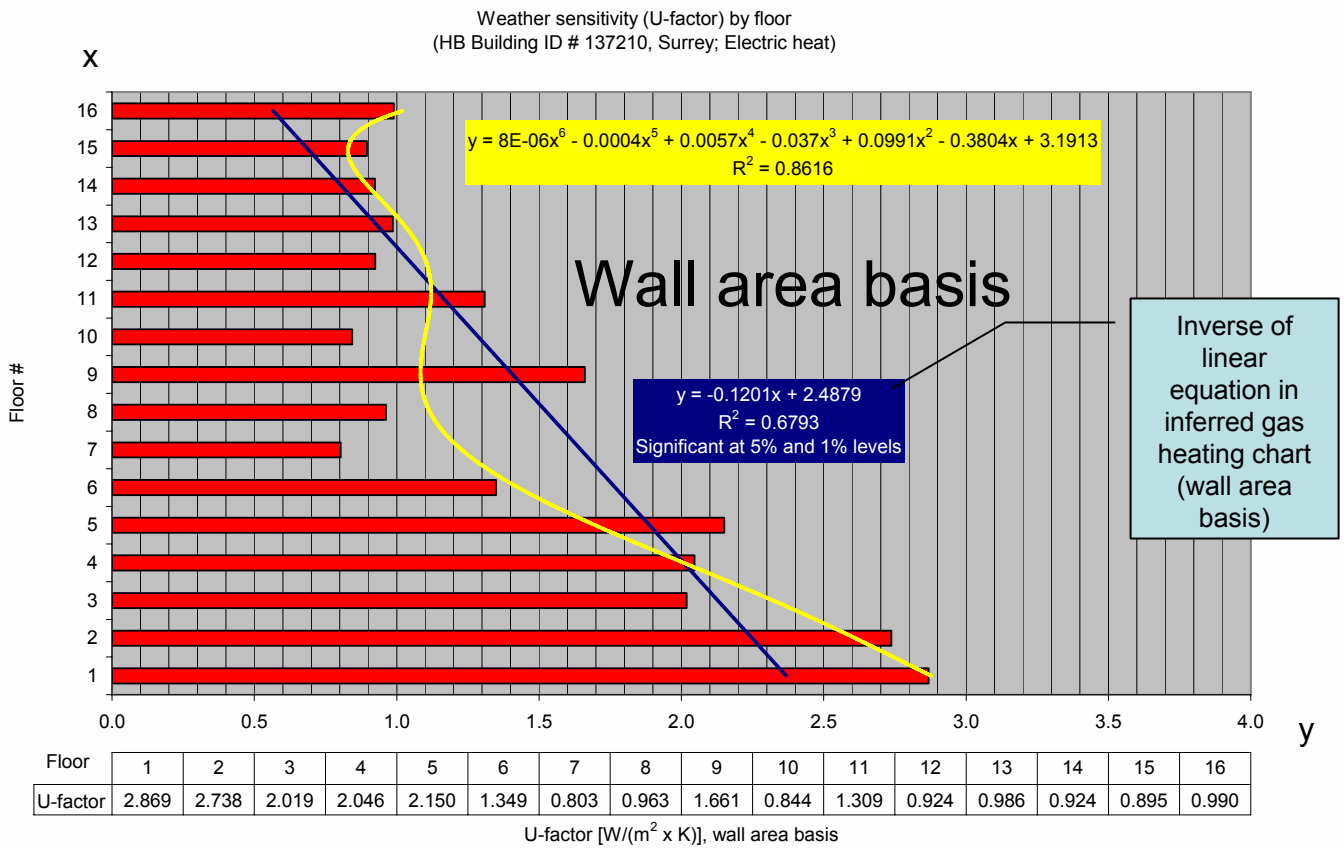
Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor	1.373	1.311	0.966	0.979	1.029	0.646	0.384	0.461	0.795	0.404	0.627	0.443	0.472	0.442	0.428	0.474

U-factor [W/(m^2 x K)], floor area basis

BC hydro FOR GENERATIONS

Case Study: HB Building ID # 137210, Surrey

Electric Heat



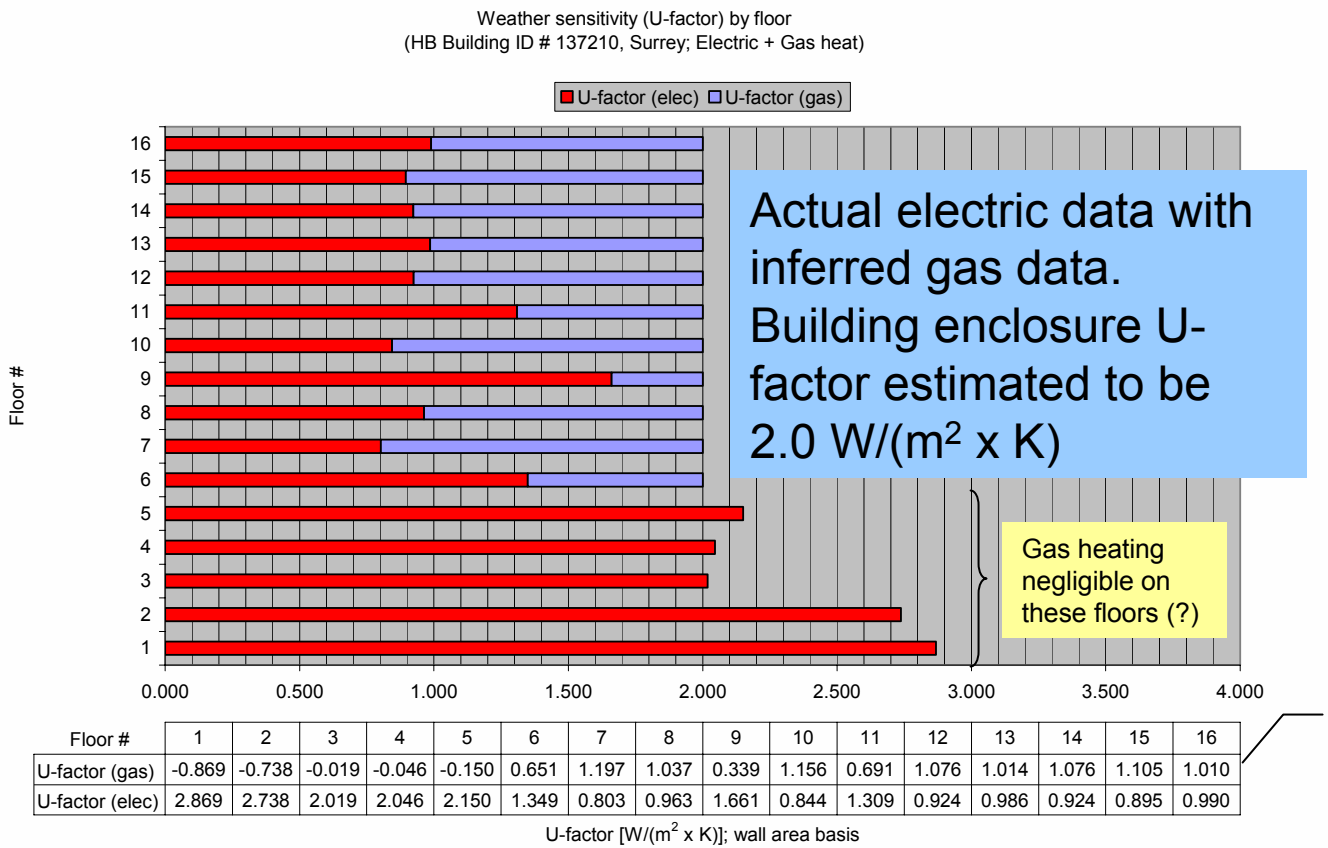
Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor	2.869	2.738	2.019	2.046	2.150	1.349	0.803	0.963	1.661	0.844	1.309	0.924	0.986	0.924	0.895	0.990

U-factor [W/(m^2 x K)], wall area basis

BC hydro FOR GENERATIONS

Case Study: HB Building ID # 137210, Surrey

Electric Heat



Actual electric data with inferred gas data. Building enclosure U-factor estimated to be 2.0 W/(m^2 x K)

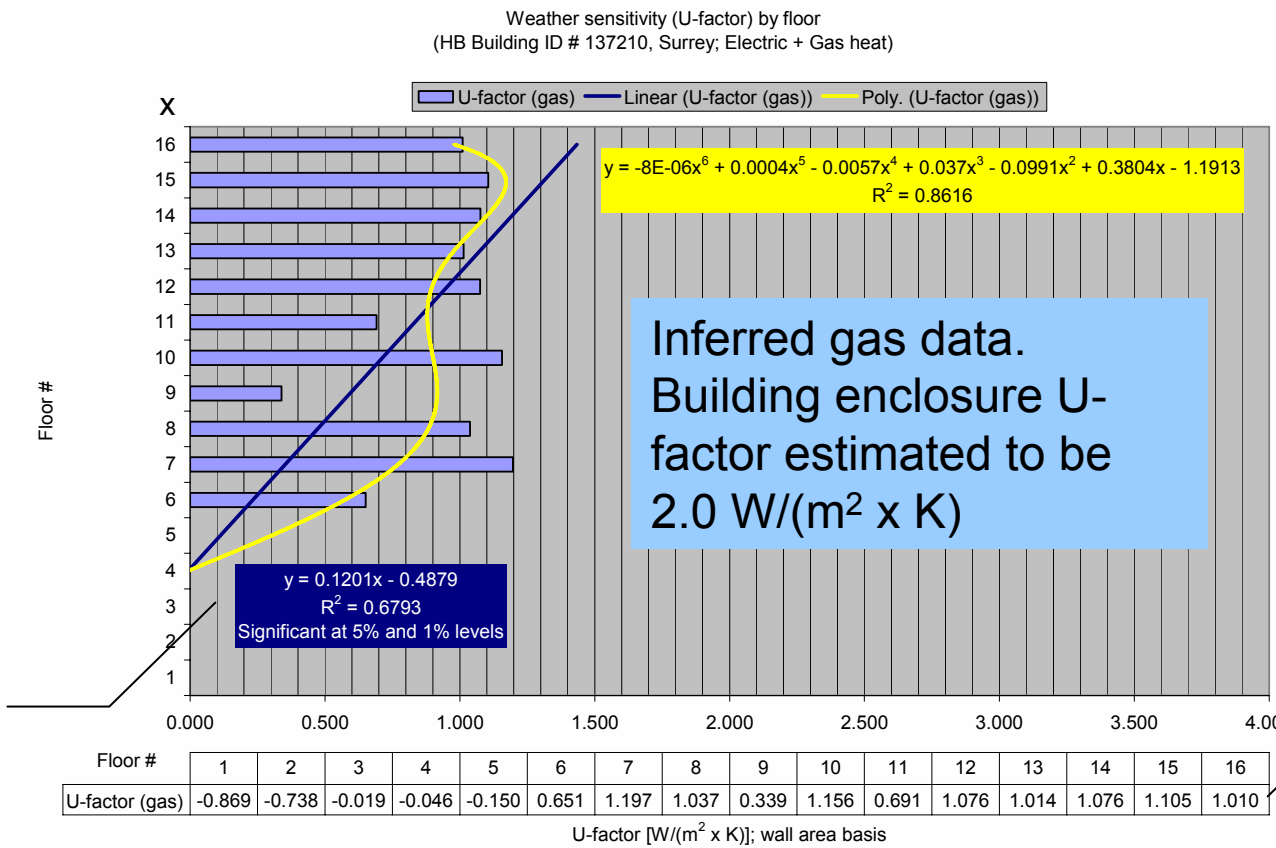
Gas heating negligible on these floors (?)

Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor (gas)	-0.869	-0.738	-0.019	-0.046	-0.150	0.651	1.197	1.037	0.339	1.156	0.691	1.076	1.014	1.076	1.105	1.010
U-factor (elec)	2.869	2.738	2.019	2.046	2.150	1.349	0.803	0.963	1.661	0.844	1.309	0.924	0.986	0.924	0.895	0.990

Mean U-factor (gas) = 0.533 W/(m^2 · K)

Case Study: HB Building ID # 137210, Surrey

Electric Heat



Inverse of linear equation in electrical heating chart (wall area basis)

Mean U-factor (gas) = 0.533 W/(m^2 · K)

BC hydro FOR GENERATIONS

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BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 137210, Surrey

Steps for inferring gas data for HB Building ID # 137210, Surrey

Step 1: Estimate overall building enclosure U-factor
This was done as shown on a previous slide. The **Grand mean U-factor** models a mix of high-rise building stock in BC

U = 2.0 W / (m^2 · K); wall area basis (wab)

Step 2: Find Gross Floor Area (GFA)
GFA = 633 m^2 / floor x 16 floors = 10,128

Step 3: Find Gross Wall Area (GWA)
Perimeter = (27.5 + 27.5 + 23 + 23) m = 101 m
GWA = 16 floors x 3 m/floor x Perimeter = 4848

Step 4: Transform U-factor to floor area basis (fab)
U (floor area basis) = U (wall area basis) x GWA / GFA
= [2.0 W / (m^2 · K)] x (4,848 m^2 / 10,128 m^2)
= 0.957 W / (m^2 · K)

.

Step 5: Transform units of U-factor to be (kWh/m^2) / HDD
Note that heating degree-days, HDD = (K · day)

U = [0.957 W / (m^2 · K)] x (24 h/day)/(1000 W / kW)

= 0.0230 (kWh/m^2) / HDD

This result is the composite-fuel weather sensitivity (floor area basis)

Step 6: Determine heating distribution of fuels from average proportions of gas and electric U-factors tabulated in the data table
Gas = 0.27; Electricity = 0.73

Step 7: Find slope of gas consumption weather sensitivity relationship (floor area basis)
Gas slope = 0.27 x composite fuel weather sensitivity
= 0.27 x 0.0230 (kWh/m^2) / HDD
= 0.0062 (kWh/m^2) / HDD or 0.258 W / (m^2 · K); fab
Gas slope (wab) = 0.258 W / (m^2 · K) x GFA/GWA) = 0.539 W / (m^2 · K)

Result: Starting with only weather sensitivity data for electric space-heating of suites plus an assumed overall building enclosure U-factor (based on the realities of BC's high-rise building stock) we were able to estimate quantitatively two aspects of this building's gas consumption:

1) Gas is responsible for 27% of the space-heating in this building

2) A heating degree change of 1 HDD is accompanied by a 0.0062 kWh/m^2 change in gas consumption (floor area basis).

BC hydro
FOR GENERATIONS

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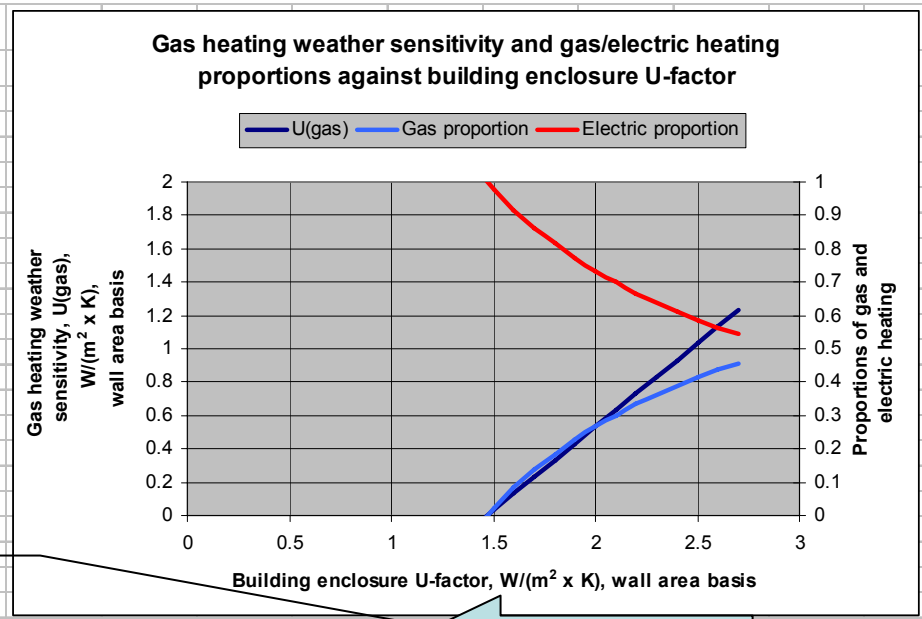
Equivalent to Mean U-factor (gas) = 0.533 W/(m^2 · K)

Case Study: HB Building ID # 137210, Surrey

Modeled effect of rehabilitation of a building enclosure

Range of possible U-factors
for HB Building ID # 137210, Surrey

U(building)	U(gas)	Gas proportion	Electric proportion
1.3	-0.167	-0.128	1.128
1.4	-0.067	-0.048	1.048
1.5	0.033	0.022	0.978
1.6	0.133	0.083	0.917
1.7	0.233	0.137	0.863
1.8	0.333	0.185	0.815
1.9	0.433	0.228	0.772
2	0.533	0.267	0.733
2.1	0.633	0.301	0.699
2.2	0.733	0.333	0.667
2.3	0.833	0.362	0.638
2.4	0.933	0.389	0.611
2.5	1.033	0.413	0.587
2.6	1.133	0.436	0.564
2.7	1.233	0.457	0.543



Rehabilitation reduces the building enclosure U-factor

U-factor decreases

This is a simple model of building enclosure rehabilitation in terms of the steady-state thermal transmittance (U-factor). Reducing the enclosure U-factor, from values above 2 W/(m^2 x K) to below this value, reduces the weather sensitivity of the gas heating system and lowers the proportion of gas heating in the building. Rehabilitation increases the proportion of electric heating. The same effect would be observed for any building using electric base heaters in suites and gas heating of common areas. **This effect is relevant to the goal of reducing greenhouse gas emissions from buildings in BC where most electric energy is supplied from hydro sources.**

BC hydro FOR GENERATIONS

Case Study: HB Building ID # 182131, Prince George

Source: http://homes.point2.com/CA/British-Columbia/Northern-British-Columbia/Prince-George/Prince-George-City-Central/11092012-Photos.aspx

Building specifications

- Prince George
- 84 Suites, 12 levels
- Built 1965, brick
- Estimated length from aerial view = 42 m
- Estimated width from aerial view = 15 m
- Estimated floor area = 630 m^2

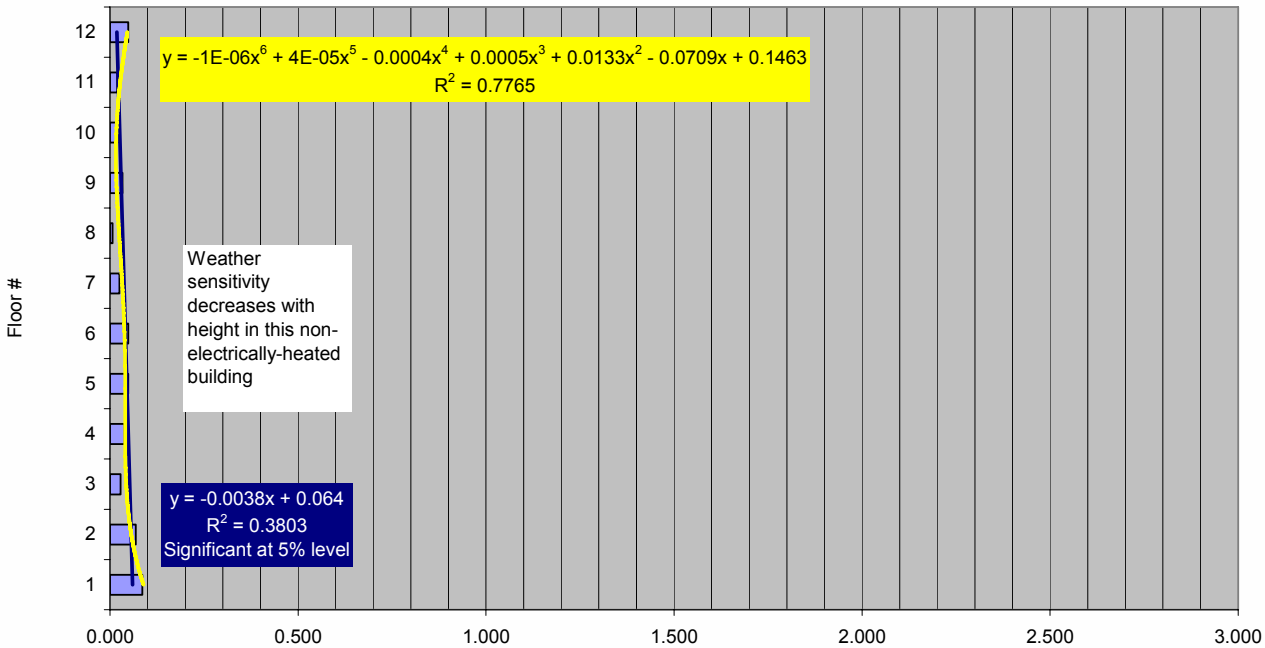
Aerial view building length and width estimates were done using Bing (http://www.bing.com/maps) or Google (http://www.google.com/maps) aerial views

Non-electric heat

BC hydro FOR GENERATIONS

Non-electric heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 182131, Prince George, Non-electric heat)



Floor #	1	2	3	4	5	6	7	8	9	10	11	12
U-factor	0.086	0.069	0.028	0.038	0.048	0.048	0.025	0.007	0.033	0.021	0.019	0.048

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 290820, Nanaimo

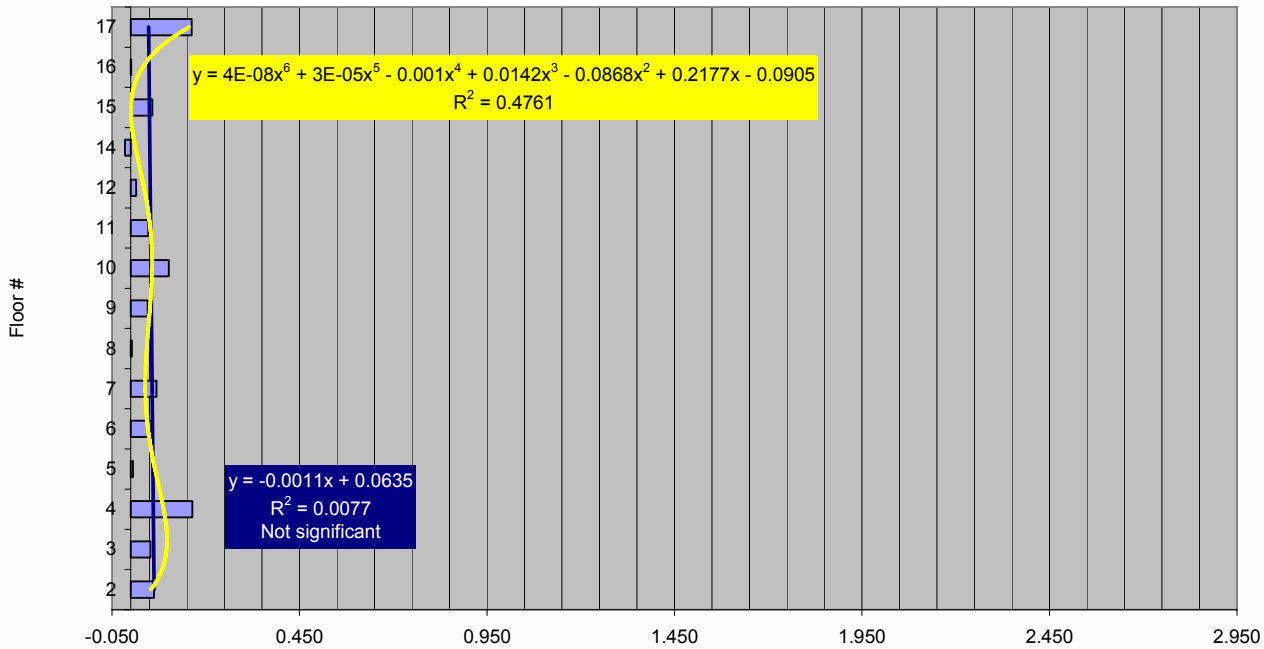
Source: http://maps.nanaimo.ca/data/property/104230.html

Building specifications
- Nanaimo
- 100 Suites, 17 levels
- Built 1968
- Estimated length from aerial view = 29 m
- Estimated width from aerial view = 14 m
- Estimated floor area = 406 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 290820, Nanaimo, Electric heat)



Floor #	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factor	0.063	0.052	0.164	0.006	0.054	0.069	0.003	0.045	0.102	0.047	0.014	-0.015	0.057	0.001	0.162

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 196478, Nanaimo

Source: http://nanaimocondo.ca/cameron-island/

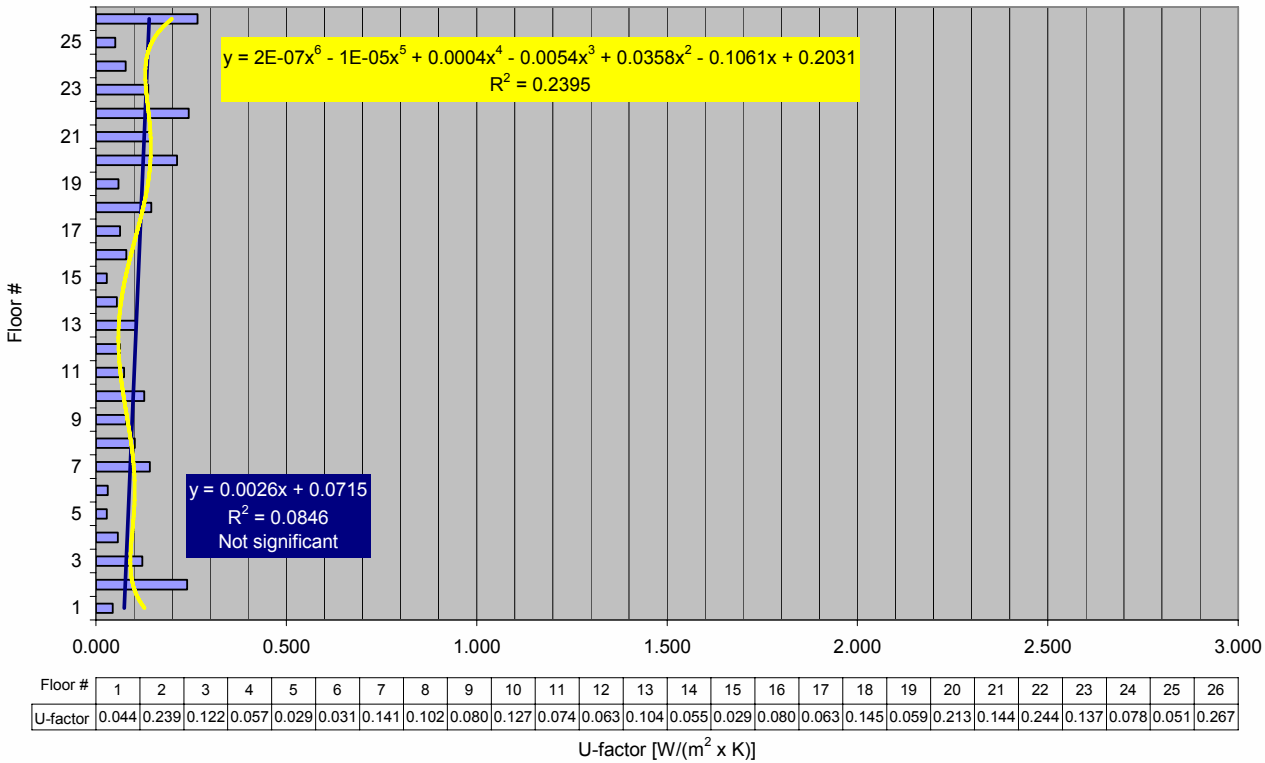
Building specifications

- Nanaimo
- 118 Suites, 26 levels
- Built 1997
- Estimated diameter from aerial view = 36 m
- Estimated floor area = 1018 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 196478, Nanaimo; Electric heat)



Floor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
U-factor	0.044	0.239	0.122	0.057	0.029	0.031	0.141	0.102	0.080	0.127	0.074	0.063	0.104	0.055	0.029	0.080	0.063	0.145	0.059	0.213	0.144	0.244	0.137	0.078	0.051	0.267

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 396049, Victoria

Source: http://www.bing.com/maps

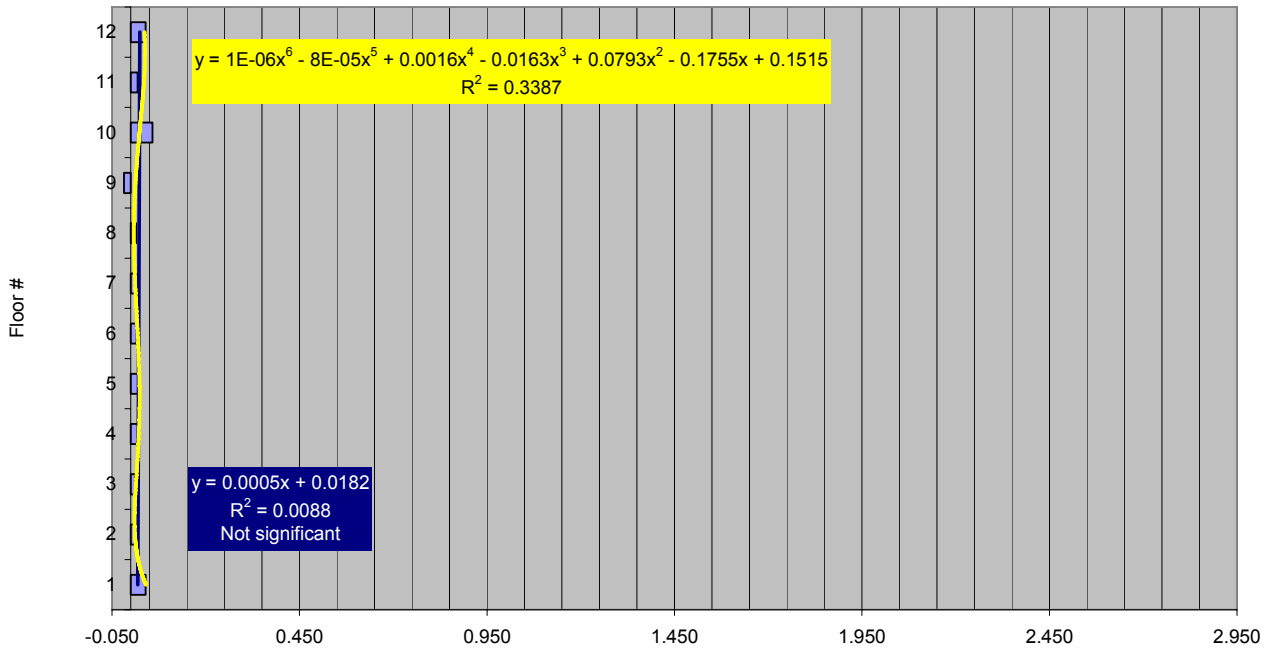
Building specifications

- Victoria
- 95 Suites, 12 levels
- Built 1970
- Estimated length from aerial view = 46 m
- Estimated width from aerial view = 20 m
- Estimated floor area = 920 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 396049, Victoria; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12
U-factor	0.040	0.014	0.011	0.021	0.024	0.016	0.018	0.014	-0.018	0.058	0.018	0.040

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 217713, Victoria

Source: http://www.bing.com/maps

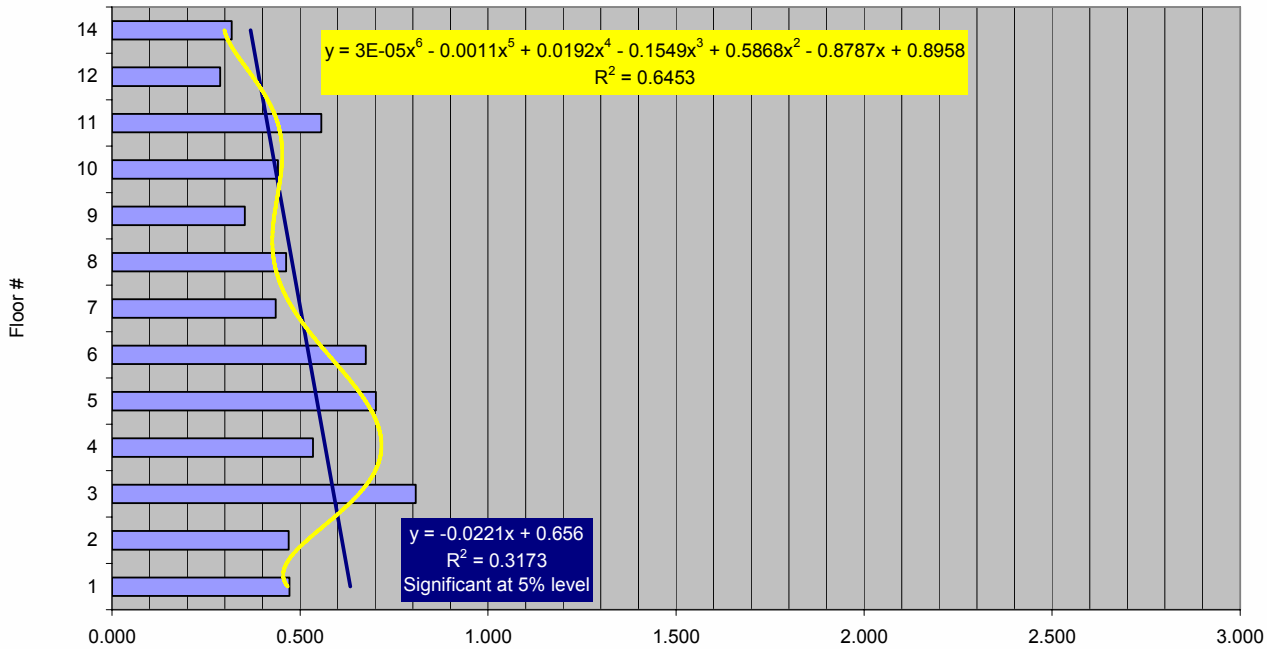
Building specifications

- Victoria
- 119 Suites, 13 levels
- Built 1982
- Steel and concrete
- Estimated length from aerial view = 40 m
- Estimated width from aerial view = 17 m
- Estimated floor area = 680 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 217713, Victoria; Electric heat)



Floor #	1	2	3	4	5	6	7	8	9	10	11	12	14
U-factor	0.472	0.470	0.808	0.535	0.701	0.675	0.435	0.463	0.353	0.441	0.557	0.288	0.319

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 567933, Victoria

Source: http://www.bing.com/maps

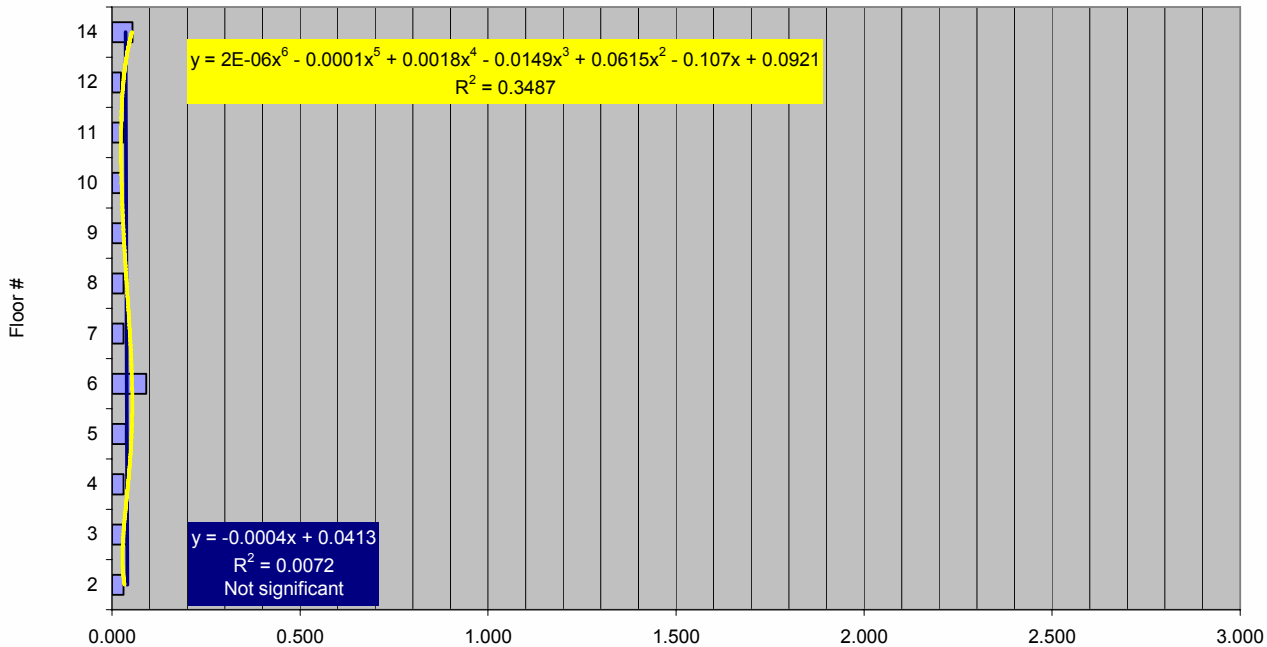
Building specifications

- Victoria
- 82 Suites, 12 levels
- Built 1966
- Estimated length from aerial view = 30 m
- Estimated width from aerial view = 16 m
- Estimated floor area = 480 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 567933, Victoria; Electric heat)



Floor	2	3	4	5	6	7	8	9	10	11	12	14
U-factor	0.030	0.043	0.030	0.036	0.091	0.030	0.030	0.036	0.024	0.030	0.024	0.055

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 630367, Victoria

Source: http://www.bing.com/maps

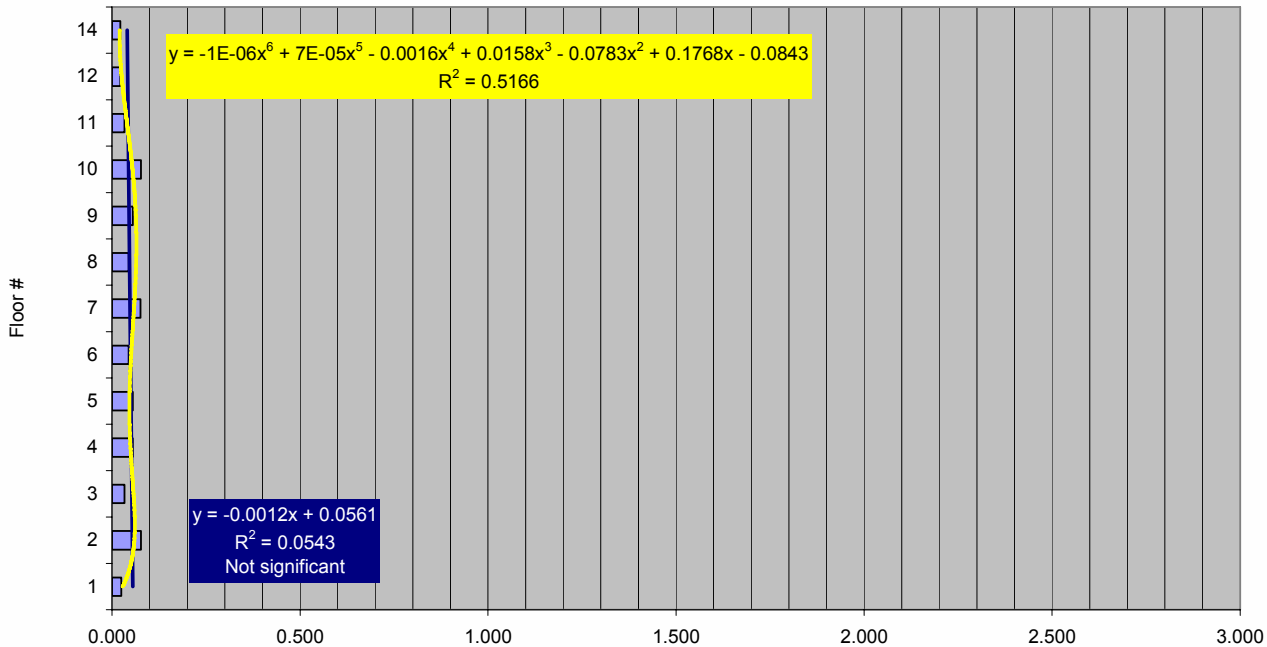
Building specifications

- Victoria
- 121 Suites, 13 levels
- Built 1964
- Estimated length from aerial view = 21 m
- Estimated width from aerial view = 18 m
- Estimated floor area = 378 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 630367, Victoria; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14
U-factor	0.024	0.077	0.033	0.055	0.055	0.044	0.076	0.044	0.055	0.077	0.033	0.022	0.022

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 657256, Victoria

Source: http://www.bing.com/maps

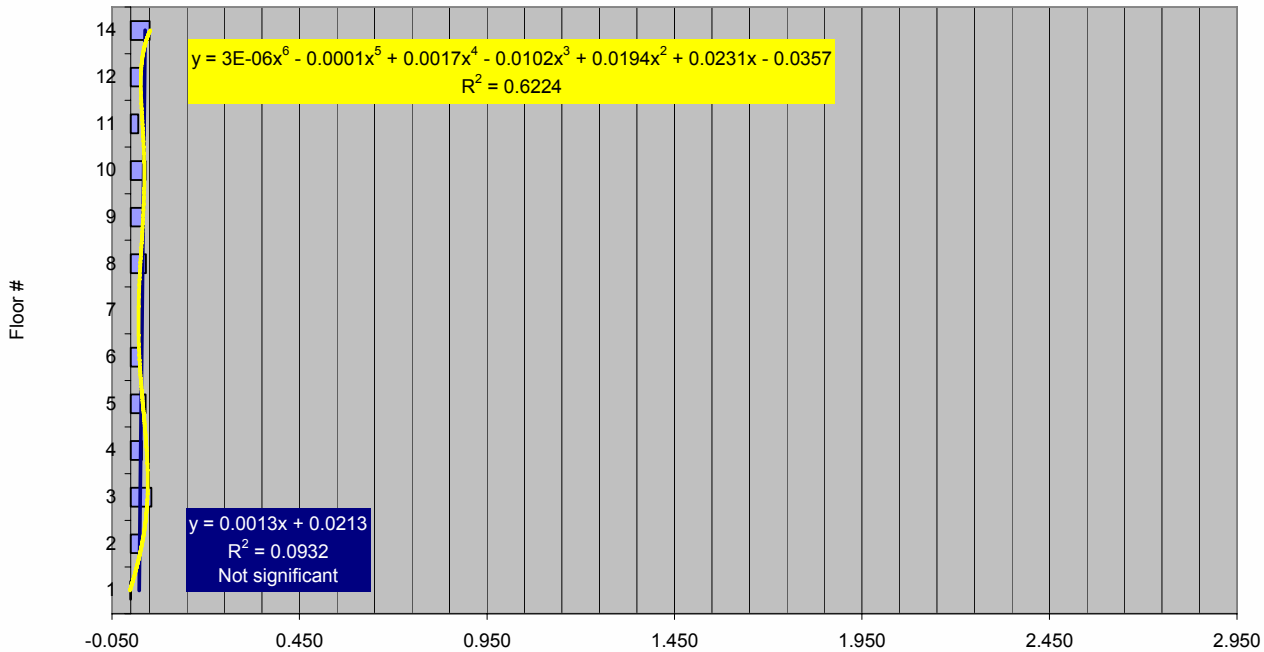
Building specifications

- Victoria
- 144 Suites, 13 levels
- Built 1966
- Estimated length from aerial view = 50 m
- Estimated width from aerial view = 20 m
- Estimated floor area = 1000 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID #657256, Victoria; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14
U-factor	-0.001	0.025	0.055	0.030	0.040	0.030	0.000	0.040	0.032	0.040	0.020	0.035	0.050

U-factor [W/(m2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 667371, Victoria

Source: http://www.bing.com/maps

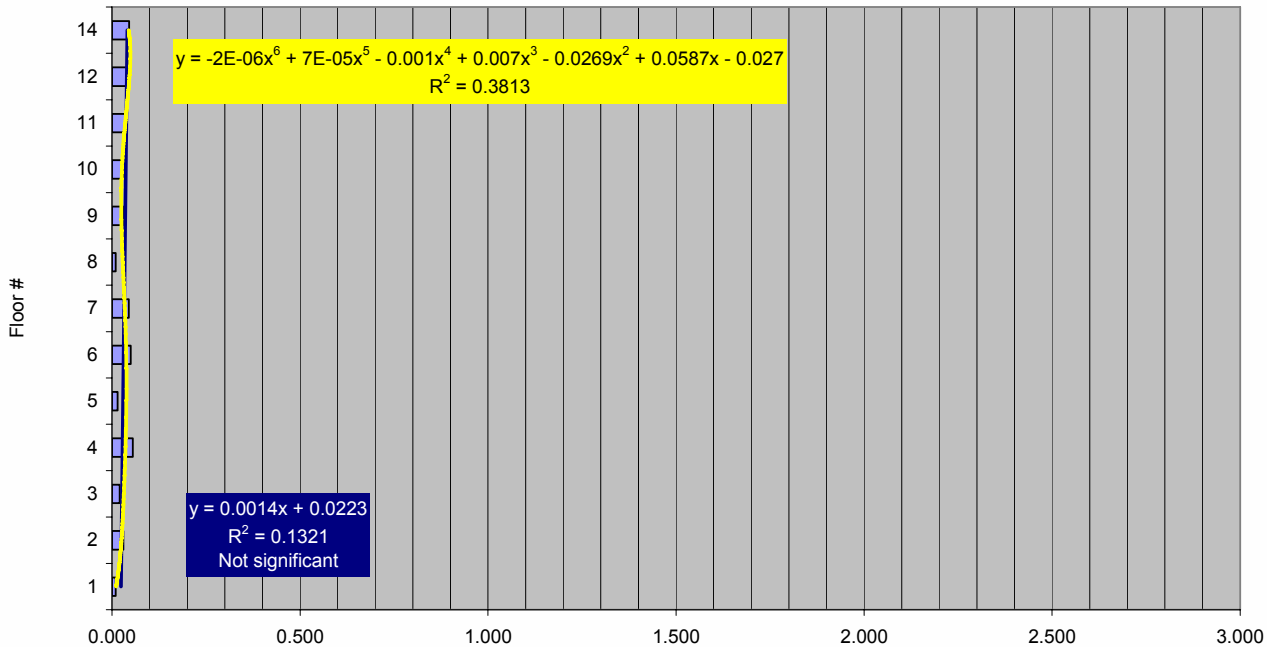
Building specifications

- Victoria
- 148 Suites, 13 levels
- Built 1965
- Estimated length from aerial view = 50 m
- Estimated width from aerial view = 20 m
- Estimated floor area = 1000 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 667371, Victoria; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14
U-factor	0.010	0.030	0.020	0.055	0.015	0.050	0.045	0.010	0.030	0.030	0.035	0.045	0.045

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 844023, Victoria

Source: http://www.bing.com/maps

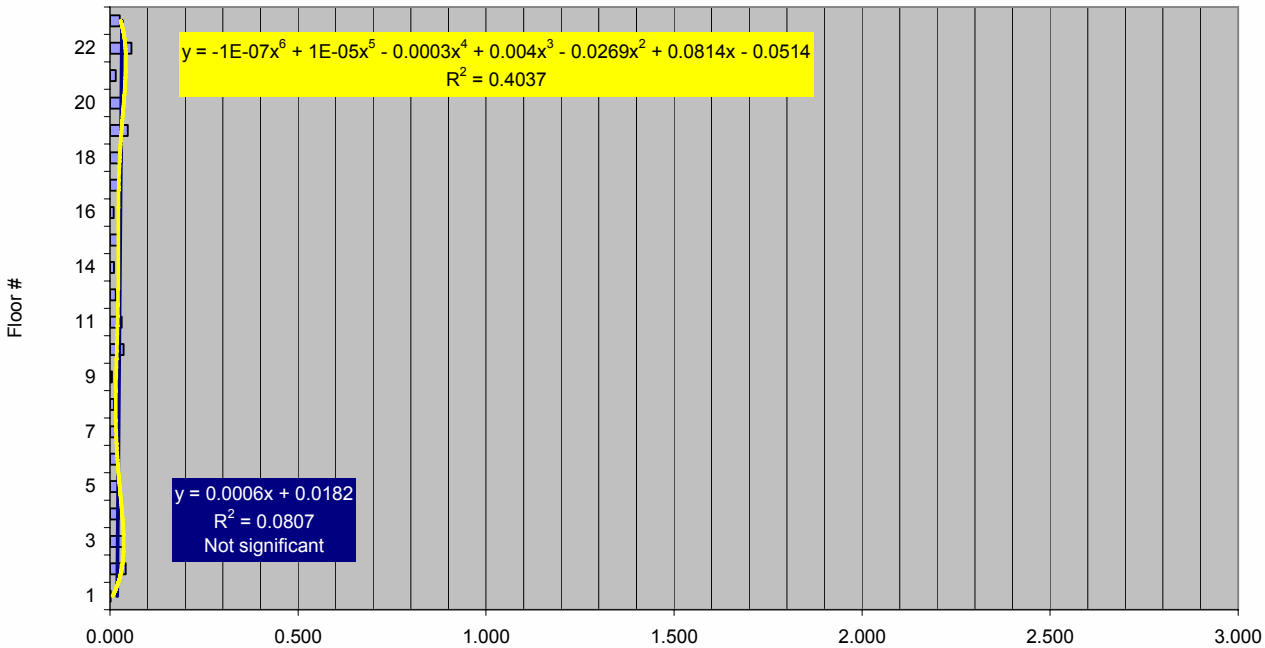
Building specifications

- Victoria
- 207 Suites, 22 levels
- Built 1970
- Estimated length from aerial view = 40 m
- Estimated width from aerial view = 20 m
- Estimated floor area = 800 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 844023, Victoria; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23
U-factor	0.002	0.042	0.036	0.023	0.026	0.021	0.021	0.010	0.005	0.036	0.031	0.015	0.010	0.026	0.010	0.026	0.031	0.047	0.036	0.015	0.057	0.026

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 493833, Abbotsford

Source: http://www.bing.com/maps

Building specifications

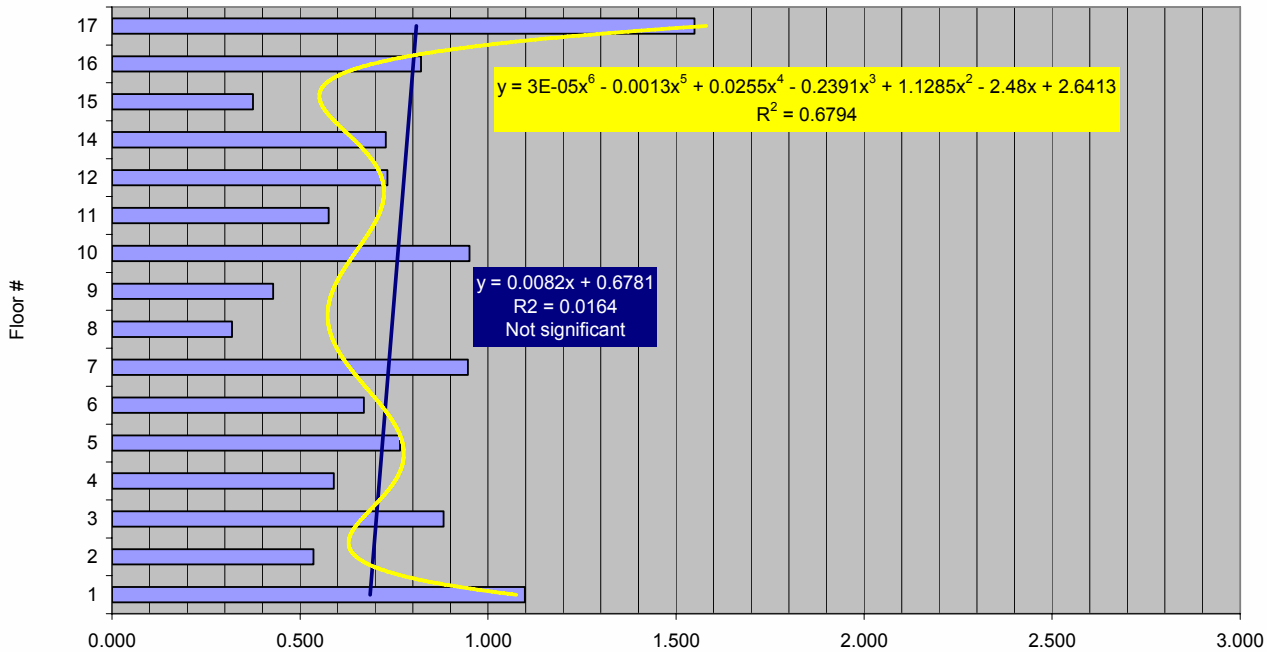
- Abbotsford
- 95 Suites, 16 levels
- Built 1990
- Estimated length from aerial view = 28 m
- Estimated width from aerial view = 20 m
- Estimated floor area = 560 m^2

Regency Park (Gladwin Road) tall buildings. Source: http://www.bing.com/maps

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 493833, Abbotsford; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factor	1.097	0.536	0.882	0.589	0.766	0.670	0.946	0.319	0.429	0.951	0.576	0.732	0.728	0.375	0.821	1.549

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Case Study: HB Building ID # 497077, Abbotsford

Source: http://www.bing.com/maps

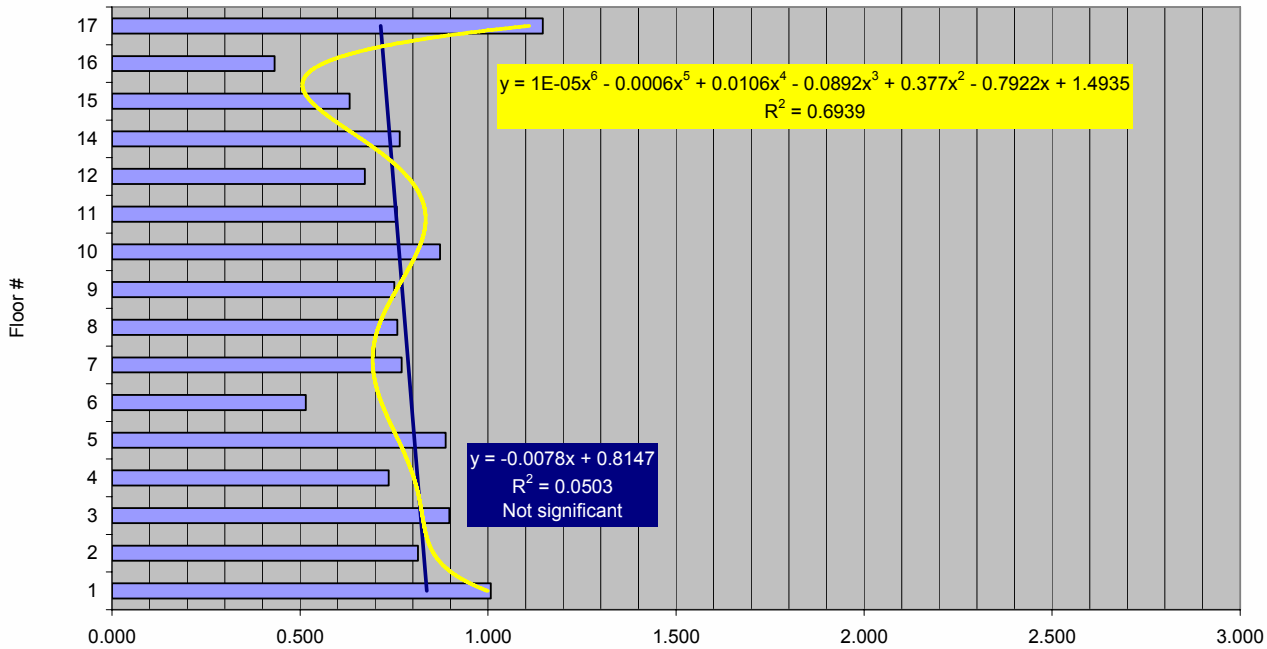
Building specifications

- Abbotsford
- 92 Suites, 16 levels
- Built 1990
- Estimated length from aerial view = 27 m
- Estimated width from aerial view = 19 m
- Estimated floor area = 513 m^2

Regency Park (Gladwin Road) tall buildings. Source: http://www.bing.com/maps

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 497077, Abbotsford; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factor	1.007	0.814	0.897	0.736	0.887	0.516	0.770	0.758	0.750	0.872	0.757	0.673	0.765	0.632	0.432	1.145

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 500135, Abbotsford

Source: http://www.bing.com/maps

Building specifications

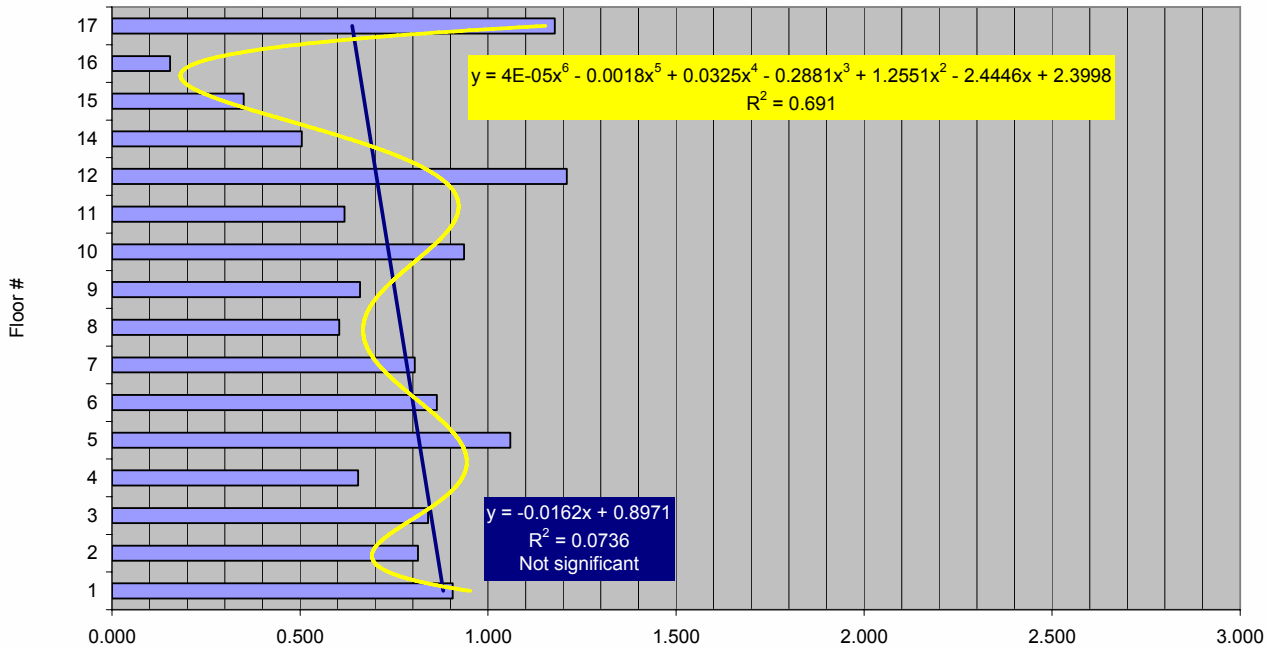
- Abbotsford
- 93 Suites, 16 levels
- Built 1992
- Estimated length from aerial view = 27.5 m
- Estimated width from aerial view = 20 m
- Estimated floor area = 550 m^2

Regency Park (Gladwin Road) tall buildings. Source: http://www.bing.com/maps

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 500135, Abbotsford; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factor	0.906	0.814	0.841	0.655	1.059	0.864	0.805	0.605	0.659	0.936	0.618	1.209	0.505	0.350	0.155	1.177

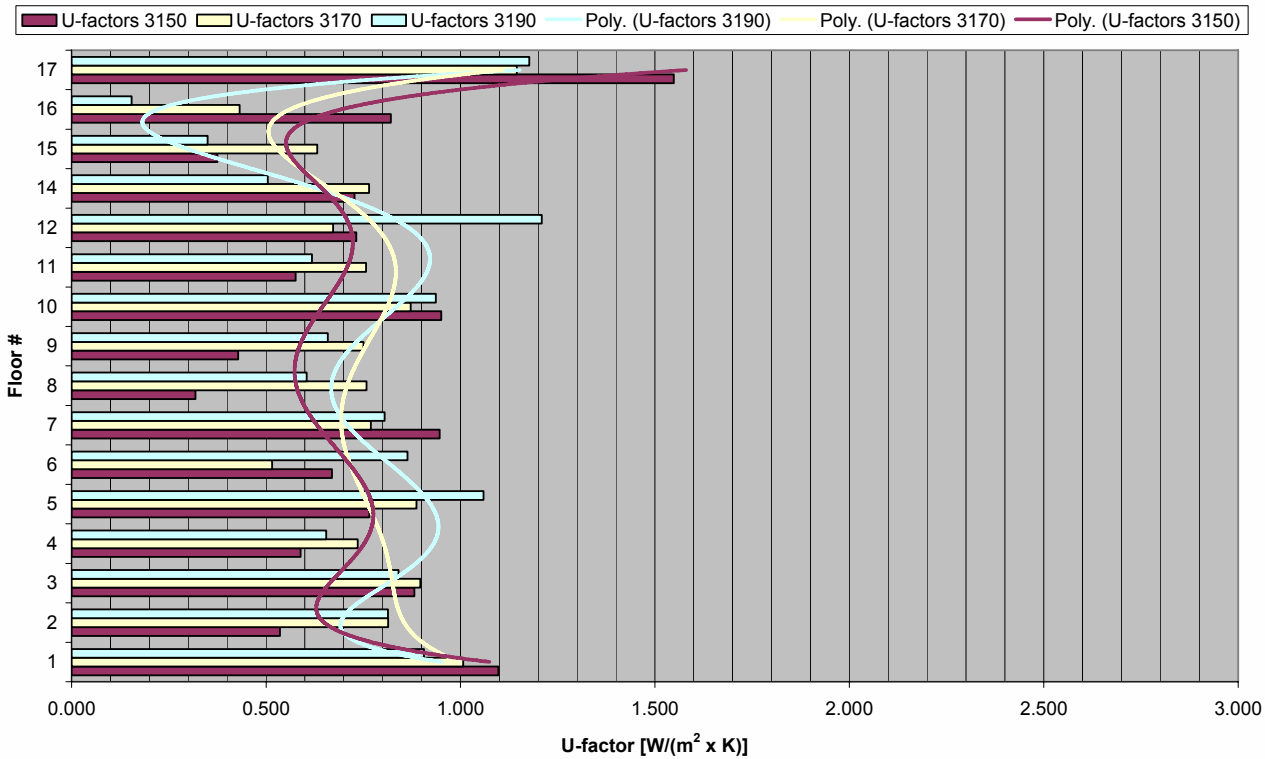
Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

U-factor comparisons between floors
for trio of identical high-rise residential buildings, Abbotsford



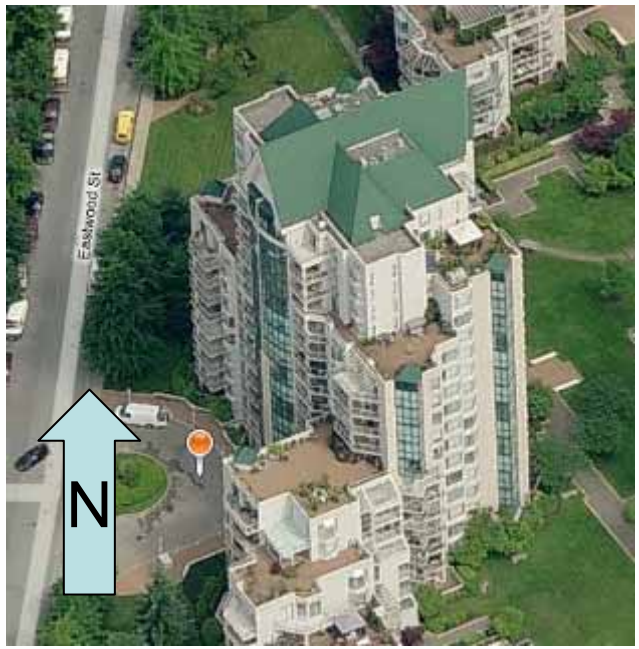
Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 80228, Coquitlam



Source: http://www.bing.com/maps

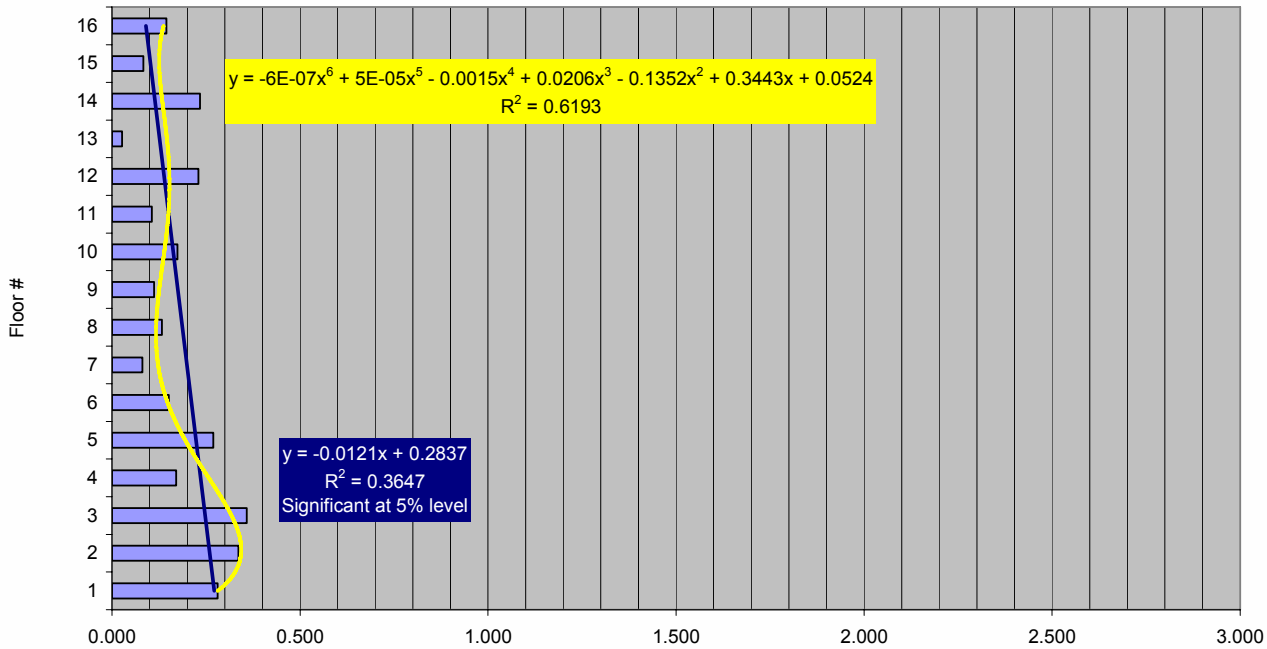
Building specifications

- Coquitlam
- 110 Suites, 16 levels
- Built 1993
- Estimated length from aerial view = 38 m
- Estimated width from aerial view = 26 m
- Estimated floor area = 988 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 80228, Coquitlam; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor	0.281	0.336	0.358	0.171	0.269	0.151	0.081	0.133	0.112	0.174	0.106	0.230	0.027	0.234	0.084	0.144

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 80983, Coquitlam

Source: http://www.bing.com/maps

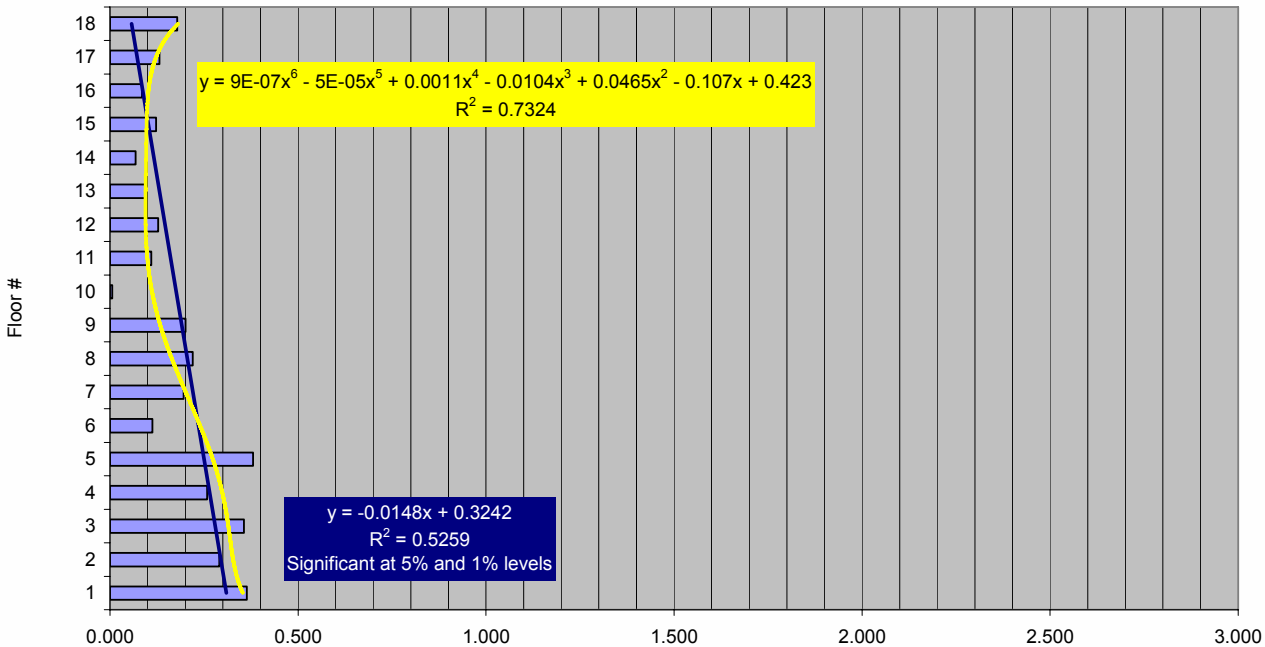
Building specifications

- Coquitlam
- 109 Suites, 18 levels
- Built 1995
- Estimated length from aerial view = 38 m
- Estimated width from aerial view = 21 m
- Estimated floor area = 798 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 80983, Coquitlam; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
U-factor	0.363	0.291	0.356	0.258	0.380	0.113	0.196	0.220	0.201	0.006	0.110	0.128	0.097	0.068	0.123	0.085	0.132	0.179

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 82957, Coquitlam

Source: http://www.bing.com/maps

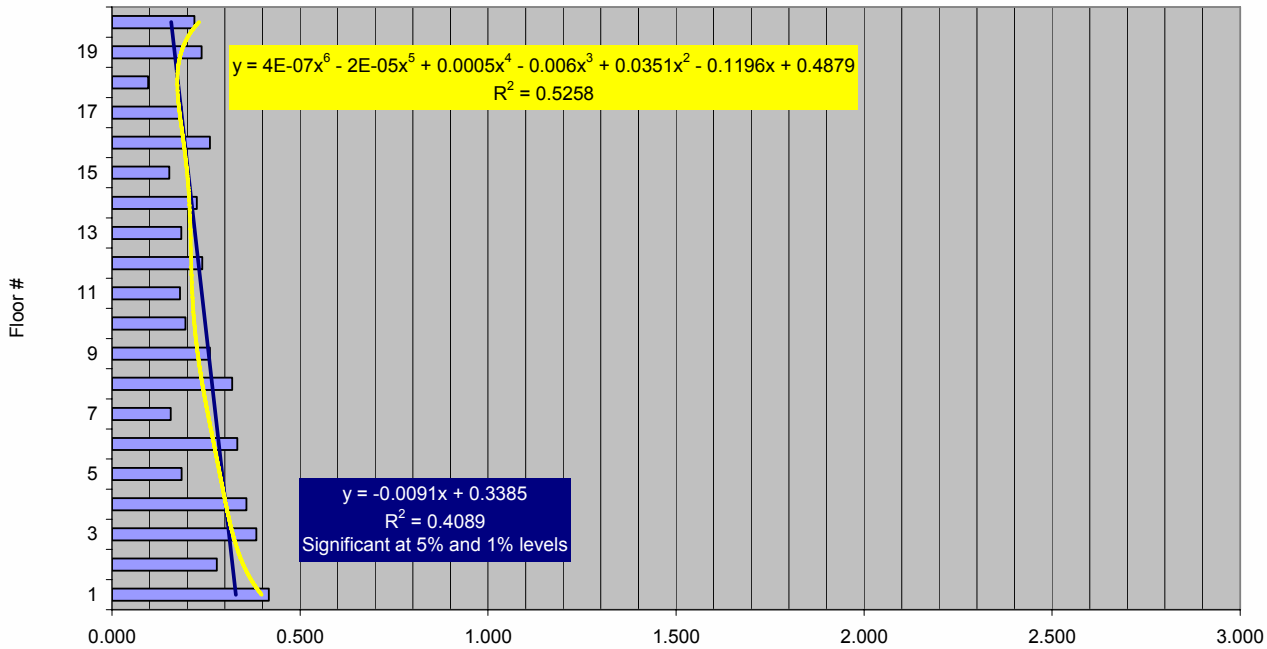
Building specifications

- Coquitlam
- 135 Suites, 20 levels
- Built 1997
- Estimated length from aerial view = 36 m
- Estimated width from aerial view = 22 m
- Estimated floor area = 792 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 80983, Coquitlam; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
U-factor	0.417	0.278	0.384	0.358	0.185	0.333	0.156	0.320	0.260	0.195	0.180	0.240	0.184	0.226	0.153	0.260	0.185	0.096	0.238	0.219

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

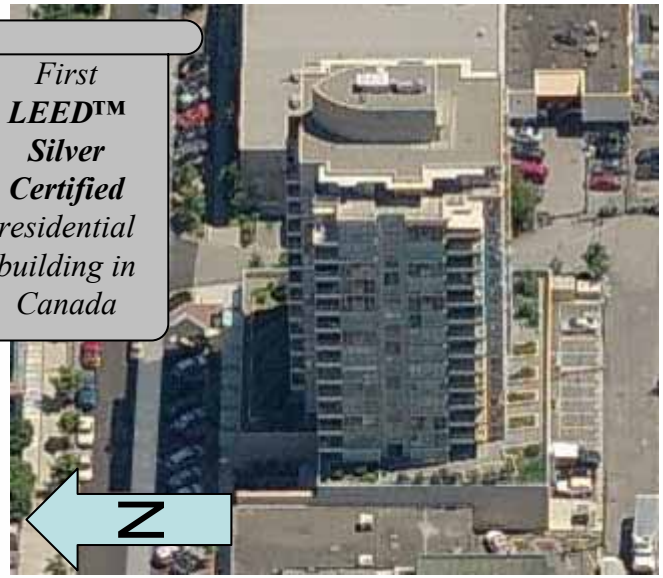
BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: SAS Building ID # 11121038, North Vancouver

First ***LEED™ Silver Certified*** *residential building in Canada*



http://www.bing.com/maps/

Building specifications

- North Vancouver
- 65 Suites, 13 levels, with 3 commercial levels
- Built 2005
- Solid concrete with punched windows, 6 inches of batt insulation between and behind interior studs; relatively low window to wall ratio (0.46) – (rRBI, 2003, 7)
- Gross Floor Area (GFA) = 8,200 m^2
- Floor area = 513 m^2

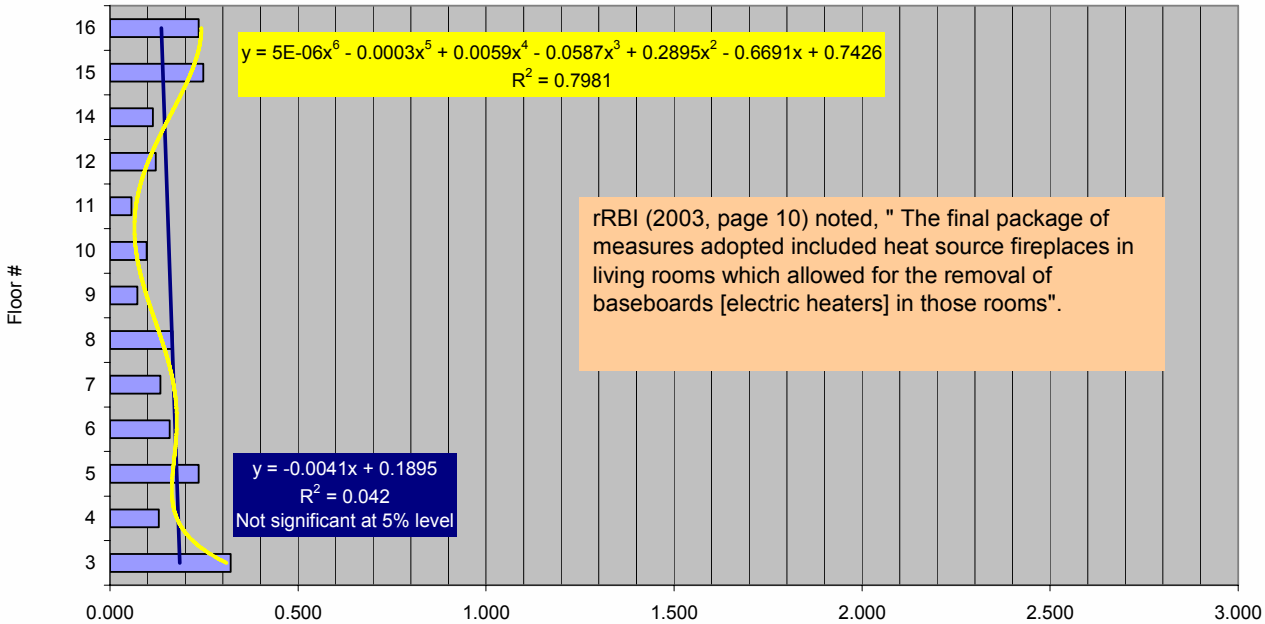
Contribution of LEED™ BC requirements to reducing weather sensitivity

- Building envelope designed to ASHRAE 90.1 1999
- "…more energy efficient than the typical curtain wall construction prevalent in the Greater Vancouver area.' (rRBI, 2003, 7)
- "…original envelope design is significantly better than local standard practice in terms of thermal performance." (rRBI, 2003, 10)
- 30% savings for domestic hot water (rRBI, 2003, 10)

BC hydro FOR GENERATIONS

Electric Heat

Weather Sensitivity (U-factor) by Floor: SAS Building ID # 11121038
(Electric heat, North Vancouver, Built 2005)



rRBI (2003, page 10) noted, " The final package of measures adopted included heat source fireplaces in living rooms which allowed for the removal of baseboards [electric heaters] in those rooms".

Floor #	3	4	5	6	7	8	9	10	11	12	14	15	16
U-factor	0.321	0.130	0.236	0.158	0.134	0.167	0.073	0.097	0.057	0.122	0.114	0.248	0.236

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

*First **LEED Silver Certified** residential building in Canada*

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 48498, North Vancouver

Source: http://www.bing.com/maps

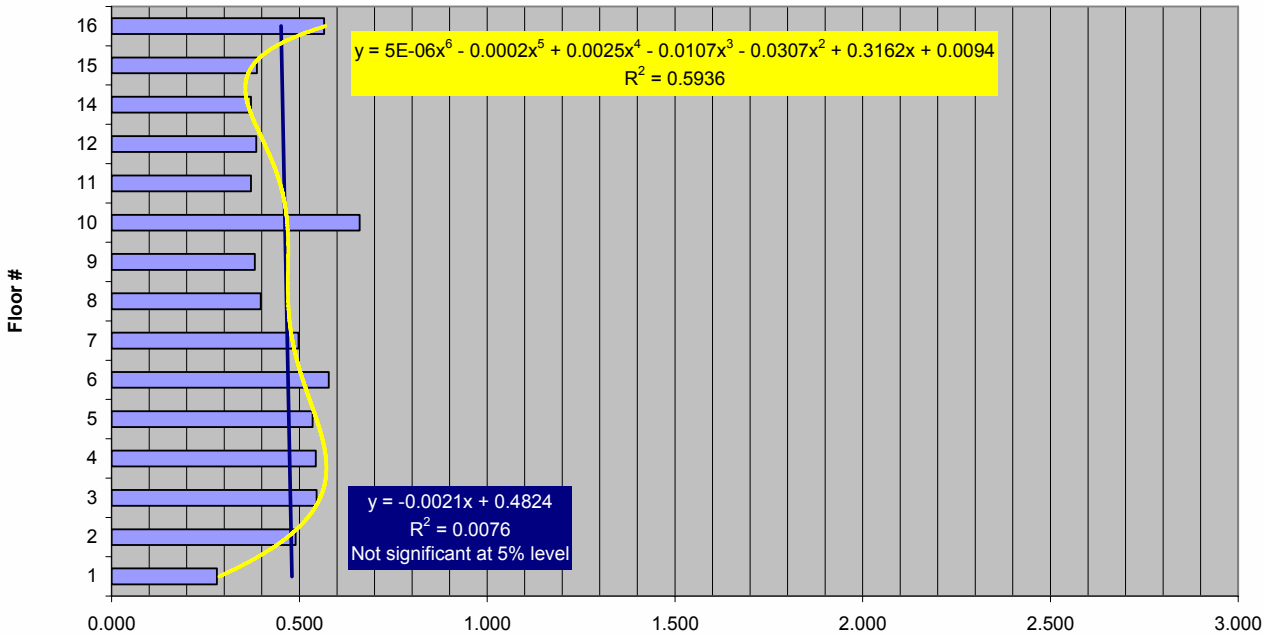
Building specifications

- North Vancouver
- 85 Suites, 15 levels
- Built 1981
- Estimated floor area = 472 m^2 (from areal view)

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 48498, North Vancouver; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16
U-factor	0.280	0.490	0.546	0.544	0.535	0.578	0.498	0.397	0.381	0.661	0.371	0.385	0.371	0.387	0.566

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 212087, North Vancouver

Source: http://www.bing.com/maps

Building specifications

- North Vancouver
- 85 Suites, 15 levels
- Built 1999
- Concrete, glass
- Estimated length from aerial view = 27 m
- Estimated width from aerial view = 27 m
- Estimated floor area = 729 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 212087, North Vancouver, Electric heat)

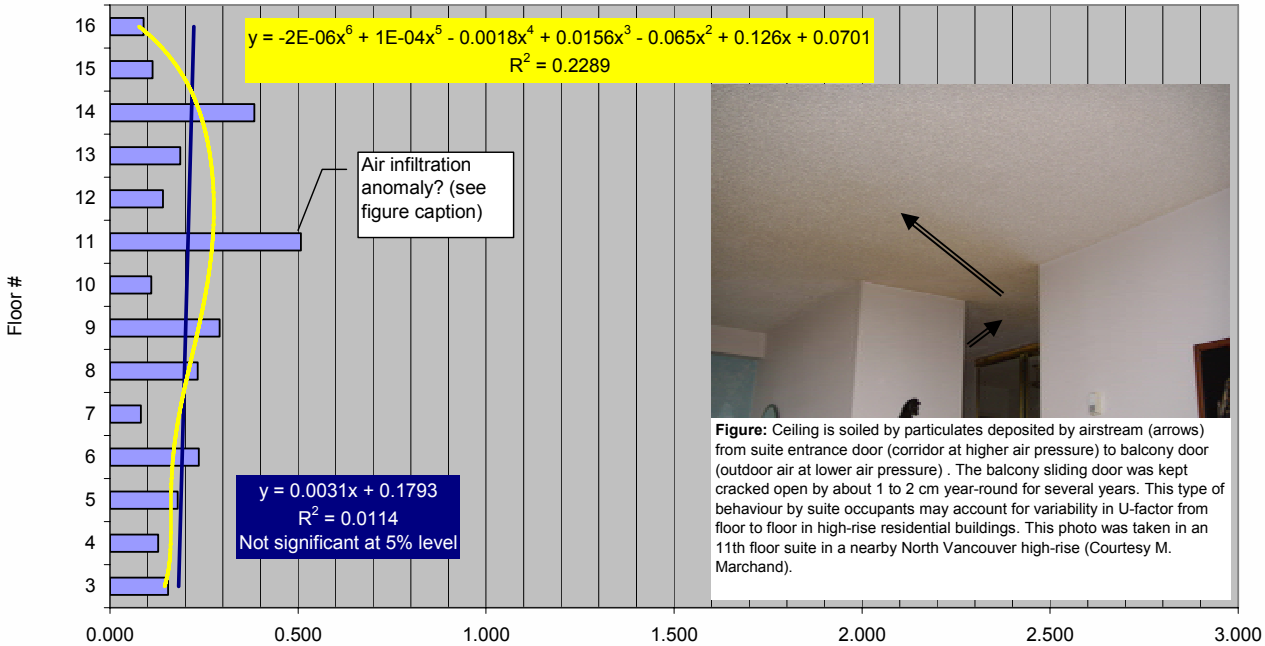


Figure: Ceiling is soiled by particulates deposited by airstream (arrows) from suite entrance door (corridor at higher air pressure) to balcony door (outdoor air at lower air pressure) . The balcony sliding door was kept cracked open by about 1 to 2 cm year-round for several years. This type of behaviour by suite occupants may account for variability in U-factor from floor to floor in high-rise residential buildings. This photo was taken in an 11th floor suite in a nearby North Vancouver high-rise (Courtesy M. Marchand).

Floor #	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor	0.154	0.128	0.180	0.236	0.082	0.233	0.291	0.110	0.508	0.141	0.187	0.384	0.113	0.089

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 1041126, Surrey

Source: http://www.bing.com/maps

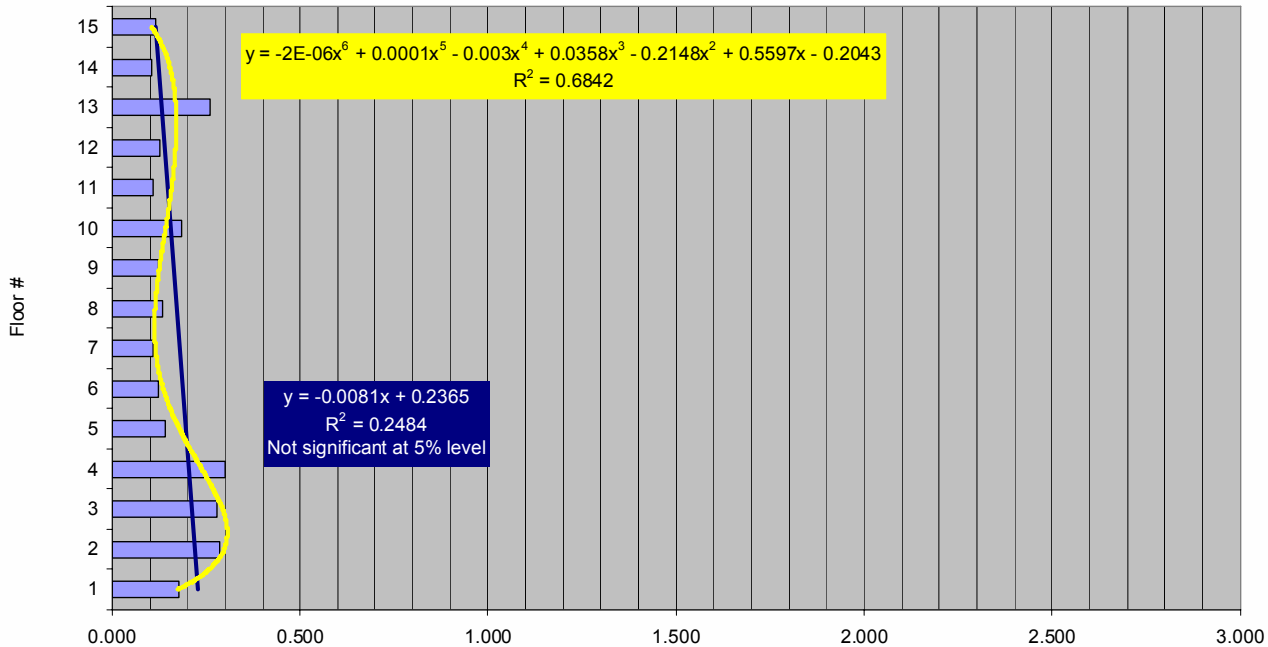
Building specifications

- Surrey
- 117 Suites, 15 levels
- Built 1994
- Estimated length from aerial view = 28 m
- Estimated width from aerial view = 25 m
- Estimated floor area = 700 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 1041126, Surrey; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
U-factor	0.178	0.287	0.277	0.301	0.140	0.122	0.108	0.136	0.123	0.184	0.110	0.126	0.262	0.103	0.115

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 182490, Surrey

Source: http://www.bing.com/maps

Building specifications

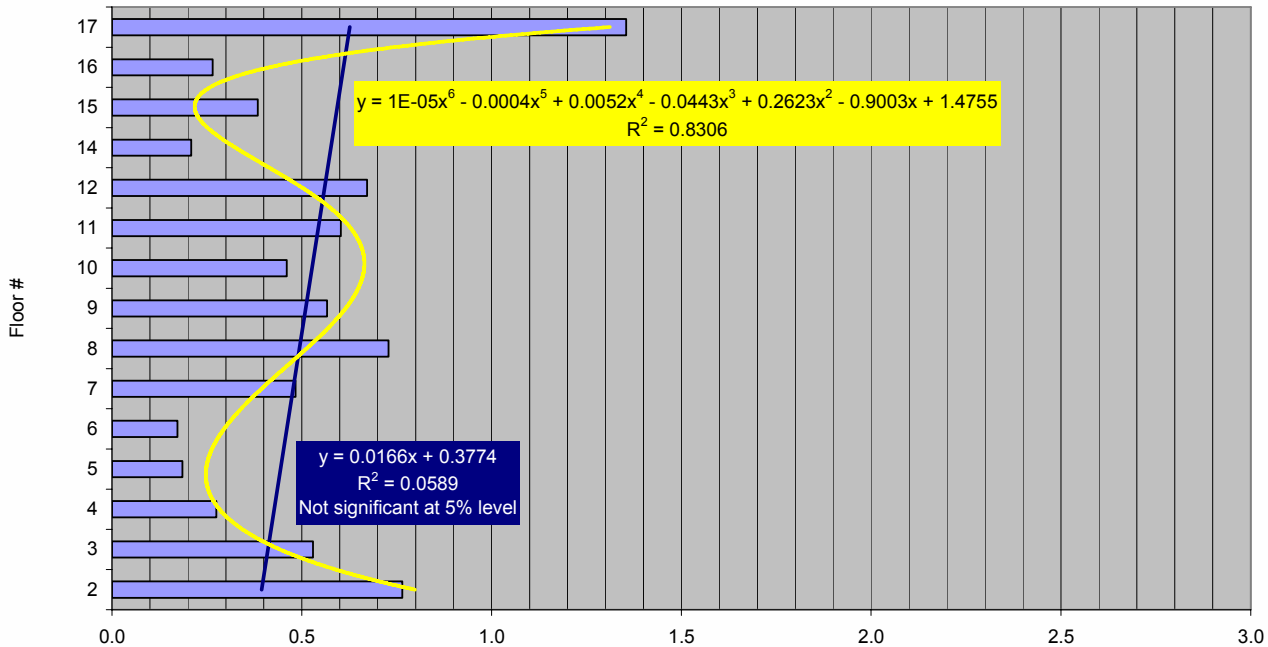
- Surrey
- 90 Suites, 15 levels
- Built 1990
- Estimated diameter from aerial view = 31 m
- Estimated floor area = 755 m^2

Source: http://www.bing.com/maps

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 182490, Surrey; Electric heat)



Floor	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factor	0.765	0.530	0.275	0.185	0.172	0.483	0.728	0.566	0.460	0.603	0.672	0.209	0.384	0.265	1.354

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 182622, Surrey

Source: http://www.bing.com/maps

Building specifications

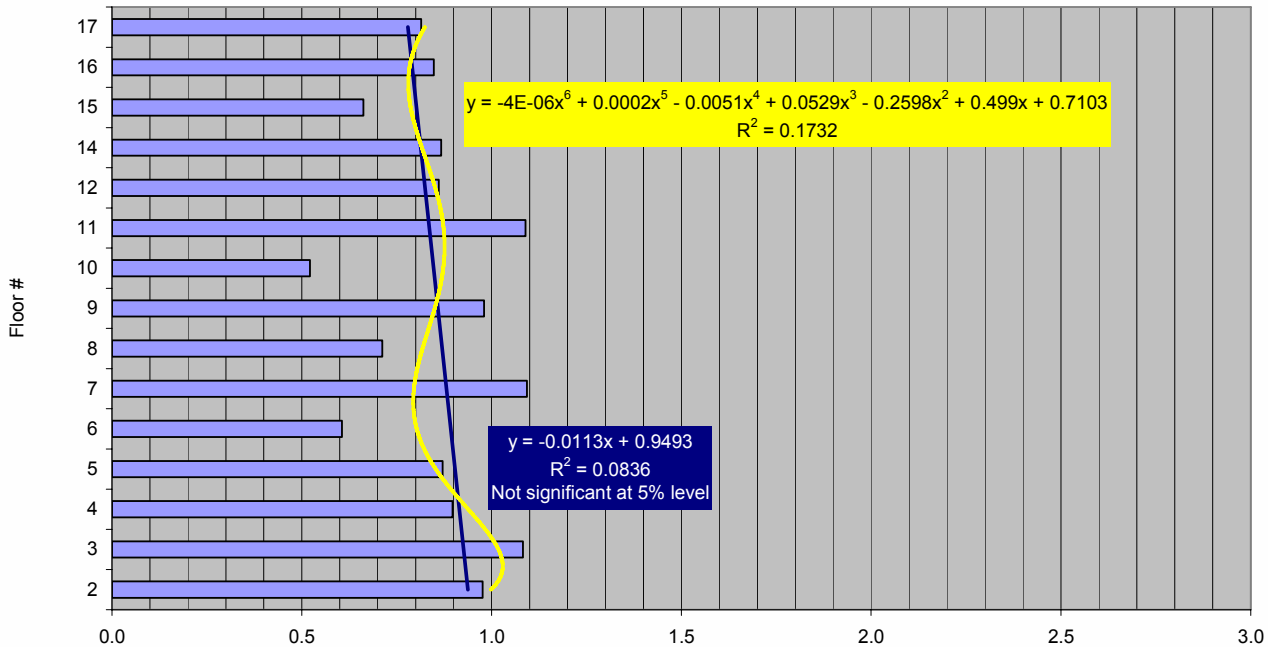
- Surrey
- 90 Suites, 15 levels
- Built 1990
- Estimated diameter from aerial view = 31 m
- Estimated floor area = 755 m^2

Source: http://www.bing.com/maps

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 182622, Surrey; Electric heat)



Floor	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factor	0.977	1.083	0.897	0.871	0.606	1.093	0.712	0.980	0.522	1.089	0.861	0.868	0.662	0.848	0.815

U-factor [W/(m^2 x K)]

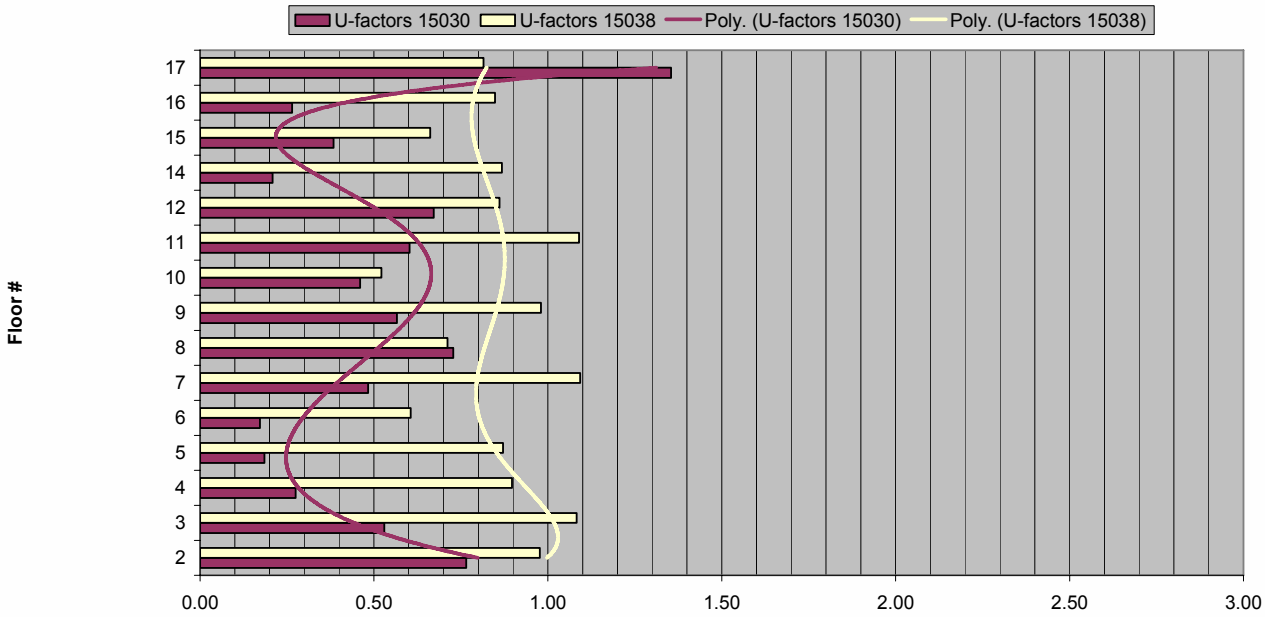
Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Comparison of Weather Sensitivities of Adjacent HB Buildings ID #s 182490 and 182622, Surrey



Floor	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factors 15038	0.98	1.08	0.90	0.87	0.61	1.09	0.71	0.98	0.52	1.09	0.86	0.87	0.66	0.85	0.81
U-factors 15030	0.76	0.53	0.27	0.19	0.17	0.48	0.73	0.57	0.46	0.60	0.67	0.21	0.38	0.26	1.35

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 134438, Surrey

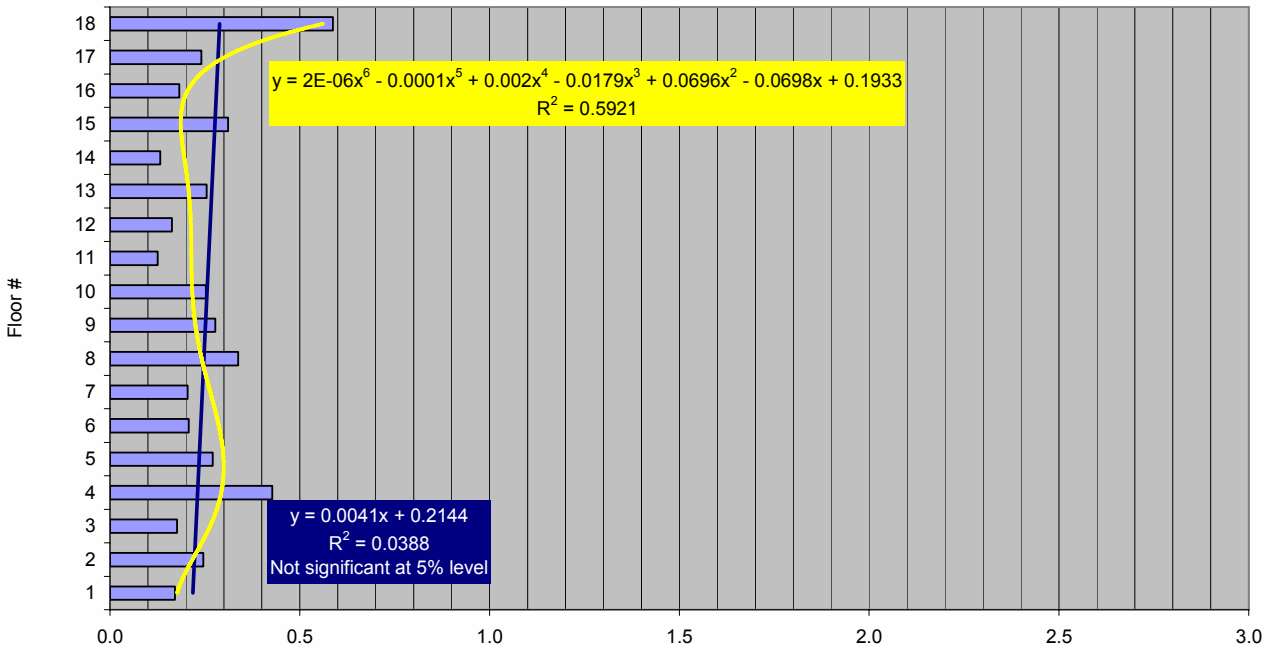
Source: http://www.bing.com/maps

Building specifications

- Surrey
- 127 Suites, 18 levels
- Built 1993
- Estimated length from aerial view = 23 m
- Estimated width from aerial view = 23 m
- Estimated floor area = 529 m^2

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 134438, Surrey; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
U-factor	0.171	0.246	0.176	0.428	0.270	0.207	0.204	0.338	0.277	0.252	0.126	0.163	0.255	0.132	0.311	0.182	0.241	0.587

U-factor [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 135428, Surrey

Source: http://www.bing.com/maps

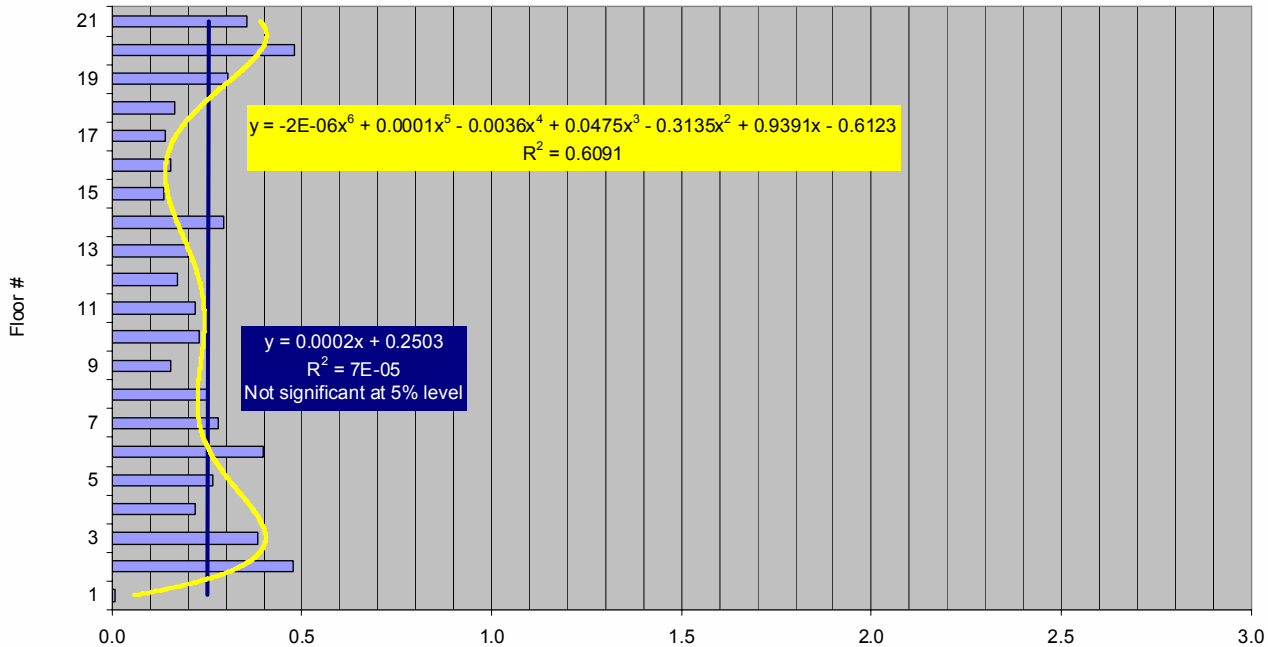
Building specifications

- Surrey
- 149 Suites, 21 levels
- Built 1993
- Estimated length from aerial view = 24 m
- Estimated width from aerial view = 24 m
- Estimated floor area = 576 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 135428, Surrey; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
U-factor	0.007	0.476	0.384	0.217	0.266	0.399	0.280	0.255	0.154	0.231	0.219	0.174	0.202	0.295	0.137	0.156	0.139	0.165	0.304	0.479	0.356

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 176403, Surrey

Source: http://www.bing.com/maps

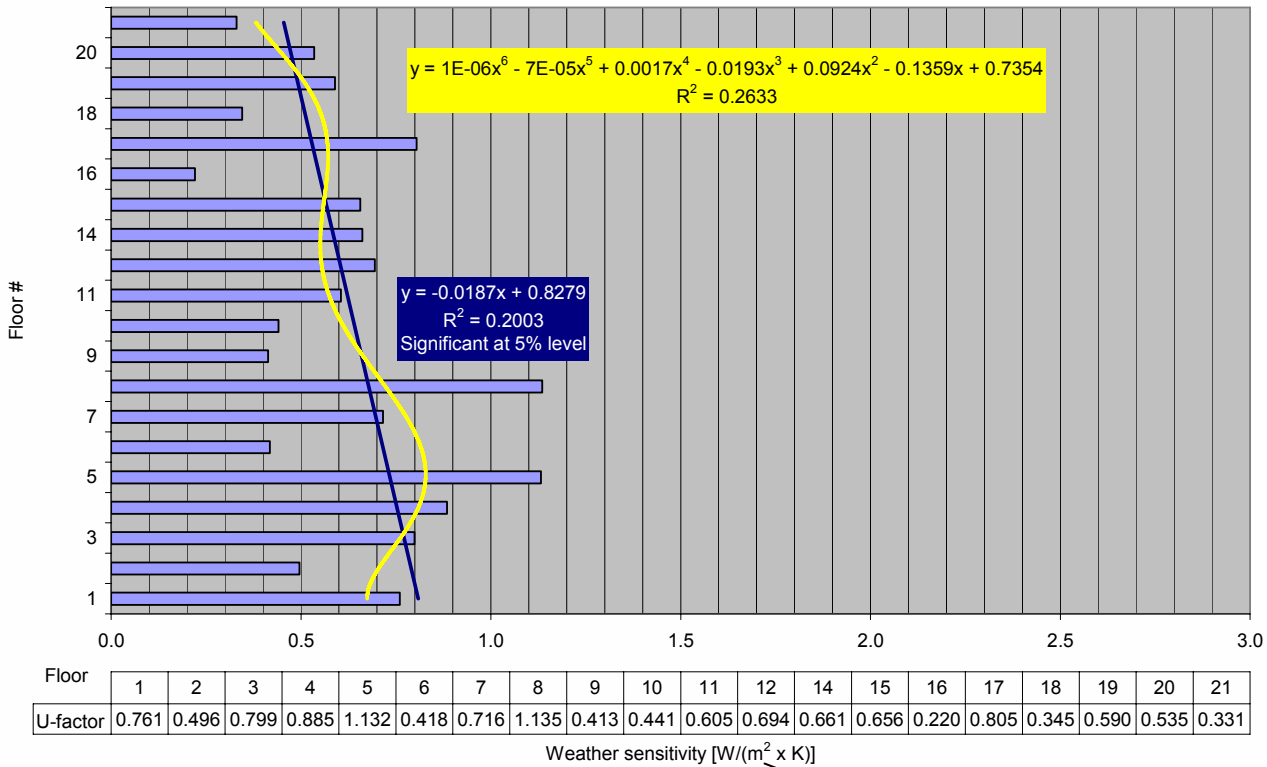
Building specifications

- Surrey
- 96 Suites, 20 levels
- Built 1994
- Estimated length from aerial view = 21 m
- Estimated width from aerial view = 18 m
- Estimated floor area = 378 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 176403, Surrey; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21
U-factor	0.761	0.496	0.799	0.885	1.132	0.418	0.716	1.135	0.413	0.441	0.605	0.694	0.661	0.656	0.220	0.805	0.345	0.590	0.535	0.331

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 3881, Surrey

Source: http://www.bing.com/maps

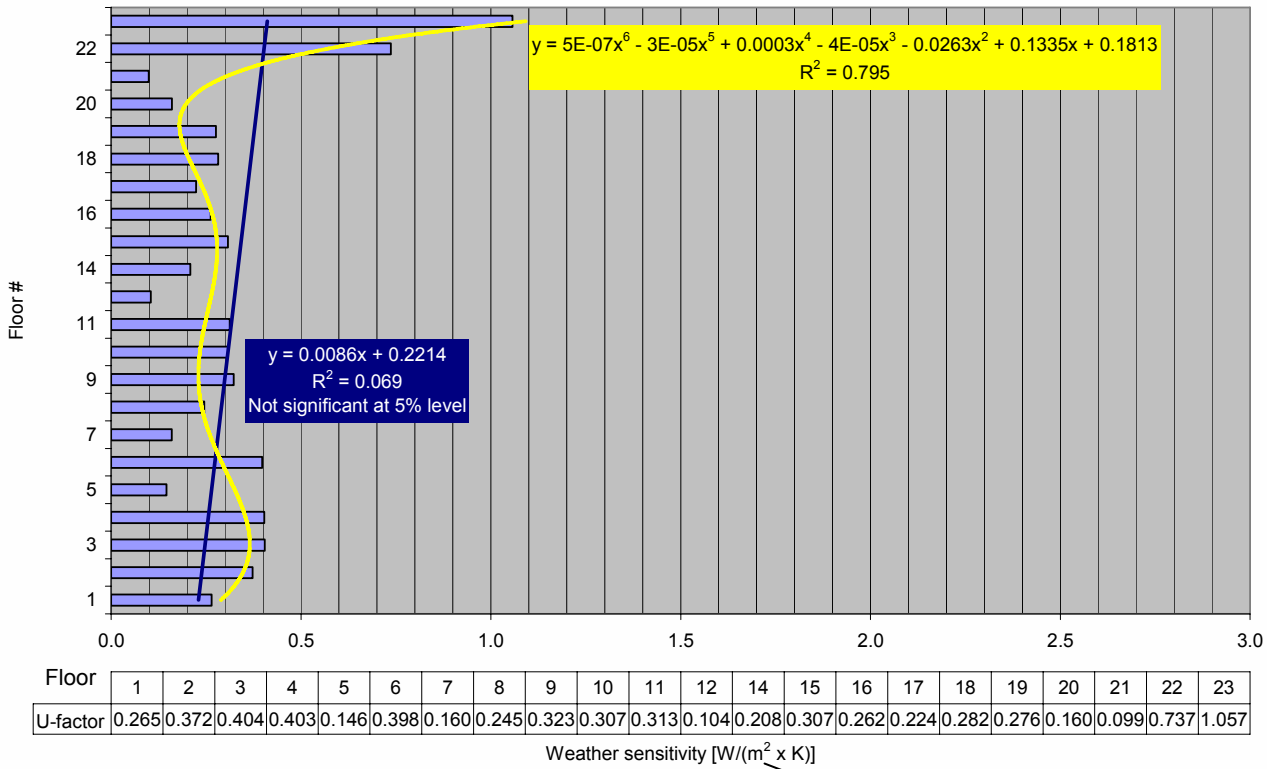
Building specifications

- Surrey
- 163 Suites, 22 levels
- Built 1992
- Estimated floor area from aerial view = 640 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 3881, Surrey; Electric heat)



Floor	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23
U-factor	0.265	0.372	0.404	0.403	0.146	0.398	0.160	0.245	0.323	0.307	0.313	0.104	0.208	0.307	0.262	0.224	0.282	0.276	0.160	0.099	0.737	1.057

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 813129, Richmond

Source: http://www.bing.com/maps

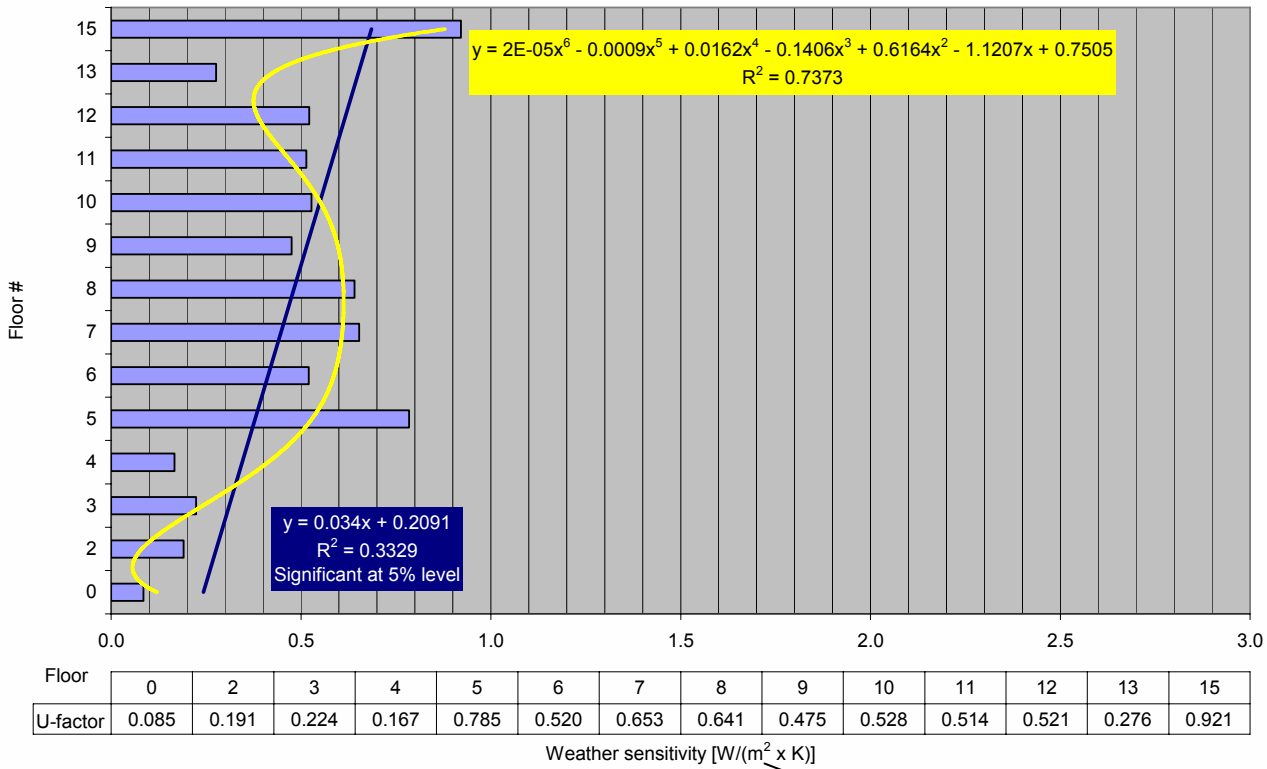
Building specifications

- Richmond
- 88 Suites, 14 levels
- Built 1996
- Estimated length from aerial view = 26 m
- Estimated width from aerial view = 24.5 m
- Estimated floor area = 637 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 813129, Richmond; Electric heat)



Floor	0	2	3	4	5	6	7	8	9	10	11	12	13	15
U-factor	0.085	0.191	0.224	0.167	0.785	0.520	0.653	0.641	0.475	0.528	0.514	0.521	0.276	0.921

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 798145, Richmond

Source: http://www.bing.com/maps

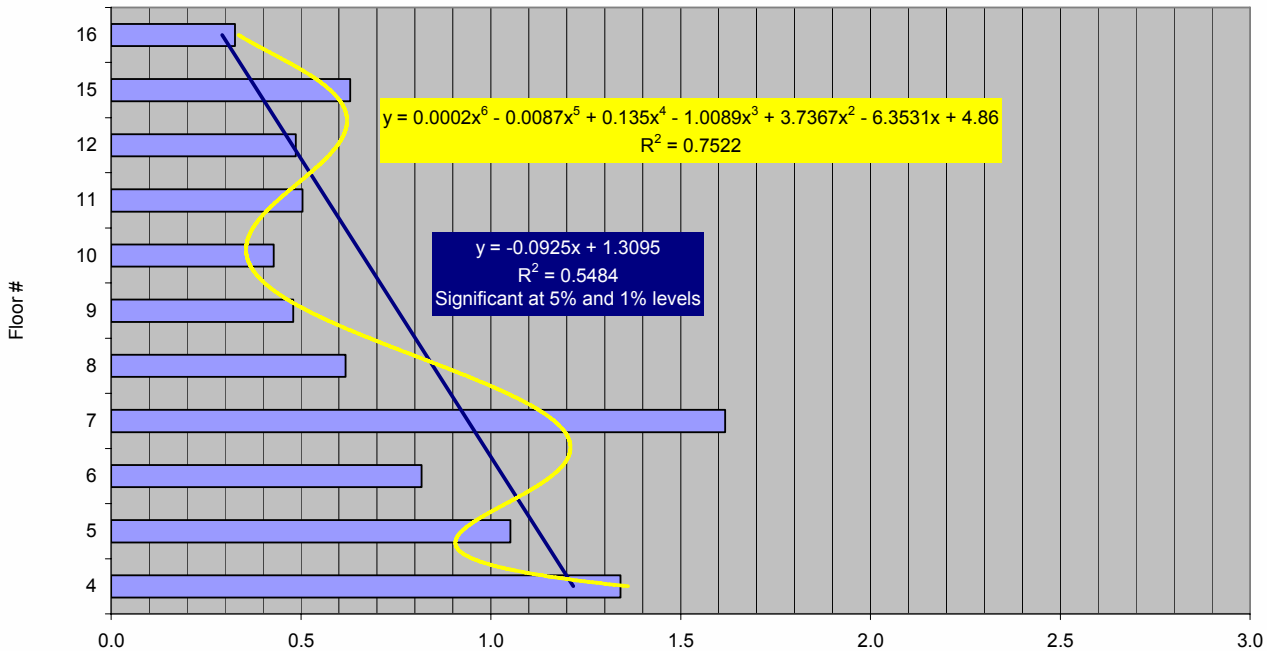
Building specifications

- Richmond
- 88 Suites, 11 levels
- Built 2003
- Estimated length from aerial view = 29 m
- Estimated width from aerial view = 22 m
- Estimated floor area = 638 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 798145, Richmond; Electric heat)



Floor	4	5	6	7	8	9	10	11	12	15	16
U-factor	1.342	1.052	0.818	1.617	0.617	0.480	0.428	0.504	0.487	0.630	0.327

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 991132, Richmond

Source: http://www.bing.com/maps

Building specifications

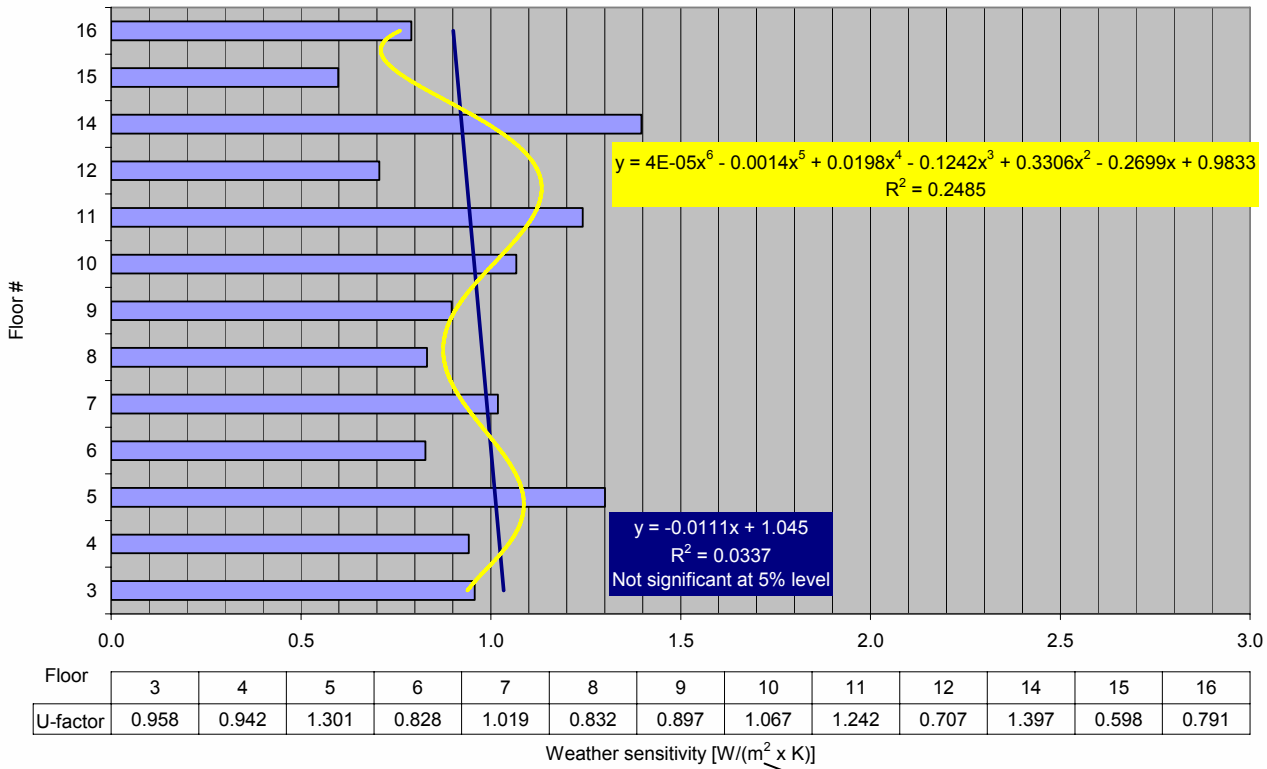
- Richmond
- 118 Suites, 13 levels
- Built 1995
- Estimated floor area from aerial view = 531 m^2

Source: http://www.bing.com/maps

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 991132, Richmond; Electric heat)



Floor	3	4	5	6	7	8	9	10	11	12	14	15	16
U-factor	0.958	0.942	1.301	0.828	1.019	0.832	0.897	1.067	1.242	0.707	1.397	0.598	0.791

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 992112, Richmond

Source: http://www.bing.com/maps

Building specifications

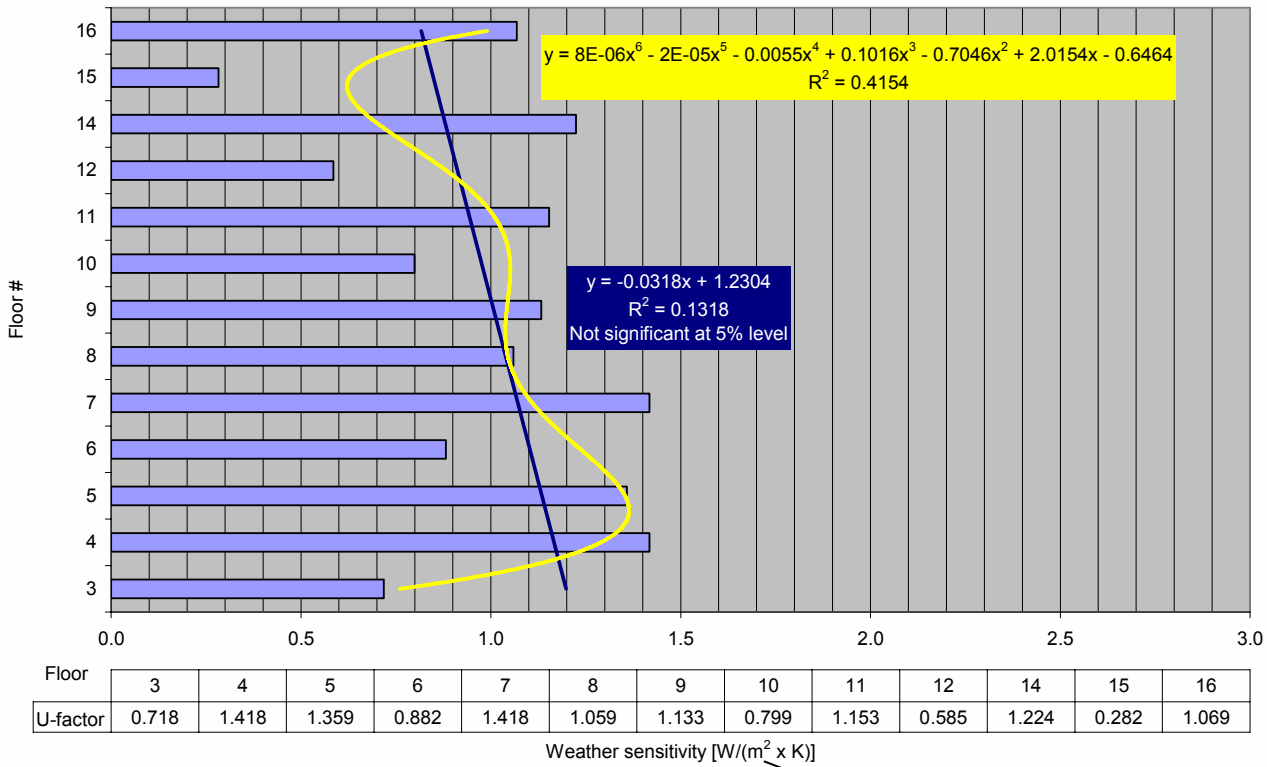
- Richmond
- 115 Suites, 13 levels
- Built 1995
- Estimated floor area from aerial view = 531 m^2

Source: http://www.bing.com/maps

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 992112, Richmond; Electric heat)



Floor	3	4	5	6	7	8	9	10	11	12	14	15	16
U-factor	0.718	1.418	1.359	0.882	1.418	1.059	1.133	0.799	1.153	0.585	1.224	0.282	1.069

Weather sensitivity [W/(m^2 x K)]

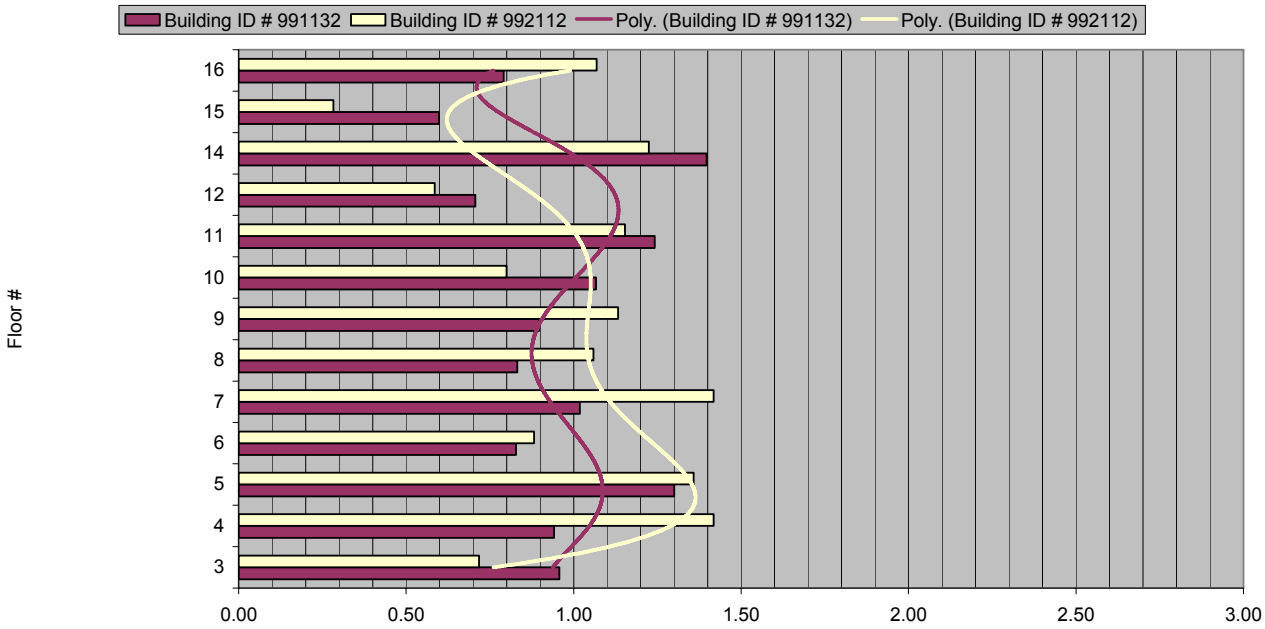
Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Weather sensitivity (U-factor) floor by floor comparison
between HB Building ID #s 991132 and 992112, Richmond



Floor #	3	4	5	6	7	8	9	10	11	12	14	15	16
Building ID # 992112	0.72	1.42	1.36	0.88	1.42	1.06	1.13	0.80	1.15	0.58	1.22	0.28	1.07
Building ID # 991132	0.96	0.94	1.30	0.83	1.02	0.83	0.90	1.07	1.24	0.71	1.40	0.60	0.79

Weather Sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro
FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 914626, Richmond

Source: http://www.bing.com/maps

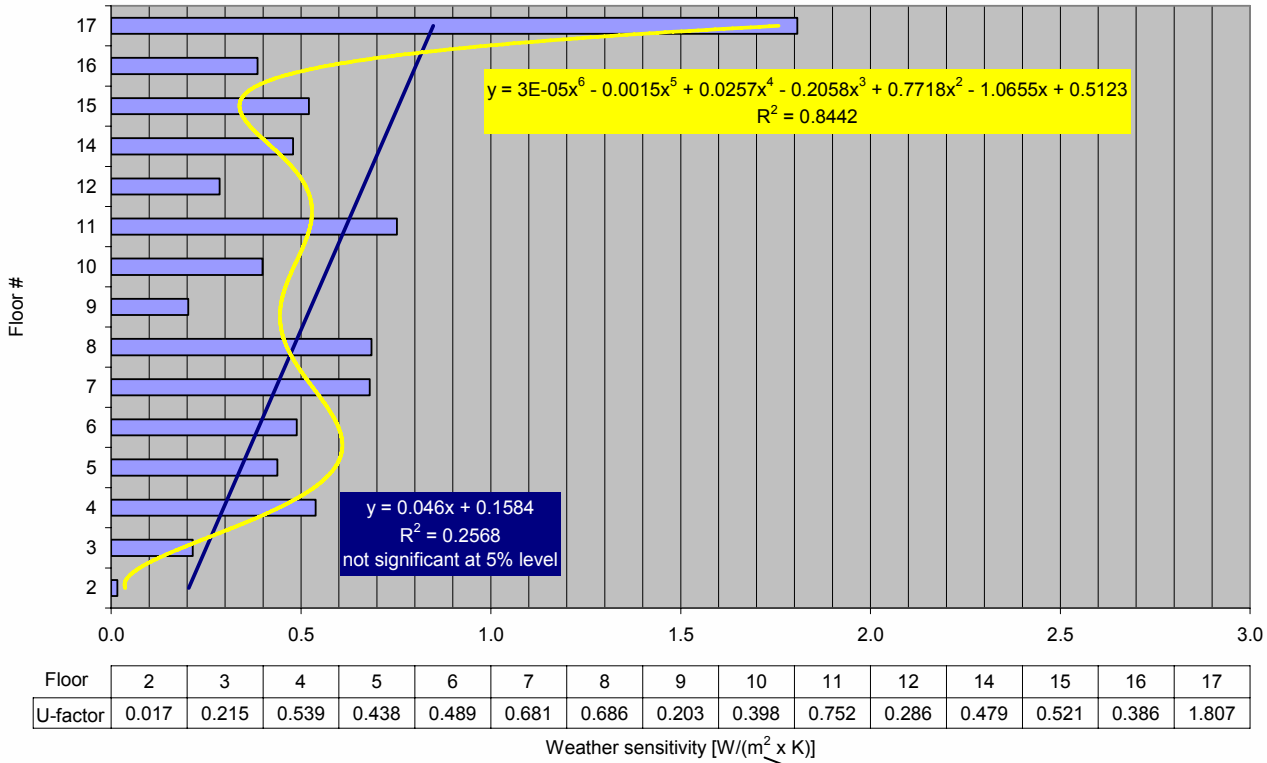
Building specifications

- Richmond
- 106 Suites, 15 levels
- Built 1992
- Estimated length from aerial view = 35 m
- Estimated width from aerial view = 20 m
- Estimated floor area = 700 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 914626, Richmond; Electric heat)



Floor	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
U-factor	0.017	0.215	0.539	0.438	0.489	0.681	0.686	0.203	0.398	0.752	0.286	0.479	0.521	0.386	1.807

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 950708, Richmond

Source: http://www.bing.com/maps

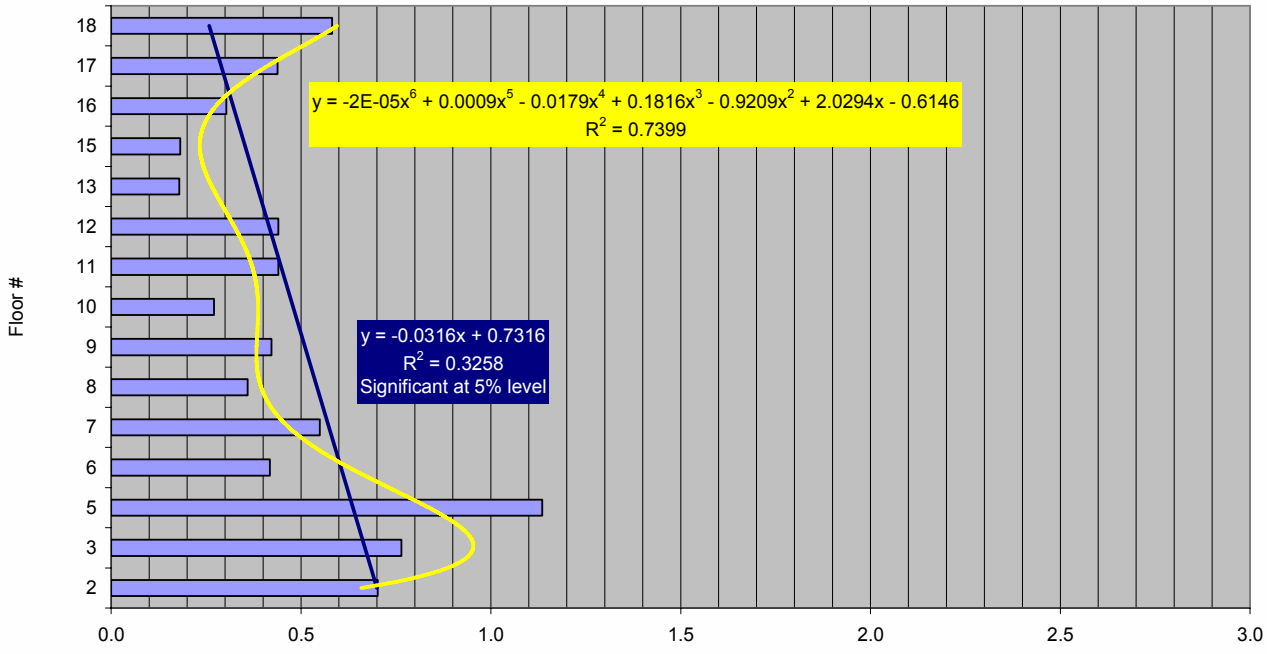
Building specifications

- Richmond
- 109 Suites, 14 levels
- Built 2003
- Estimated length from aerial view = 29 m
- Estimated width from aerial view = 26 m
- Estimated floor area = 754 m^2

BC hydro FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 950708, Richmond; Electric heat)



Floor	2	3	5	6	7	8	9	10	11	12	13	15	16	17	18
U-factor	0.702	0.765	1.135	0.418	0.549	0.360	0.422	0.271	0.440	0.440	0.180	0.182	0.303	0.438	0.582

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

BC hydro FOR GENERATIONS

Roland Wahlgren and Harinder Bains
BC Hydro Customer Information Management—Load Analysis

Electric Heat

Case Study: HB Building ID # 955635, Richmond

Source: http://www.bing.com/maps

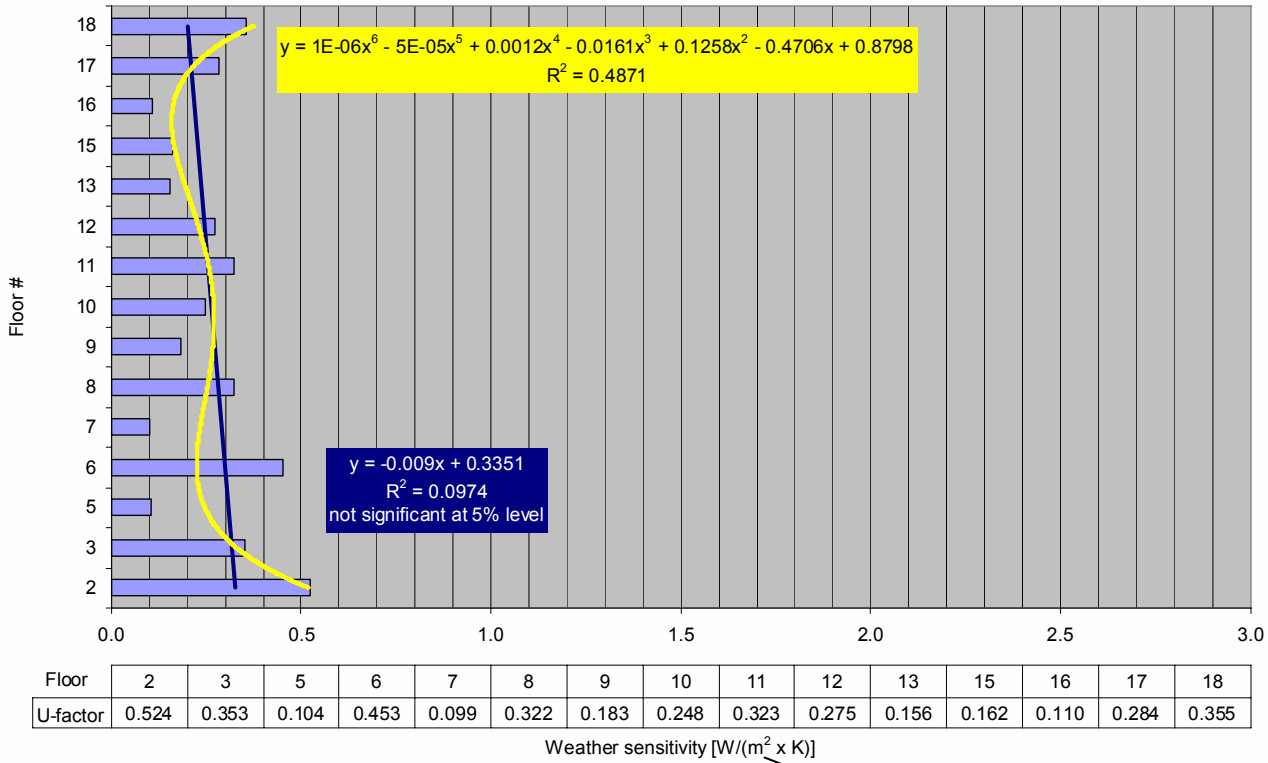
Building specifications

- Richmond
- 113 Suites, 15 levels
- Built 1999
- Estimated length from aerial view = 24 m
- Estimated width from aerial view = 21 m
- Estimated floor area = 504 m^2

BC hydro
FOR GENERATIONS

Electric Heat

Weather sensitivity (U-factor) by floor
(HB Building ID # 955635, Richmond; Electric heat)



Floor	2	3	5	6	7	8	9	10	11	12	13	15	16	17	18
U-factor	0.524	0.353	0.104	0.453	0.099	0.322	0.183	0.248	0.323	0.275	0.156	0.162	0.110	0.284	0.355

Weather sensitivity [W/(m^2 x K)]

Floor area basis; Multiply values by 2 to estimate U on a wall area basis

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Conclusions

High-Rise Residential Building Weather Sensitivity for British Columbia
Case Studies outside Vancouver and Burnaby

Important findings include:

- Weather-driven electrical energy consumption in a sample of 35 electrically heated residential high-rise buildings outside of Vancouver/Burnaby often is stable with height (69%), sometimes decreases with height (28%), or rarely increases with height (3%). We speculate that gas-heated common area temperatures may be driving these patterns. Instrumentation of individual buildings is needed to verify this conjecture;
- Analyses of weather sensitivity of electrical heating is confounded by natural gas heating of building common areas. This heat infiltrates suites that also have electrical baseboard heaters;
- When gas heating data is available for a building the relative proportions of gas and electric heating can be estimated, as can the efficiency of the gas heating system; and
- Missing gas data can be inferred if: (1) weather sensitivity of electric energy consumption is known and (2) a reasonable assumption is made about a building enclosure's thermal transmissivity. Rehabilitation of building enclosures for gas/electric buildings reduces the proportion of gas consumed but increases the proportion of electrical energy consumed. **This finding is relevant to the goal of reducing greenhouse gas emissions in BC.**

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