Carli, Inc.

18 Tanglewood Rd.
Amherst, MA 01002

TEL: (413) 256-4647
FAX: (413) 256-4823

carli@fenestration.com
http://www.fenestration.com

Project Report:

INVESTIGATION OF THE EFFECT OF FENESTRATION SYSTEMS ON THE ENERGY PERFORMANCE OF A TYPICAL COMMERCIAL BUILDING

Report submitted to:

Report submitted by:

Dr. Charlie Curcija, President

1. INTRODUCTION

Effect of fenestration systems on energy performance of a typical commercial building has been investigated in this study. It is the goal of this study to explore different options in modeling site built products and their effects on energy performance of the whole building. As the building simulation takes into account the interaction of different building components, occupancy, schedules, lighting, equipment and HVAC systems, it is pertinent to make use of these models for investigating the effect of different building components in general and frame and glazing systems in particular as in the present study.

In this study a detailed energy performance of a sample commercial office building has been simulated in order to investigate the effects of different fenestration options on the overall energy performance of a building. Besides the analysis of the energy performance of actual fenestration systems in a building, the effects of varying framing configurations, glazing configurations, spacer types on load and energy has also been investigated. The energy analysis of the building was also done for Washington, DC and Minneapolis, MN to investigate the effect of different climatic locations.

2. BUILDING DESCRIPTION

A typical photograph, floor plan, a typical elevation and a partial section of the building studied are given in Figs 1, 2 3 and 4. The building has 10 floors with gross area of approximately 194,000 ft^2. The building envelope consists of a typical curtain wall structure. It is a typical curtain wall structure building. The total glazing area of the windows is approximately 50,000 sq ft. with approximately 9% of frame area. Forty two different window configurations have been identified in the whole building. The representative location/type of different possible configurations at North elevation is shown in Figs 3. The figures also show different frame cross sections (e.g. CS2_A_17; CS represents the cross section) and glazing system used (e.g. GL-1A). A few representative details of cross sections are given in Appendix 1. The spandrel glass and matching stone have been used in details of building to match the exterior surface with the glazing system for aesthetics.

Fig.1 Photograph of the building

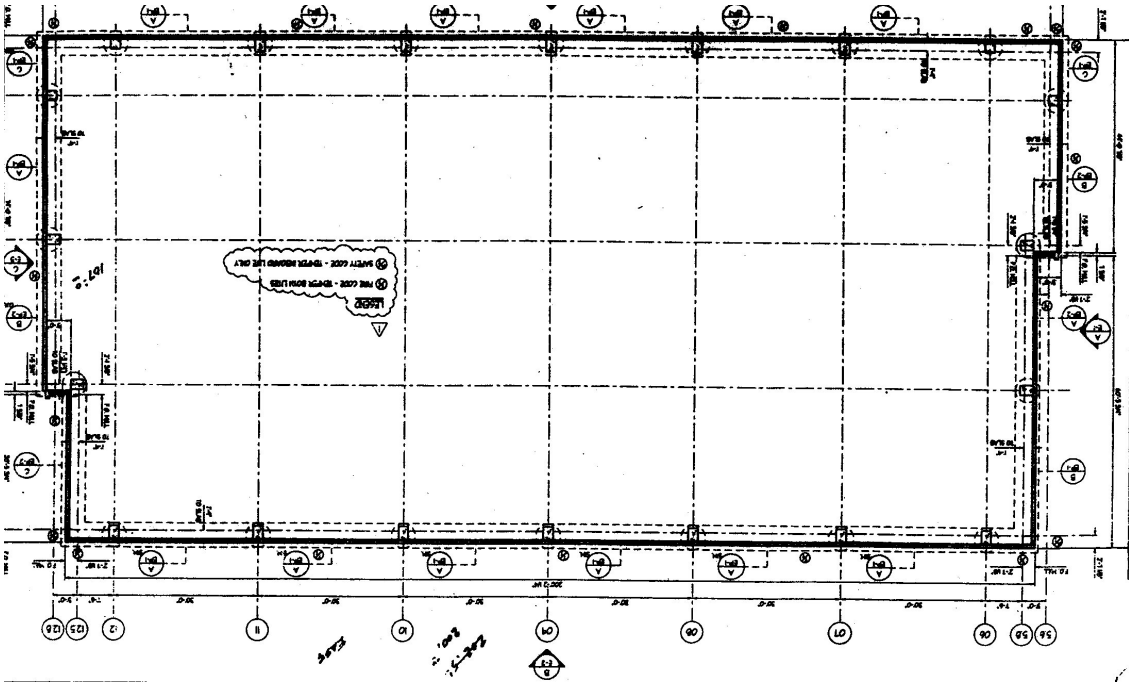


Fig. 2: A typical floor plan (2nd Floor)

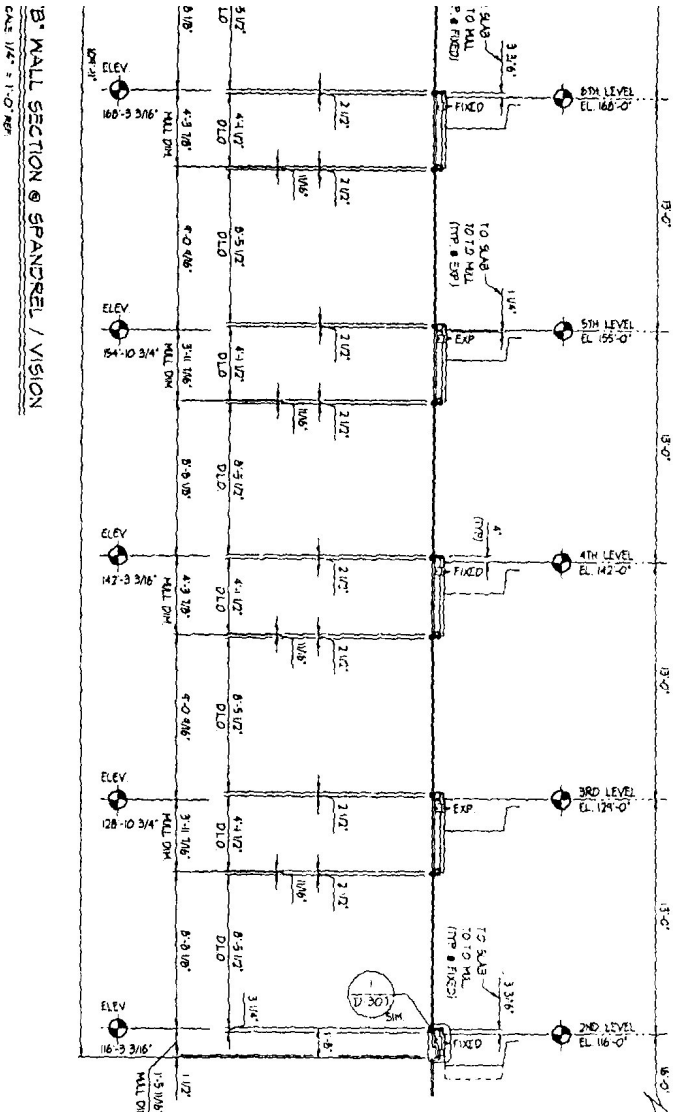


Fig 3: A typical wall Section

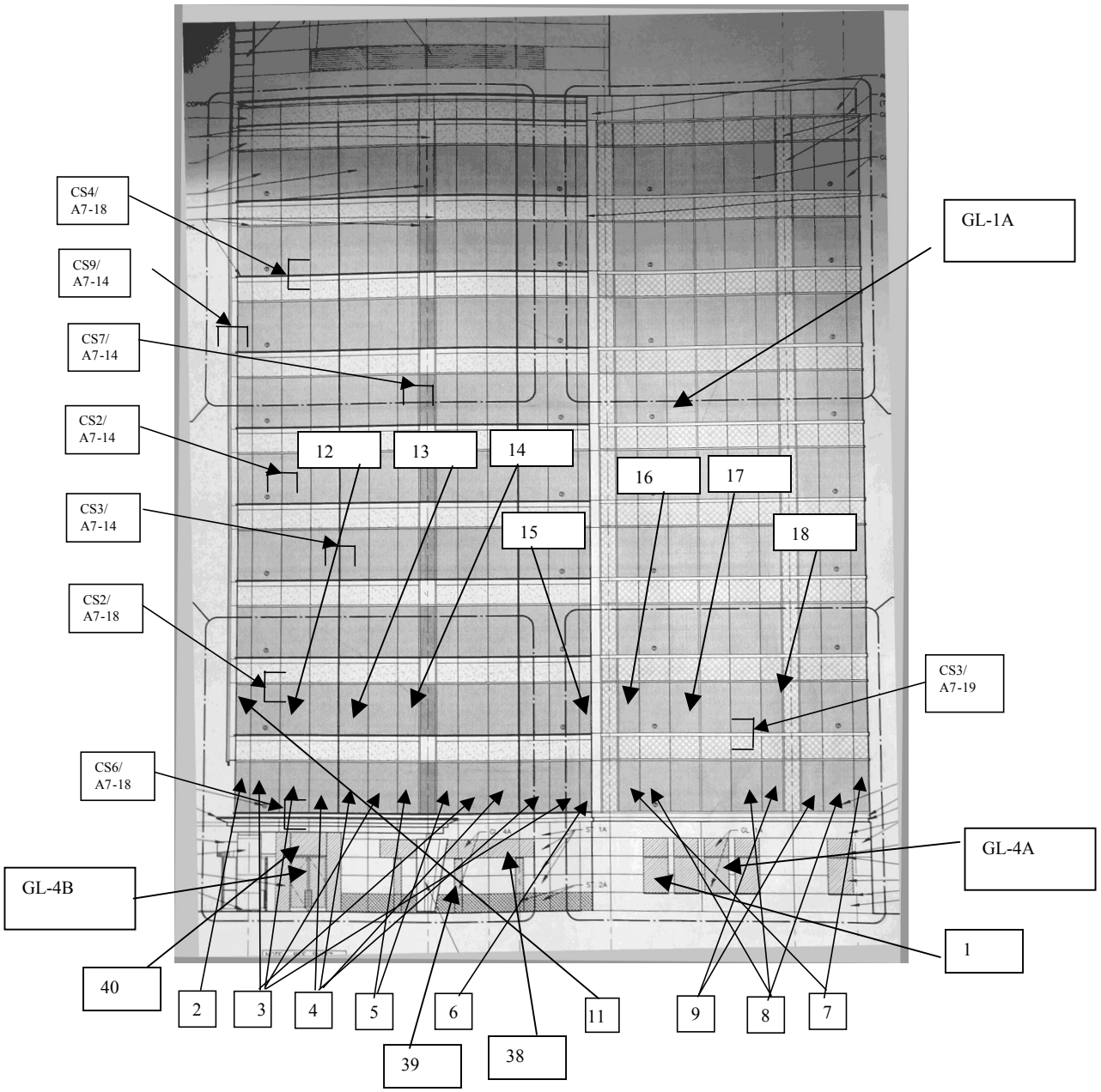


Fig 4: North Elevation showing the different window configurations

3. BUILDING SIMULATION

A detailed simulation of a commercial building has been carried out to investigate the effect of various type of framing system in a curtain wall type structure. DOE 2.2 based computer simulation tool incorporated into GUI based PowerDoe has been used in the study for carrying out building simulation. All the details of building geometry and HVAC systems have been obtained from the detailed architectural and mechanical details. The simulation has been carried out for base case building (i.e. the actual building as per actual architectural drawings) and for different fenestration options described later. For simulation purposes the building was divided into five zones in each floor. Some important parameters input to the building simulation model are listed as follows:

Construction

Stone Wall:	("Stone 1 1/4 in", "Batt R-11", "GypBd 1/2in"
Spandrel wall:	(Spandrel glass mat", "Air > 4in vert", "Batt R-11)
Columns:	(Stone 1 1/4 in", "Air < 3/4 in vert",
	"CMU 5/8 hollow", "Air < 4 in vert", "PC 1A Cement Mortar)", "Gypsum Board 5/8)
:	("PC 1A Cement Mortar (CM02)", "Air < 4 in vert",
	"PC 1A Cement Mortar (CM02)", "Batt R-11",
:	("Gypsum Spandrel glass mat", "Air < 4 in vert", "Batt R-11",
	"Air < 4 in vert", "PC 1A Cement Mortar ",
	"Gypsum Board 5/8 (GP02)"Board 5/8 (GP02)")
Roof:	"Built up roof", "Batt R-11","PC 1A Cement Mortar"
Floor:	"PC 1A Cement Mortar ", "Carpet & Fiber Pad"
Underground Floor:	("earth", "Conc HW 140lb 12in)

Miscellaneous:

Occupant Density:	160-190 sf/person
Lighting:	1.2 W/sq ft
Plug load:	0.75 W/sq ft
Ventilation:	15 CFM/person
Schedule:	US office (Typical)

Systems:

Cooling:	Rotary Screw Chillers
Heating:	Hot water boiler
Cooling Tower:	Open

Thermostat set points:

Cooling:	76
Heating:	70

The glazing systems have been created using WINDOW4. The description of glazing system used is given in Table 1.

Table 1: Description of glazing systems used in the building

Glazing	Description	U factor (Btu/hr-ft^2-F)	SHGC	VT
GL-1A	Coated insulated vision glass VA-1-22 with coating (e=0.528) at 2nd surface	0.43	0.24	0.20
GL-3A	Coated insulated vision glass Viracon 2/M super LowE, coating (e=0.04) on surface 2	0.29	0.30	0.60
GL-4A	Monolithic vision glass, clear, ¾" min thickness	0.99	0.81	0.88
GL-4B	Tempered monolithic vision glass, clear, ¾" min thickness	0.99	0.81	0.88

The detailed glazing properties including the angle dependent properties were incorporated into the PowerDoe library. Different curtain wall configurations have been modeled using THERM and WINDOW. A few modeled cross sections alongwith U factor are given in Appendix 2.

A detailed model of building has been created in PowerDoe. 3D view of the building in PowerDoe has been shown in Fig. 4. As floors 3 to 9 are identical, therefore for the simulation purposes only one floor has been shown for these floors and the multiplier was used to calculate the thermal performance of the rest of the identical floor. As the major goal of this study is to investigate the effect of fenestration energy performance on overall peak load and energy of the building, the detailed modeling of major framing systems using THERM and WINDOW programs have been carried out. The area of different glazing systems and frame areas have been calculated based on the architectural drawings of the building and based on different configurations. The area distribution is given in Appendix 2 . The output in terms of U factor, SHGC and VT from these programs serves as an input to PowerDoe.

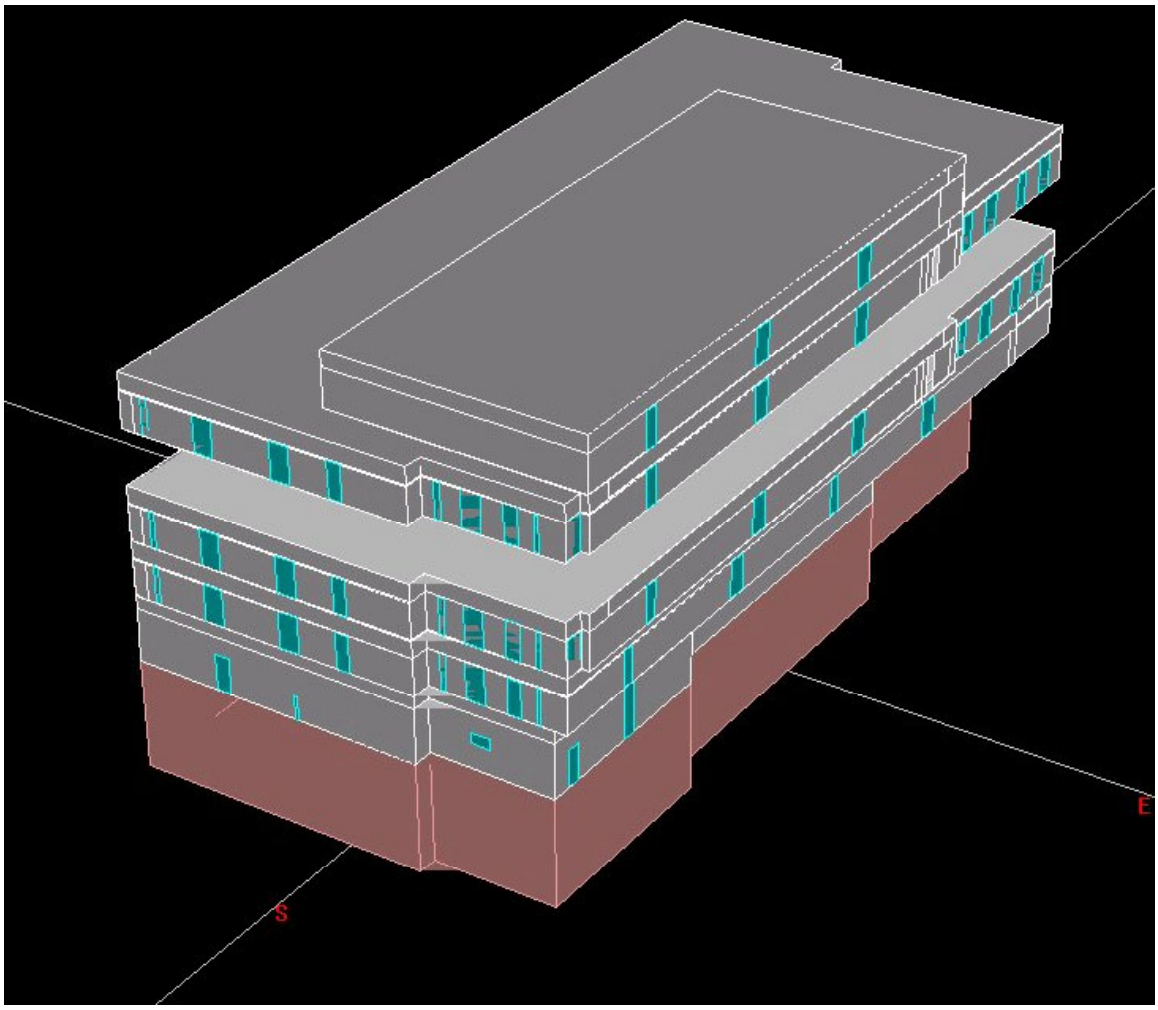


Fig 4: 3D model of the building created in PowerDoe

As the building consists of different curtain wall configurations, different configurations have been modeled using THERM2.1a and Window4 programs. Appendix 2 shows the cross sections modeled in THERM 2.1a. The CS prefix used to represent the cross sections in the building has been removed to represent the cross sections modeled in THERM.

The window dimensions and glazing systems were used as per the architectural drawings. The program takes into account the actual size of the fenestration products. As PowerDoe requires glazing and frame conductance individually as the inputs, the calculations of overall fenestration system U factor by Window program may not be required. The base case model was prepared using the detailed curtain wall configurations. To see the effect of different framing structures, two extreme cases of framing U factor (i.e. thermally very good frame and very bad frame) have also been considered for the building load and energy calculations.

Table 2 shows the contribution in space cooling and heating loads and energy by different building components.

Table 2: Load and energy distribution by major building components for actual building

Components	Peak Load (actual building) (kBtu/h)		Energy (actual building) (kBtu/h)	
	Cooling	Heating	Cooling	Heating
Window glass + frame conductance	1142.011	-1068.406	1728.459	-1116.322
Window solar	477.351	36.761	1622.656	191.264
Walls+roof conduction	48.478	-75.978	100.986	-70.969
Occupant	311.953	17.169	822.531	76.250
Lighting	427.896	63.044	1348.300	192.003
Equipment	229.123	38.374	730.125	106.184
Infiltration	29.294	-63.098	22.337	-66.424
Misc.	33.811	-75.308	0.569	-266.463
Latent (occupant and infiltration)	195.657		485.796	
Total	2895.575	38.374	6375.964	-954.478

It is evident from Table 2 that the windows contribute significantly to the peak load and energy. In this case; with the low SHGC glazing windows constitute 55.92% of the cooling load of the building while its contribution to cooling energy is 52.55%. It is clear from the table that the frame and window glass conduction has a major share in the window contribution, which is 70.52% and 52.12% respectively in case of cooling load and cooling energy.

For the case where the actual glazing system of the building is replaced by double clear gazing system (U=0.57 Btu/hr.ft^2.F, SHGC=0.76, VT=0.81) the overall cooling load and energy are 4379.807 kBtu/h and 11119.847 MBtu respectively. The contribution of window glass plus frame conduction is 1089.252 while solar contribution is 2010.642 kBtu/h while their contribution in energy is 835.331 and 7206.186 MBtu respectively. These results show that the window contribution in overall load and energy could be as high as 70.76% and 72.32% respectively. In this case the share of frame and window glass conduction when compared to overall window energy contribution is 35.14% in cooling load and only 10.39% in energy.

The space heating and cooling load and annual energy is given in Table 3. The different U factors indicate that the all the framing systems are being replaced with a particular type of framing system (denoted by U factor). In modern offices the lighting, occupancy and plug load also constitute a large portion of cooling load and energy. As this study is mainly concentrated

on the investigation of fenestration products, it will also be desirable to compare the performance of different framing configurations vis-à-vis the performance of windows only. Therefore, load or energy of window only contribution is also given in Table in the parenthesis. The percentage difference (% Diff) in the table are based on the window energy use only.

The results of cooling and heating load along with the energy are shown in Figs 5 and 6. Monthly electricity and gas consumption by end-use is given in Fig. 7. For the sake of clarity the figures for all other cases are given in Appendix 3.

Table 3: Effect of frame U value on building load and energy for the building located in Dallas, Texas

U factor of frame (Btu/hr.ft^2.F)		**Building Peak Load (kBtu/hr)**				**Building Energy MBtu**			
		Cooling	% Diff	Heating	% Diff	Cooling	% Diff	Heating	% Diff
Actual		2895.57 (1619.36)		1127.44 (1031.64)		6375.96 (3351.12)		954.48 (925.06)	
0.5	Total	2776.71 (1500.49)		1019.81 (924.02)		6180.35 (3129.60)		840.60 (785.28)	
	Diff.	118.86	7.34	107.62	10.43	195.61	6.61	113.88	15.11
2.0	Total	3052.12 (1772.20)		1264.11 (1194.92)		6599.68 (3603.28)		1082.49 (1081.49)	
	Diff.	-156.54	-9.43	-136.67	-15.83	-223.72	-7.52	-128.01	-16.91

Note: Values in parenthesis show the window only contribution and % Diff. is based on the window only contribution

Table 3 shows that the maximum cooling load difference (window contribution only) between the actual case and worse case scenario in this study (U = 2.0 Btu/hr.ft^2.F) is 156.54 Btu/h i.e. 9.43% while the energy difference is 223.72 MBtu i.e. 7.52%. Assuming a simple kWh rate of $0.07/kWh, the saving could be translated into $4588.50. The percentage difference calculated in comparison to overall energy for actual and worse case comes out to be 5.4% and 3.5 % respectively for load and energy. When two extreme cases (i.e. U = 0.5 and U=2.0 Btu/hr.ft^2.F) are compared among themselves, the window only contribution difference in cooling load is 271.71 kBtu/hr i.e. 18.1% while energy differs by 473.68 MBtu 15.13%. For these extreme cases the difference for the whole building comes out to be 9.90% and 6.78% respectively for cooling load and energy.

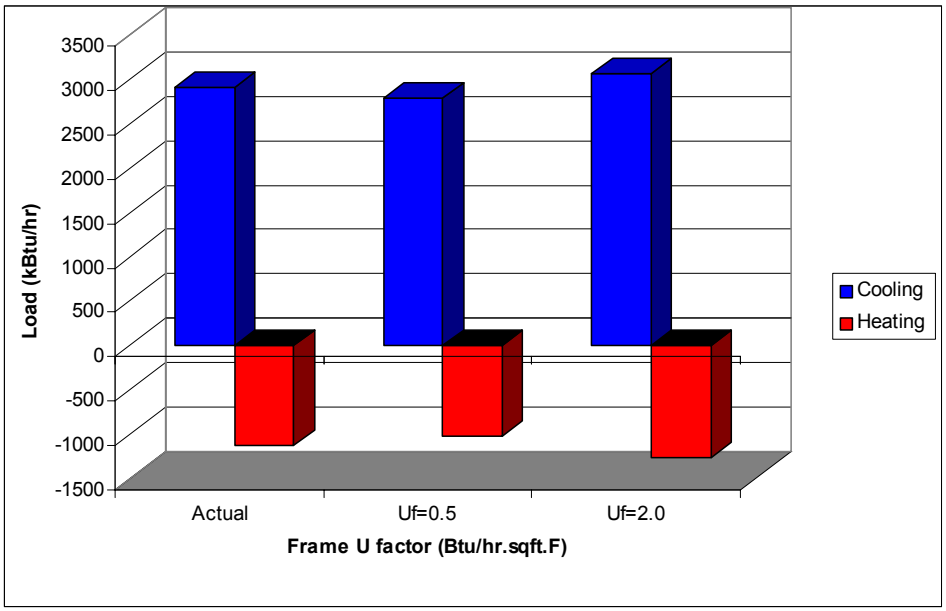


Fig 5: Cooling and heating load (kBtu/h) for actual building

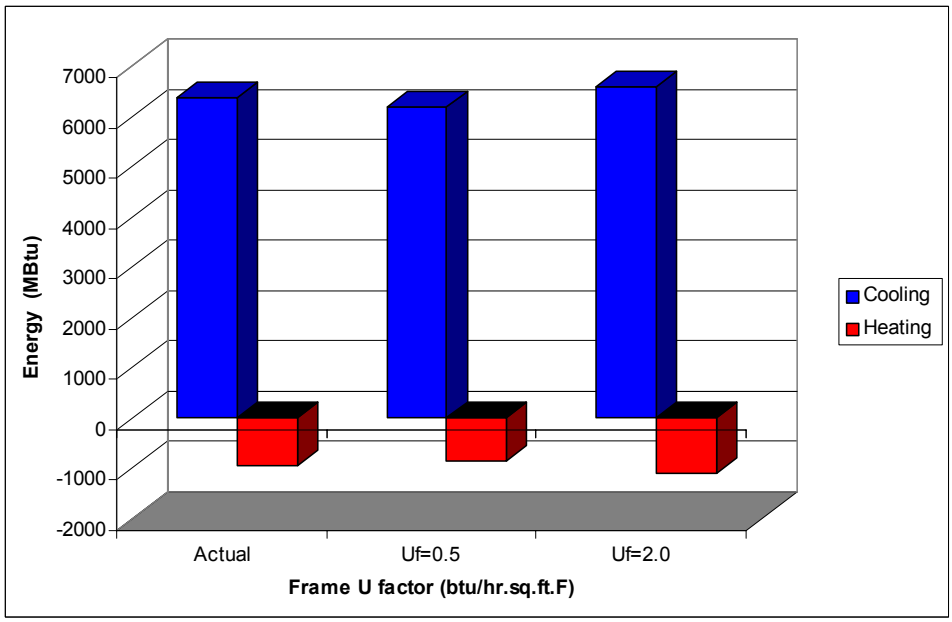
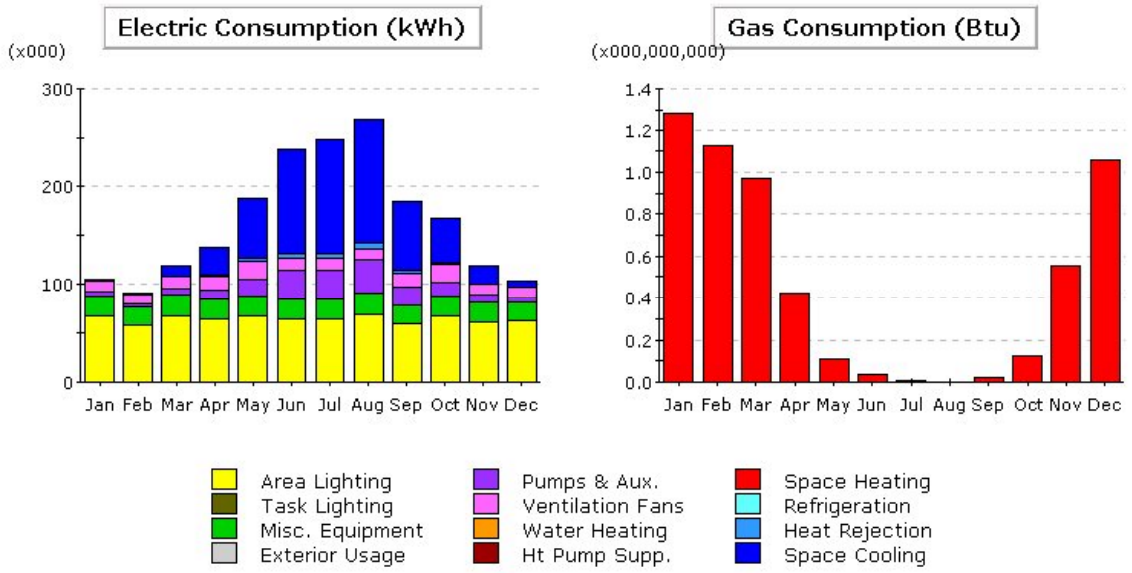


Fig 6: Cooling and heating energy (kBtu/h) for actual building



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.2	0.6	12.0	29.0	62.1	107.4	116.8	126.7	70.0	46.8	18.4	5.2	596.1
Heat Reject.	0.0	0.0	0.3	0.9	2.1	4.5	5.0	5.5	2.5	1.4	0.5	0.1	22.8
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.2	9.8	12.1	14.2	19.5	12.6	12.0	12.1	15.4	18.4	11.3	10.7	159.4
Pumps & Aux.	3.7	3.2	6.6	9.7	16.8	28.7	29.6	33.6	17.9	13.6	7.7	4.4	175.4
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	103.9	90.3	119.3	137.9	188.2	237.9	248.0	268.9	184.0	167.9	118.7	102.4	1,967.5

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.28	1.13	0.97	0.42	0.11	0.04	0.01	-	0.02	0.13	0.56	1.06	5.72
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.28	1.13	0.97	0.42	0.11	0.04	0.01	-	0.02	0.13	0.56	1.06	5.72

Fig 7: Monthly energy consumption by end use for actual building at Dallas, TX

3.1 Effect of glazing systems

Besides the framing system the variation for different glazing types have also been considered. Two extreme glazing system have been considered are double clear glazing (U=0.57 Btu/hr.ft^{2}F, SC=0.76) and double glazing with lowE coating (e2=0.04, tint, SHGC=0.28 and U=0.233 Btu/hr.ft^{2}F) Again, it was assumed that a particular type of glazing replaced the glazing system of whole building. Heating and cooling loads and energy for different glazing option is given in Table 4.

Table 4: Load and energy of the building for various glazing options

U factor of frame (Btu/hr.ft^2.F)		**Building Peak Load (kBtu/hr)**				**Building Energy MBtu**			
		Cooling	% Diff	Heating	% Diff	Cooling	% Diff	Heating	% Diff
Actual		2895.57 (1619.36)		1127.44 (1031.64)		6375.96 (3351.11)		954.48 (925.06)	
Double clear	Total	4379.81 (3099.89)		1285.749 (1216.55)		11119.47 (8041.52)		810.49 (727.97)	
	Diff.	-1484.2	-91.43	-158.31	-17.92	-4743.51	-139.97	143.99	21.31
Double LowE	Total	2660.64 (1380.73)		775.08 (676.21)		6300.08 (3173.58)		589.277 (458.98)	
	Diff.	234.93	14.74	352.36	34.45	75.88	5.30	365.20	50.38

Note: Values in parenthesis show the window only contribution and % Diff. is based on the window only contribution

It is evident from the Table 4 that selection of glazing system has major impact on load and energy.

3.2 Effect of spacers

Effect of different spacer type was also analyzed alongwith the actual Aluminum spacer used in the frames. The heating and cooling load and energy are given in Table 5 for three cases of spacer types generally used.

Table 5: Effect of spacers in the overall load and energy of the building

U factor of frame (Btu/hr.ft^2.F)		Building Peak Load (kBtu/hr)				Building Energy MBtu			
		Cooling	% Diff	Heating	% Diff	Cooling	% Diff	Heating	% Diff
Actual (Al spacer)		2895.57 (1619.36)		1127.44 (1031.64)		6375.96 (3351.11)		954.48 (925.06)	
Steel	Total	2890.07 (1613.86)		1110.649 (1014.85)		6379.08 (3350.60)		937.61 (904.56)	
	Diff.	5.50	0.34	16.79	1.63	-3.12	0.02	16.87	2.22
Insulated	Total	2879.83 (1603.52)		1082.14 (986.33)		6382.80 (3347.05)		907.812 (867.42)	
	Diff.	15.74	0.98	45.3	4.39	-6.84	0.12	46.67	6.23

Note: Values in parenthesis show the window only contribution and % Diff. is based on the window only contribution

It is clear from the Table 5 that the spacer does not affect total load and energy significantly. This was expected as in metal frames the edge of glass and frame U factors varies little with the type of spacers because there is a significant heat flow through the highly conductive frame near the edge of glass area.

3.3 Effect of considering Center of glazing U factor for framing

Table 6 shows the results for taking the frame U factor as Center of glazing U factor.

Table 6: Effect of considering Center of glass U factor for the frames in the overall load and energy of the building

U factor of frame (Btu/hr.ft^2.F)		Building Peak Load (kBtu/hr)				Building Energy MBtu			
		Cooling	% Diff	Heating	% Diff	Cooling	% Diff	Heating	% Diff
Actual		2895.57 (1619.36)		1127.44 (1031.64)		6375.96 (3351.11)		954.48 (925.06)	
Uf= Ucog	Total	2757.77 (1481.56)		1004.21 (905.69)		6151.12 (3094.84)		824.47 (763.59)	
	Diff.	137.80	8.51	123.23	12.21	224.84	7.65	130.01	17.46

Note: Values in parenthesis show the window only contribution and % Diff. is based on the window only contribution

It is evident from Table 6 that taking Center of glazing U factor for the framing system could underestimate the peak load and overall energy.

3.4 Different climatic locations

The analysis has also been extended for two other climatic conditions. Minneapolis is chosen as a representative of heating dominated climate and Washington, DC represents the mixed climate. The results of for these locations have been given in Table 6 and 7 respectively.

Table 6: Effect of frame U value on building load and energy for the building located in Minneapolis, MN

U factor of frame (Btu/hr.ft^2.F)		Building Peak Load (kBtu/hr)				Building Energy MBtu			
		Cooling	% Diff	Heating	% Diff	Cooling	% Diff	Heating	% Diff
Actual		2668.34 (1532.96)		2535.18 (1997.63)		3569.47 (1564.30)		4497.23 (3717.97)	
0.5	Total	2556.83 (1421.45)		2326.10 (1788.55)		3515.05 (1436.49)		4065.59 (3212.93)	
	Diff.	111.51	7.27	209.08	10.47	54.42	8.17	431.64	13.58
0.2	Total	2785.19 (1649.81)		2761.81 (2224.60)		3642.87 (1709.52)		4987.93 (4280.48)	
	Diff.	-116.85	-7.62	-226.63	-11.326	-73.40	-9.28	-490.70	-15.13

Note: Values in parenthesis show the window only contribution and % Diff. is based on the window only contribution

Table 7: Effect of frame U value on building load and energy for the building located in Washington, DC

U factor of frame (Btu/hr.ft^2.F)		Building Peak Load (kBtu/hr)				Building Energy MBtu			
		Cooling	% Diff	Heating	% Diff	Cooling	% Diff	Heating	% Diff
Actual		2820.50 (1561.20)		1685.17 (1398.41)		4284.49 (1827.44)		2291.38 (1956.82)	
0.5	Total	2700.46 (1441.16)		1522.46 (1235.71)		4211.46 (1703.35)		2065.78 (1680.16)	
	Diff.	120.04	7.69	162.71	11.63	73.03	6.79	225.60	14.14
2.0	Total	2947.78 (1688.68)		1877.78 (1591.02)		4372.14 (1971.41)		2539.66 (2261.43)	
	Diff.	-127.28	-8.17	-192.61	-13.77	-87.65	-7.88	-248.28	-15.57

Note: Values in parenthesis show the window only contribution and % Diff. is based on the window only contribution

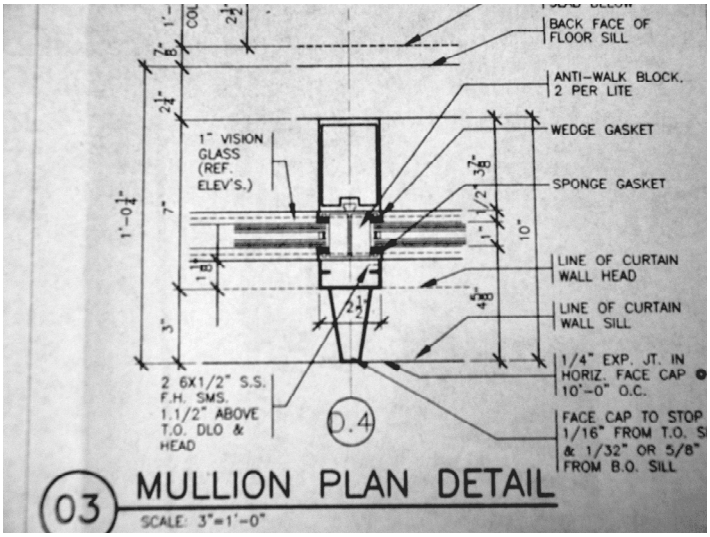
4. CONCLUSIONS

In a commercial building the number of different curtain wall configuration could be quite large. The simulation runs provided for various cases show that glazing system is a major contributor of load and energy in the building. The contribution of windows in cooling energy in this case study could be as high as 53%. The simulation run for various framing systems for the base case building (i.e. the actual building as per architectural drawings) shows that the variation of cooling energy from the base case (which takes into account the actual framing configuration) to any other systems (assuming that the configurations are replaced by an extreme framing system type i.e by assuming that the thermal performance of all the framing configuration is either very good and or is very bad) can be as high as 223.72 MBTU (i.e. 7.52%) if the comparison is made in respect to window energy only (Table 5). As the contribution of frames to cooling energy seems quite significant, this study indicates that it is necessary to do the detailed modeling of framing systems.

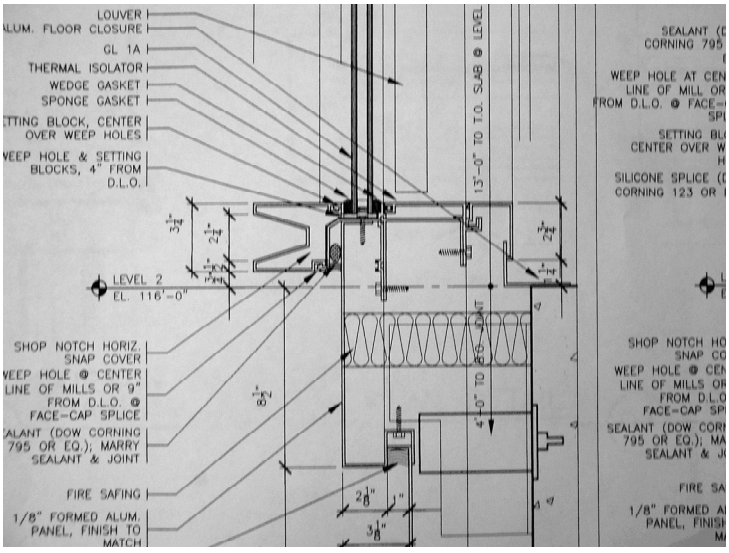
Using the Center of glazing U factor as representative of the whole window, tend to underestimate the energy (Table 11). In the present study the energy is lower than the best case of framing system scenario considered.

APPENDIX 1

Example Curtain wall configurations



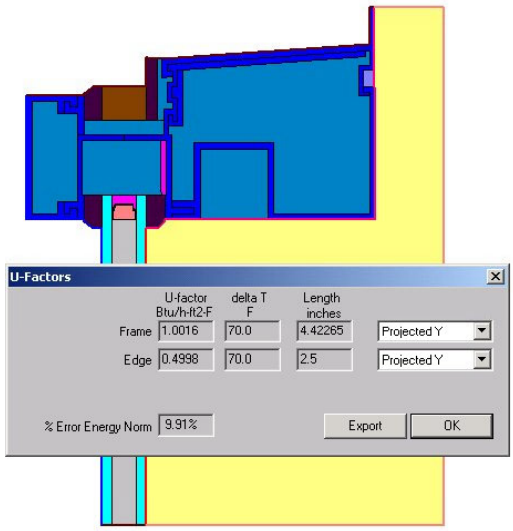
CS3/A7-14



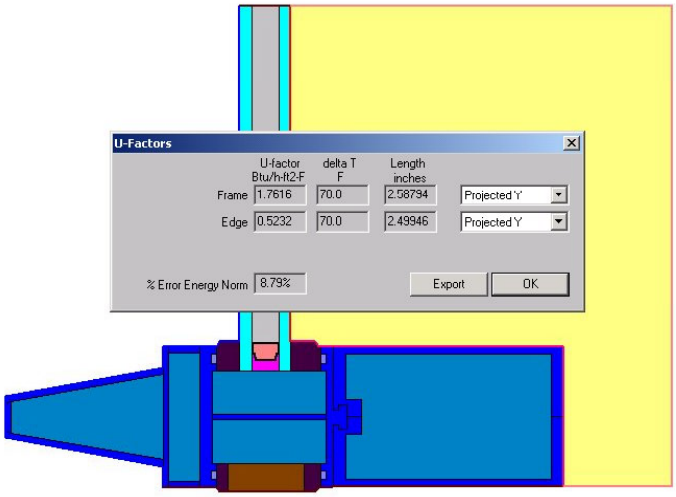
CS3/A7-18

APPENDIX 3

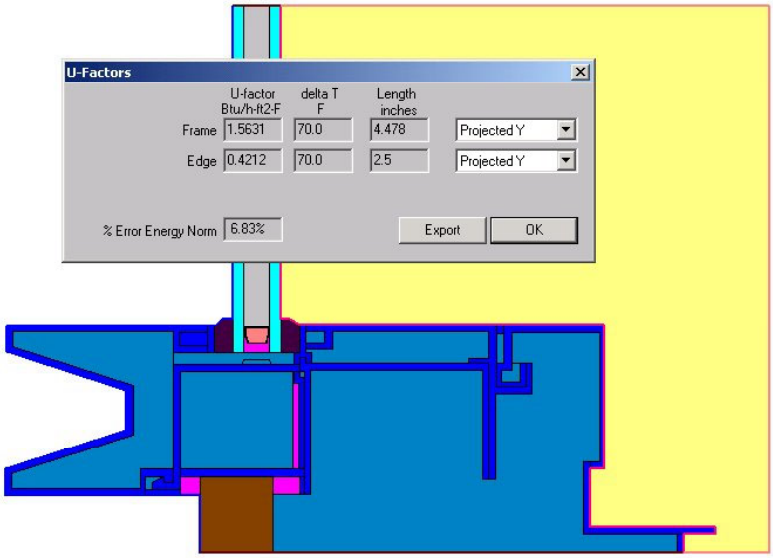
Example Curtain wall configurations modeled in THERM



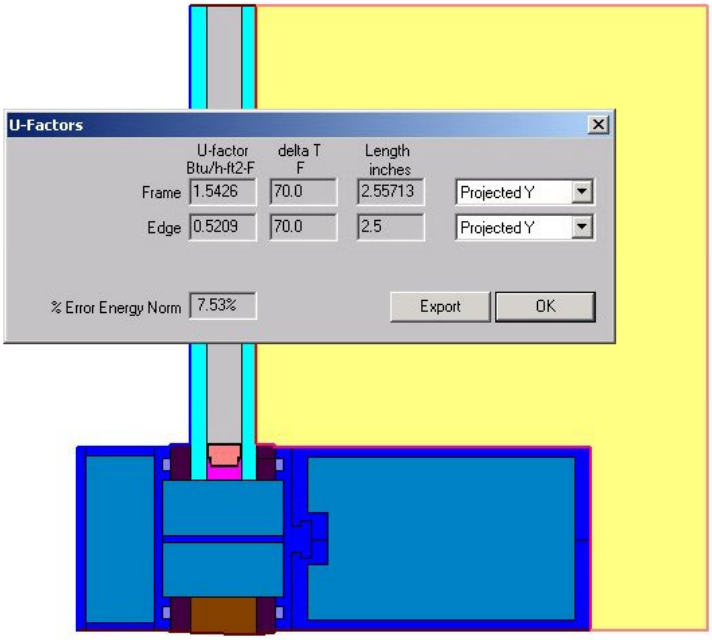
2/A7-18



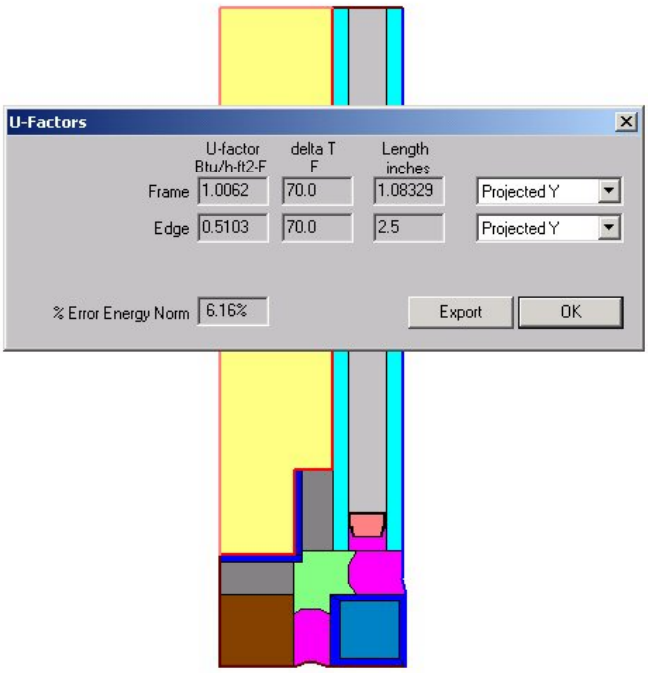
3/A7-14


U-Factors
U-factor Btu/h-ft2-F
delta T F
Length inches
Frame 1.5631 70.0 4.478 Projected Y
Edge 0.4212 70.0 2.5 Projected Y
% Error Energy Norm 6.83%
Export
OK

6/A7-20


U-Factors
U-factor Btu/h-ft2-F
delta T F
Length inches
Frame 1.5426 70.0 2.55713 Projected Y
Edge 0.5209 70.0 2.5 Projected Y
% Error Energy Norm 7.53%
Export
OK

7/A7-14

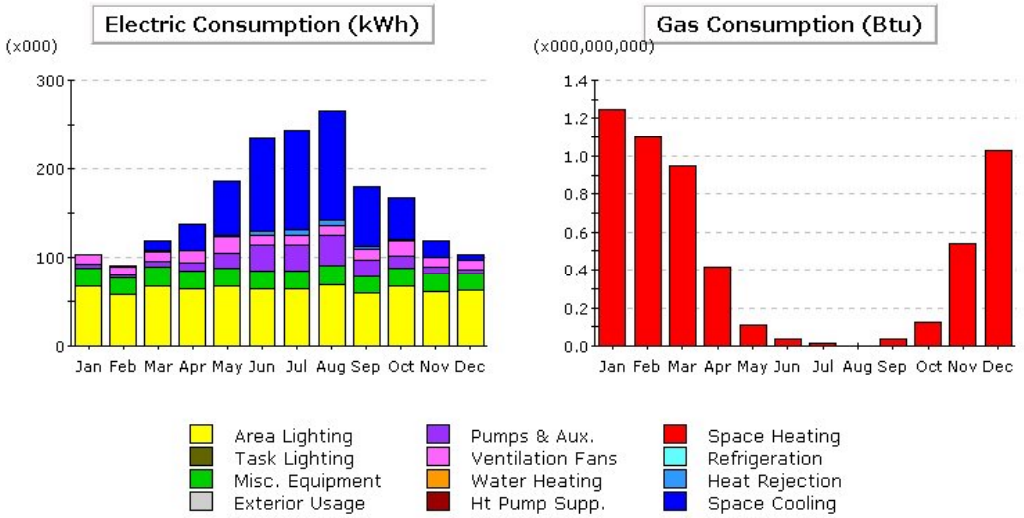

U-Factors
U-factor Btu/h-ft2-F
delta T F
Length inches
Frame
1.0062
70.0
1.08329
Projected Y
Edge
0.5103
70.0
2.5
Projected Y
% Error Energy Norm
6.16%
Export
OK

9/A7-14

APPENDIX 3

Results: Monthly energy consumption by End use for various cases

Dallas, TX



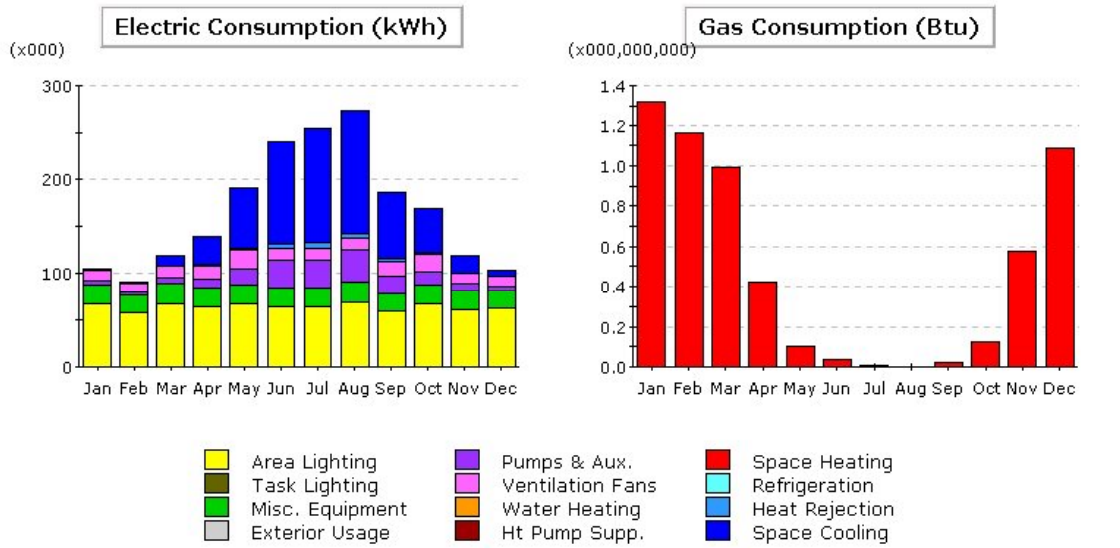
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.2	0.6	11.9	28.6	61.0	104.9	112.8	123.3	67.0	46.2	18.2	5.2	581.0
Heat Reject.	0.0	0.0	0.3	0.9	2.1	4.3	4.9	5.4	2.4	1.4	0.5	0.1	22.2
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.2	9.8	12.1	13.9	18.5	12.3	11.5	11.9	13.9	17.8	11.3	10.7	154.8
Pumps & Aux.	3.7	3.2	6.6	9.7	16.8	28.8	29.6	33.7	17.9	13.6	7.7	4.4	175.6
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	103.9	90.3	119.2	137.1	186.1	234.9	243.5	265.3	179.5	166.7	118.5	102.4	1,947.3

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.24	1.10	0.95	0.42	0.11	0.04	0.01	-	0.04	0.13	0.54	1.03	5.61
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.24	1.10	0.95	0.42	0.11	0.04	0.01	-	0.04	0.13	0.54	1.03	5.61

Fig A3.1: U factor of all the framing system = 0.5 Btu/hr-sq.ft. F (location: Dallas, TX)



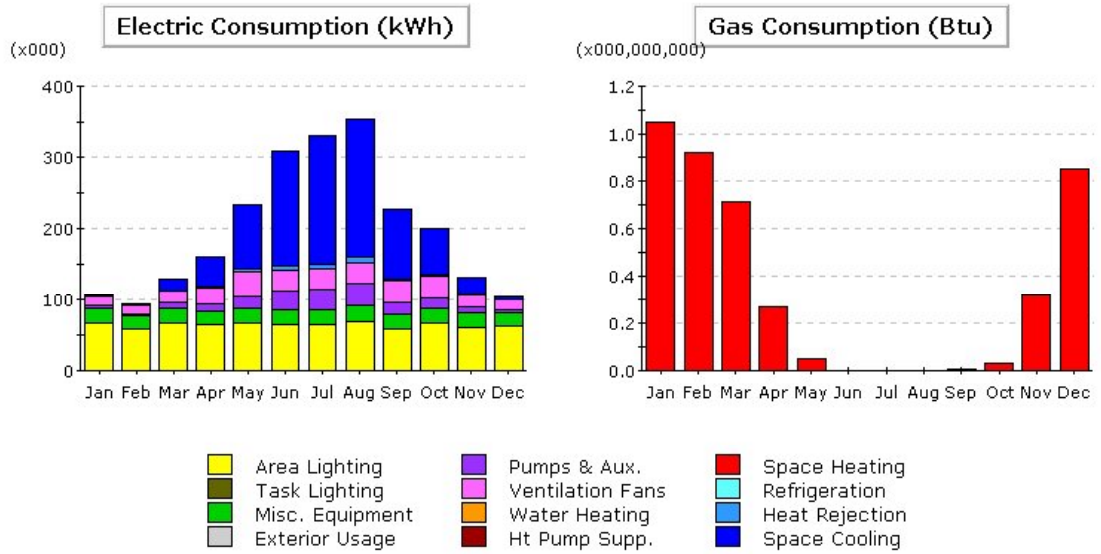
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.2	0.6	12.1	29.4	63.1	110.2	122.8	131.0	71.3	47.4	18.5	5.2	612.7
Heat Reject.	0.0	0.0	0.3	0.9	2.1	4.6	5.3	5.7	2.5	1.4	0.5	0.1	23.4
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.2	9.8	12.2	14.6	20.5	13.0	13.0	12.5	16.3	19.0	11.3	10.7	164.1
Pumps & Aux.	3.7	3.2	6.6	9.7	16.8	28.8	29.6	33.6	17.9	13.6	7.7	4.4	175.5
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	103.9	90.3	119.5	138.7	190.3	241.2	255.2	273.7	186.3	169.2	118.9	102.4	1,989.6

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.32	1.17	0.99	0.42	0.11	0.03	0.01	-	0.02	0.13	0.57	1.09	5.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.32	1.17	0.99	0.42	0.11	0.03	0.01	-	0.02	0.13	0.57	1.09	5.85

Fig A3.2: U factor of all the framing system = 2.0 Btu/hr-sq.ft. F (location: Dallas, TX)



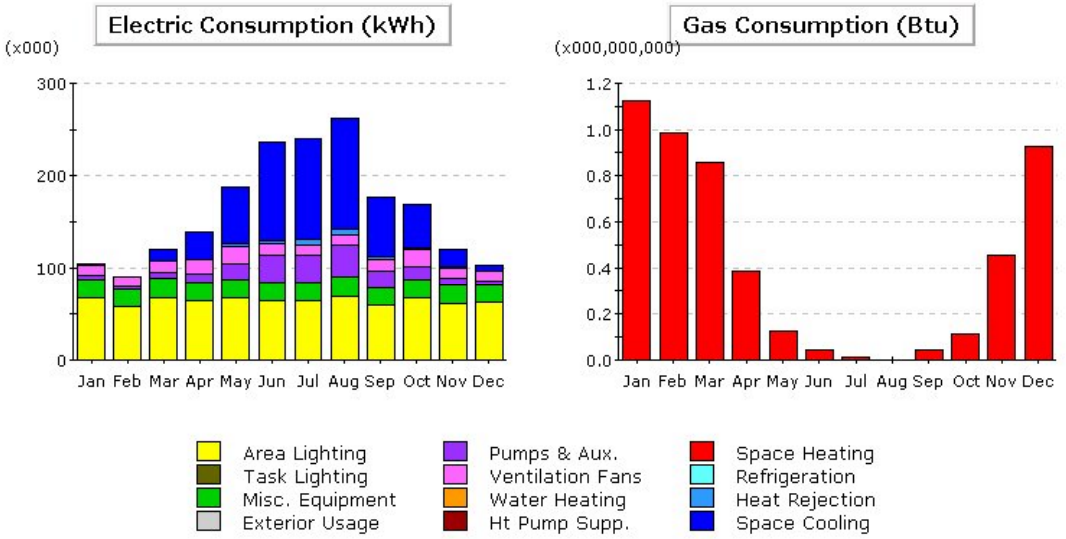
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.4	0.7	16.0	41.8	89.5	161.0	181.0	193.3	96.9	64.0	23.4	5.8	874.7
Heat Reject.	0.0	0.0	0.4	1.4	3.1	6.6	7.6	8.2	3.4	2.0	0.6	0.1	33.4
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	12.6	12.5	18.0	23.9	36.2	27.9	29.7	28.6	30.5	31.9	18.7	12.6	283.1
Pumps & Aux.	3.7	3.2	6.6	9.6	16.5	28.2	29.0	32.9	17.7	13.5	7.7	4.4	173.0
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	105.5	93.0	129.2	160.7	233.1	308.3	331.9	353.9	226.8	199.2	131.4	105.0	2,378.0

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.05	0.92	0.71	0.27	0.05	0.00	-	-	0.00	0.03	0.32	0.85	4.20
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.05	0.92	0.71	0.27	0.05	0.00	-	-	0.00	0.03	0.32	0.85	4.20

Fig A3.3: Glazing systems replaced by double clear glazing (location: Dallas, TX)



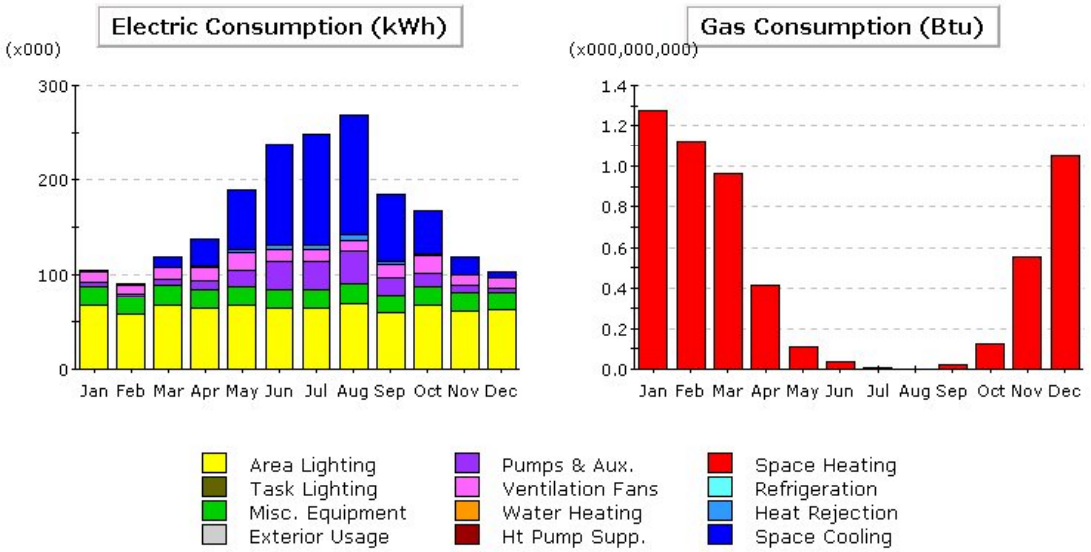
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.2	0.6	12.4	29.6	61.8	104.9	110.8	120.5	65.4	46.8	18.7	5.3	578.0
Heat Reject.	0.0	0.0	0.3	0.9	2.1	4.3	4.8	5.3	2.3	1.4	0.5	0.1	22.1
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.3	10.0	12.5	15.0	19.4	12.5	11.4	11.8	13.3	19.1	12.1	10.8	159.2
Pumps & Aux.	3.7	3.2	6.6	9.7	16.8	28.8	29.7	33.8	18.0	13.6	7.7	4.4	176.0
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	104.0	90.5	120.0	139.3	187.9	235.2	241.3	262.4	177.3	168.6	119.8	102.7	1,949.1

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.12	0.99	0.86	0.39	0.13	0.04	0.01	-	0.04	0.11	0.46	0.93	5.07
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.12	0.99	0.86	0.39	0.13	0.04	0.01	-	0.04	0.11	0.46	0.93	5.07

Fig A3.4: Glazing systems replaced by double lowE glazing (location: Dallas, TX)



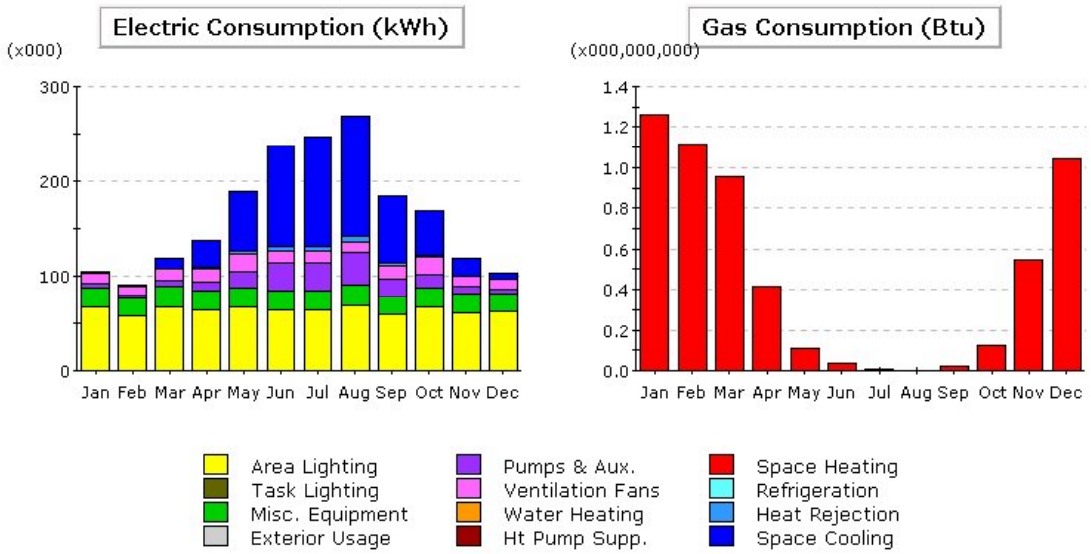
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.2	0.6	12.0	29.0	62.1	107.3	116.8	126.4	69.9	46.8	18.4	5.2	595.8
Heat Reject.	0.0	0.0	0.3	0.9	2.1	4.5	5.0	5.5	2.5	1.4	0.5	0.1	22.8
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.2	9.8	12.2	14.2	19.6	12.6	12.0	12.1	15.4	18.4	11.3	10.7	159.5
Pumps & Aux.	3.7	3.2	6.6	9.7	16.8	28.7	29.6	33.6	17.9	13.6	7.7	4.4	175.4
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	103.9	90.3	119.4	137.9	188.3	237.8	247.9	268.6	184.0	168.0	118.8	102.4	1,967.3

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.27	1.13	0.96	0.42	0.11	0.04	0.01	-	0.02	0.13	0.55	1.05	5.69
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.27	1.13	0.96	0.42	0.11	0.04	0.01	-	0.02	0.13	0.55	1.05	5.69

Fig A3.5: Actual Al spacer is replaced by Steel spacer (location: Dallas, TX)



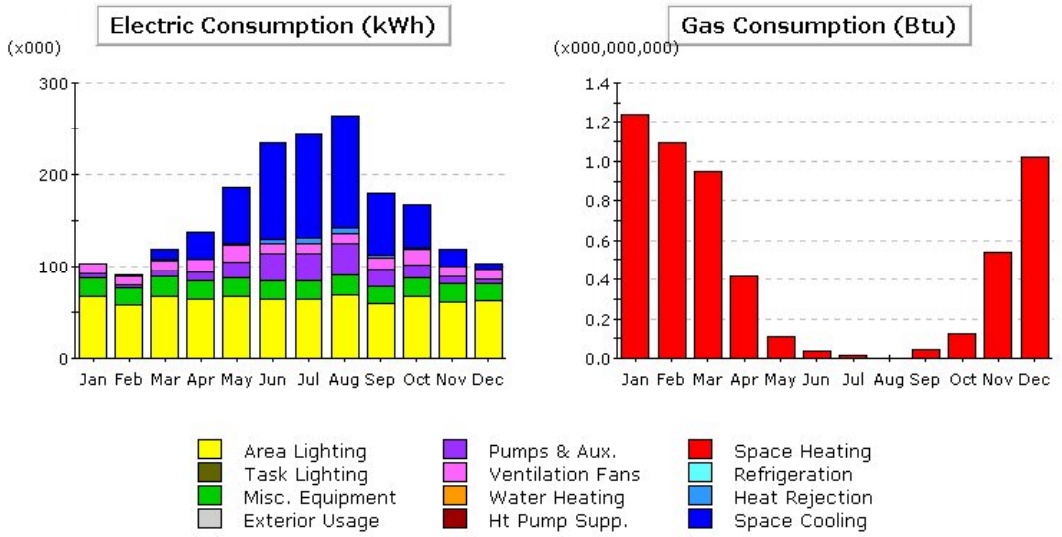
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.2	0.6	12.0	29.0	62.2	107.3	116.2	126.2	69.8	46.8	18.4	5.2	595.0
Heat Reject.	0.0	0.0	0.3	0.9	2.1	4.4	5.0	5.5	2.5	1.4	0.5	0.1	22.7
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.2	9.8	12.2	14.3	19.6	12.6	11.9	12.1	15.3	18.6	11.3	10.7	159.6
Pumps & Aux.	3.7	3.2	6.6	9.7	16.8	28.7	29.6	33.6	17.9	13.6	7.7	4.4	175.5
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	103.9	90.3	119.4	138.0	188.4	237.8	247.2	268.4	183.8	168.1	118.8	102.5	1,966.6

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.26	1.12	0.96	0.41	0.11	0.04	0.01	-	0.02	0.12	0.55	1.04	5.63
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.26	1.12	0.96	0.41	0.11	0.04	0.01	-	0.02	0.12	0.55	1.04	5.63

Fig A3.6: Actual Al spacer is replaced by Insulated spacer (location: Dallas, TX)



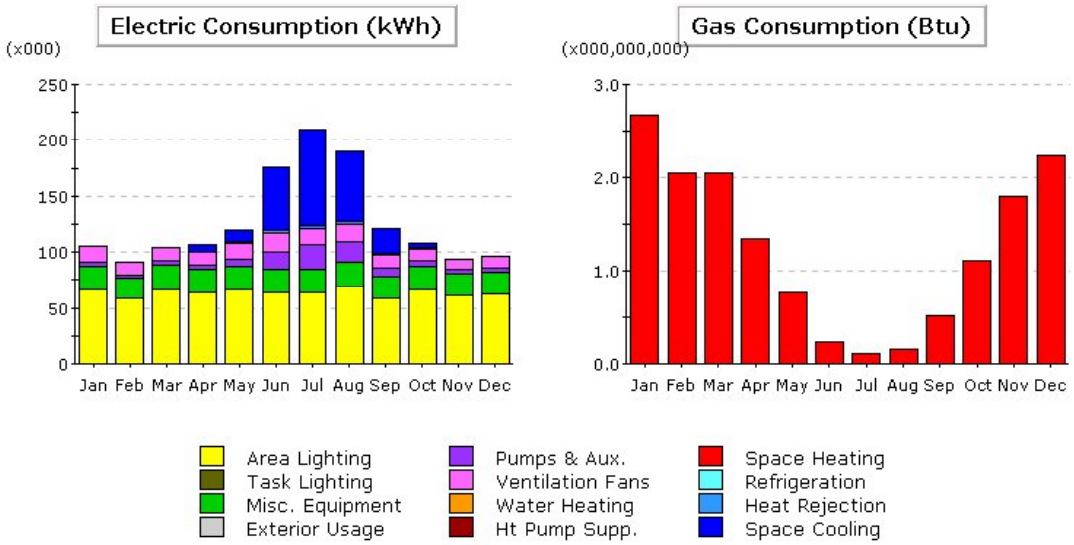
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.2	0.6	11.9	28.5	60.6	104.6	112.4	122.9	66.9	46.1	18.2	5.2	579.2
Heat Reject.	0.0	0.0	0.3	0.9	2.1	4.3	4.8	5.4	2.3	1.4	0.5	0.1	22.1
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.2	9.8	12.1	13.9	18.3	12.2	11.5	11.9	13.8	17.7	11.3	10.7	154.2
Pumps & Aux.	3.7	3.2	6.6	9.7	16.8	28.8	29.6	33.7	17.9	13.6	7.7	4.4	175.6
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	103.9	90.3	119.2	137.0	185.5	234.6	243.0	264.8	179.2	166.5	118.5	102.4	1,944.9

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.24	1.09	0.95	0.41	0.11	0.04	0.01	-	0.04	0.13	0.54	1.02	5.58
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.24	1.09	0.95	0.41	0.11	0.04	0.01	-	0.04	0.13	0.54	1.02	5.58

Fig A3.7: U factor of all the framing system is replaced by U factor of Center of glass of glazing systems (location: Dallas, TX)



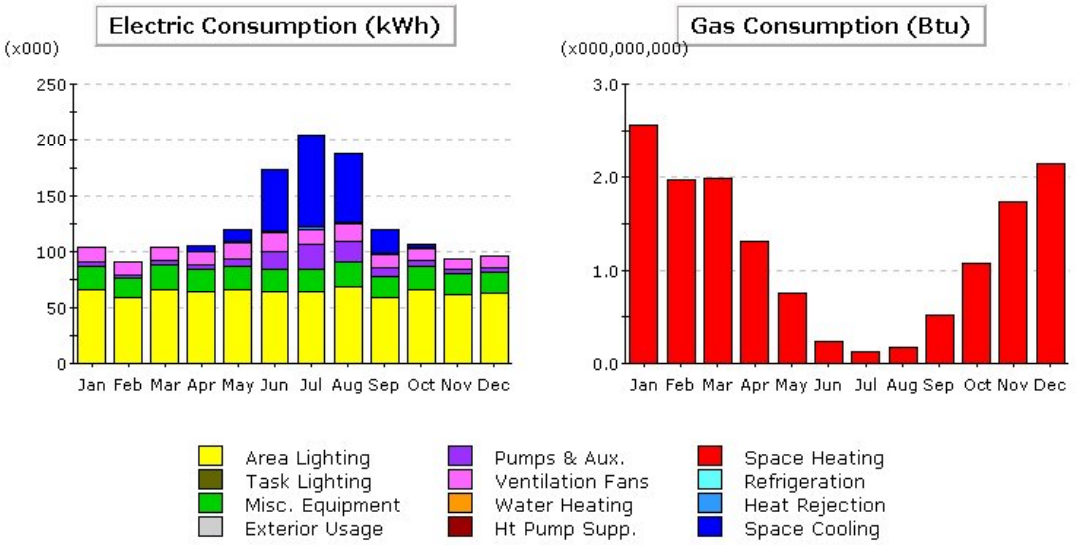
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	6.0	11.4	56.1	85.3	63.1	21.7	3.8	-	-	247.4
Heat Reject.	-	-	-	0.1	0.3	1.9	3.0	1.8	0.7	0.1	-	-	7.9
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	13.6	10.9	12.1	11.1	15.0	17.2	14.6	16.9	12.0	11.5	10.3	11.2	156.3
Pumps & Aux.	3.5	3.1	3.6	4.9	5.9	15.5	21.8	17.8	8.0	4.3	3.2	3.3	94.7
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	104.9	90.7	104.0	106.2	120.3	175.4	209.3	190.5	120.7	107.4	94.4	96.4	1,520.1

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.67	2.04	2.05	1.35	0.76	0.23	0.11	0.16	0.52	1.11	1.80	2.23	15.04
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2.67	2.04	2.05	1.35	0.76	0.23	0.11	0.16	0.52	1.11	1.80	2.23	15.04

Fig A3.8: Actual building (location : Minneapolis, MN)



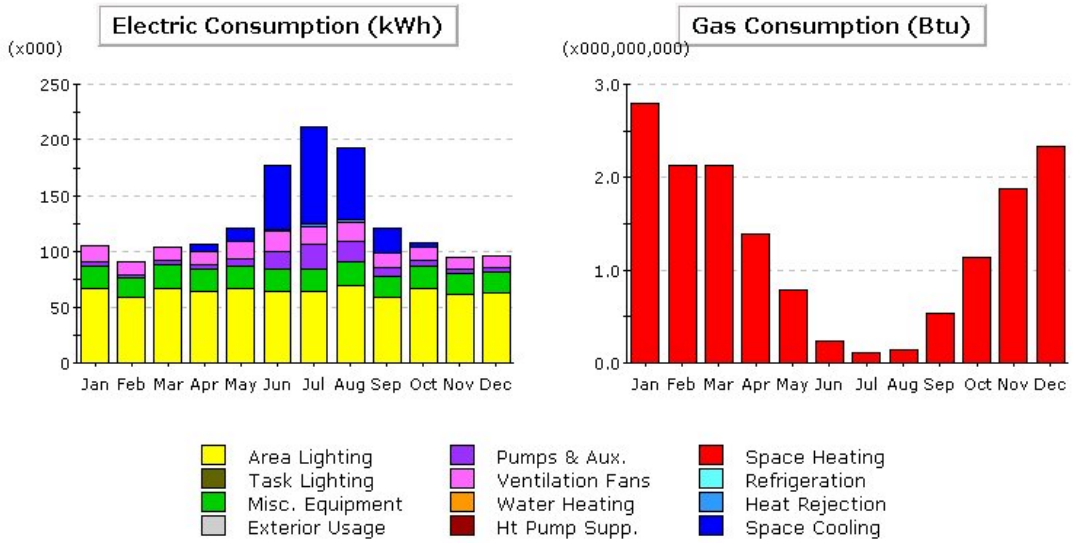
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	5.9	11.3	55.3	81.6	61.5	21.4	3.8	-	-	240.8
Heat Reject.	-	-	-	0.1	0.3	1.9	2.8	1.7	0.7	0.1	-	-	7.6
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	13.3	10.7	12.0	11.0	14.9	16.4	13.6	15.8	11.9	11.4	10.3	11.0	152.4
Pumps & Aux.	3.5	3.1	3.6	4.9	5.9	15.5	21.8	17.8	8.0	4.3	3.2	3.3	94.8
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	104.5	90.5	103.9	106.1	120.1	173.8	204.4	187.8	120.3	107.4	94.4	96.3	1,509.5

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.56	1.96	1.98	1.32	0.76	0.23	0.12	0.17	0.51	1.08	1.74	2.14	14.58
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2.56	1.96	1.98	1.32	0.76	0.23	0.12	0.17	0.51	1.08	1.74	2.14	14.58

Fig A3.9: U factor of all the framing system = 0.5 Btu/hr-sq.ft. F (location : Minneapolis, MN)



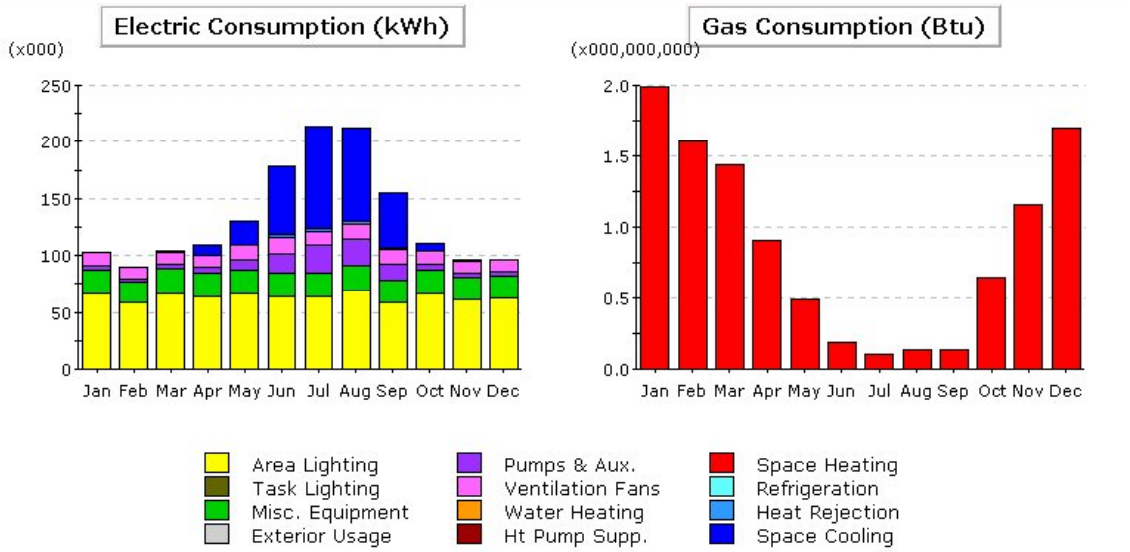
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	6.0	11.4	57.2	87.4	64.3	22.0	3.8	-	-	252.2
Heat Reject.	-	-	-	0.1	0.3	1.9	3.1	1.8	0.7	0.1	-	-	8.1
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	14.0	11.1	12.1	11.1	15.1	18.2	15.7	17.8	12.2	11.5	10.4	11.3	160.6
Pumps & Aux.	3.5	3.1	3.6	4.9	5.9	15.5	21.8	17.8	8.0	4.3	3.2	3.3	94.7
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	105.3	90.8	104.0	106.2	120.5	177.6	212.5	192.7	121.2	107.5	94.4	96.6	1,529.3

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.79	2.12	2.12	1.39	0.78	0.23	0.11	0.15	0.52	1.15	1.87	2.33	15.55
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2.79	2.12	2.12	1.39	0.78	0.23	0.11	0.15	0.52	1.15	1.87	2.33	15.55

Fig A3.10: U factor of all the framing system = 2.0 Btu/hr-sq.ft. F (location : Minneapolis, MN)



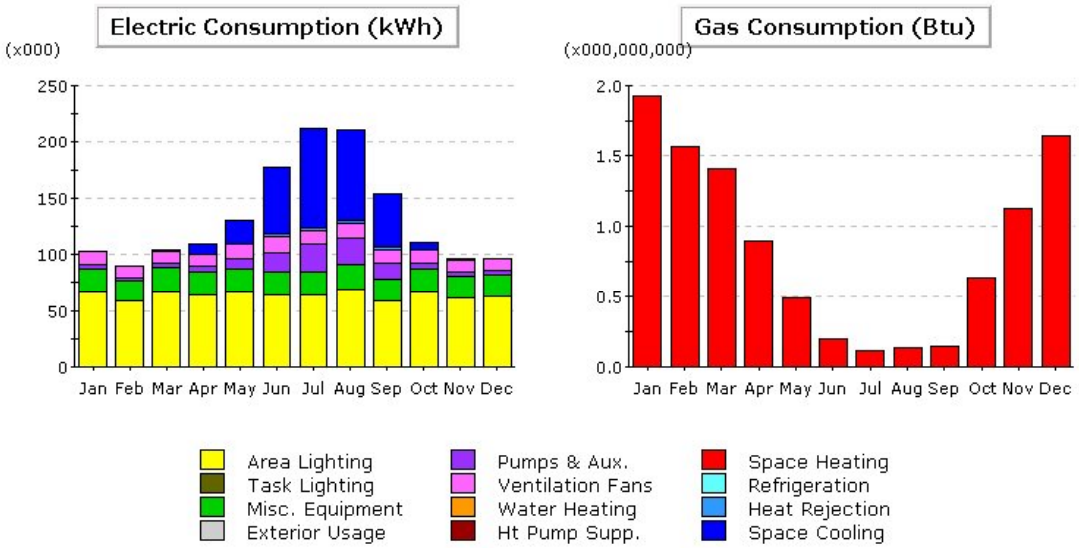
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.7	8.3	21.2	59.4	89.0	81.6	48.0	6.1	1.5	-	315.7
Heat Reject.	-	-	0.0	0.2	0.6	2.0	3.3	2.8	1.7	0.1	0.0	-	10.8
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.7	9.9	11.4	10.9	12.9	14.9	11.1	13.1	13.1	12.0	10.2	10.5	141.8
Pumps & Aux.	3.5	3.1	3.6	5.5	8.3	17.0	25.3	23.6	13.8	4.8	3.5	3.3	115.3
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	102.9	89.7	104.1	109.0	130.7	177.9	213.3	212.0	154.9	110.8	96.2	95.8	1,597.4

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.99	1.61	1.44	0.91	0.49	0.19	0.11	0.13	0.13	0.65	1.16	1.69	10.50
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.99	1.61	1.44	0.91	0.49	0.19	0.11	0.13	0.13	0.65	1.16	1.69	10.50

Fig A3.11: Actual Building (location: Washington, DC)



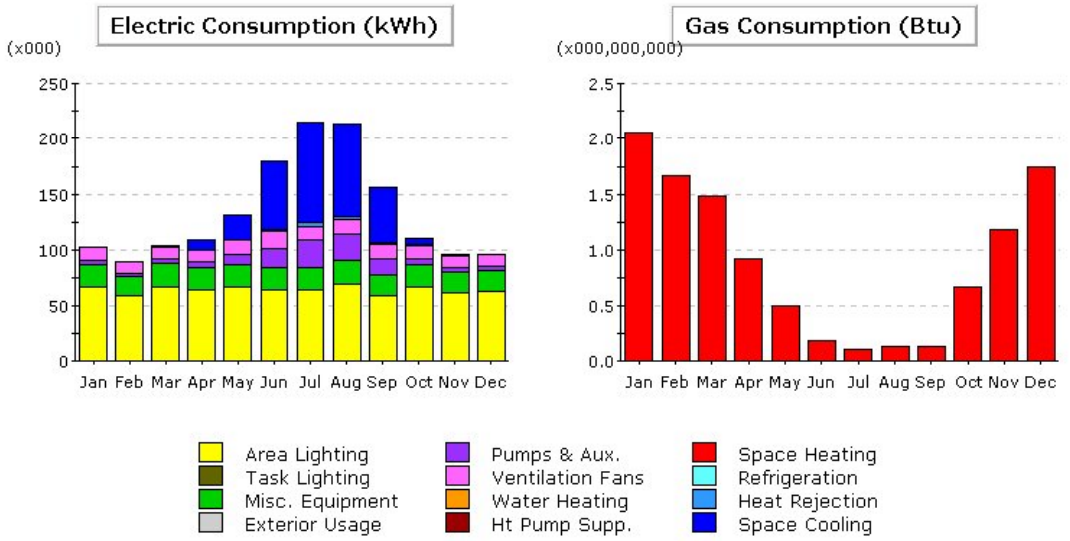
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.7	8.3	21.0	58.6	87.5	80.4	47.1	6.1	1.5	-	311.2
Heat Reject.	-	-	0.0	0.2	0.6	2.0	3.3	2.8	1.6	0.1	0.0	-	10.6
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.6	9.9	11.4	10.9	12.8	14.4	11.0	12.8	12.6	11.9	10.2	10.5	140.1
Pumps & Aux.	3.5	3.1	3.6	5.5	8.3	17.0	25.3	23.6	13.8	4.8	3.5	3.3	115.3
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	102.8	89.7	104.1	108.9	130.5	176.6	211.7	210.6	153.5	110.8	96.2	95.8	1,591.0

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.93	1.56	1.40	0.90	0.49	0.20	0.11	0.14	0.14	0.64	1.12	1.64	10.27
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.93	1.56	1.40	0.90	0.49	0.20	0.11	0.14	0.14	0.64	1.12	1.64	10.27

Fig A3.12: U factor of all the framing system = 0.5 Btu/hr-sq.ft. F (location: Washington, DC)



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.7	8.3	21.3	60.2	90.7	83.2	48.6	6.1	1.5	-	320.7
Heat Reject.	-	-	0.0	0.2	0.6	2.0	3.4	2.9	1.7	0.1	0.0	-	11.0
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	11.8	9.9	11.4	10.9	13.1	15.4	11.3	13.4	13.4	12.2	10.3	10.6	143.7
Pumps & Aux.	3.5	3.1	3.6	5.5	8.3	17.0	25.3	23.6	13.8	4.8	3.5	3.3	115.3
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	21.2	18.6	21.3	20.3	21.2	20.5	20.5	21.8	19.1	21.2	19.6	20.0	245.1
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	66.6	58.1	67.0	63.8	66.6	64.2	64.1	69.1	59.2	66.6	61.3	62.0	768.7
Total	103.0	89.7	104.1	109.0	131.0	179.3	215.3	214.0	155.9	111.0	96.2	95.8	1,604.4

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.06	1.66	1.48	0.93	0.50	0.19	0.10	0.13	0.13	0.66	1.19	1.75	10.76
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2.06	1.66	1.48	0.93	0.50	0.19	0.10	0.13	0.13	0.66	1.19	1.75	10.76

Fig A3.13: U factor of all the framing system = 2.0 Btu/hr-sq.ft. F (location: Washington, DC)