IMPACT OF WINDOW DESIGN VARIANTS ON LIGHTING AND COOLING LOADS: CLUES FOR REVISITING LOCAL BUILDING REGULATIONS

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ABSTRACT

The study is placed within the context of local building regulations in India. Building regulations, for fenestration in general and window openings in particular, are, to a large extent, ambiguous in nature. In the context of India, observations show that the regulations specify window size for the sole purpose of ventilation whereas windows are major role-players in the thermal and daylighting performance of buildings. In this paper, parametric simulation is used to generate data for cooling and lighting loads for typical commercial office spaces in the hot-dry climate of Ahmedabad, India. This data is then analysed using Multiple Regression techniques to express loads as a function of floor area, aspect ratio, window-to-wall ratio and orientation of windows. The equations derived from regression help compare the energy implications of varying window sizes and their orientations. The observations and results stress the need to re-analyse local building regulations as they fail to indicate the maximum allowable limit of window size leading to highly inefficient building design.

KEYWORDS

Building regulations, Windows, Energy efficiency, Thermal, Daylighting, Simulation, Regression

INTRODUCTION

Windows are one of the most critical design parameters affecting energy consumption in buildings. In hot climatic regions in India windows are the main source of heat gain through building envelope. In view of the fact that the average global annual solar radiation in the region is about 11000 W/m^2, window design becomes a very crucial aspect of building façade design in order to minimize solar heat gains. At the same time, windows are the primary source of daylight. In the current architectural scenario in the country it can be observed that commercial buildings are largely becoming energy intensive in nature, which means that a lot of energy is used in cooling, lighting and running the equipment. The cooling loads dominate the consumption pattern and there is also a steady growth in the lighting load share. According to Jannuzzi (Jannuzzi et al.,1991), 17% of electricity consumption in India can be attributed to lighting demand. This becomes significant when one sees the share of consumption due to domestic and commercial sectors rising from 14.7% in 1970-71 to 23.8% in 1992-93 (Natarajan, 1995).

Historical and vernacular precedents in Indian architecture show a recurring pattern of minimal opening sizes in almost all climatic regions in the country. This implies elimination of solar heat gain. Moreover, absence of glazing does not trap heat inside the building. Several ingenious techniques are still employed to harness daylight. Change in the nature of activities, diverse building materials and construction techniques, and recaliberated ideas of comfort have played an important role in creating the new cityscape of a typical urban environment in India. Now one sees buildings with large openings that span the entire width and height of a floor with no thought of appropriate sizing and orientation. One important factor in lack of serious academic and professional inclination towards energy efficiency is the absence of rules or guidelines that require the architect or designer to design and build better performing and less energy-intensive buildings. It is in this context that one feels building regulations can play a critical role in inculcating as well as enforcing better building practices.

The regulations play a significant role in determining the building envelop and hence, consequently, the quality of interior environment. Thus, one feels that building regulations offer immense possibilities of creating better living environments, and achieving energy efficiency in buildings along with allowing freedom in design aesthetics. In addition, a very positive aspect of building regulations is that they are local in nature, formulated by the local development authorities. Ideally, they are meant to deal with development problems and challenges specific to that local context. This provides a great opportunity to improvise building regulations for energy efficient building practices where the latter could, and would in fact, vary with different contexts. The process of contextualization applied to building regulations can be extended to energy efficiency measures as part of these regulations because localizing and contextualizing is what is greatly needed in a country like India which has diverse climatic zones and even more diverse natural environments that need taking care of.

Regulations in India fail to set standards for window design for efficiency in building performance. Building regulations, as specified by the Ahmedabad Municipal Corporation, mention, for ventilation of rooms, windows and/or ventilators as a minimum size of opening required for a particular room in terms of the ratio of the floor area of that room (General Development Control Regulations, 2001). Specifying the lower limit means it is possible to design buildings with 100% window-to-wall ratio without even having to use an efficient window/glazing system. Also, restrictions imposed by regulations limit the use of fixed external shading devices. For a country like India, such practices spell doom on all fronts - resource consumption, energy prices, environmental balance, and social, cultural and aesthetic sensibilities.

This study will express building electrical energy consumption as a function of window size and orientation for commercial building practices in India. An extended aim of the study is also to start a discussion where relevant inquiries can be made into the local building regulations that would result in incorporating the same with required measures for achieving energy efficiency in buildings through window design. The objective is to start viewing building regulations as a critical 'mass' which, infused with these measures, could help towards more widespread awareness and practices of designing and building with energy efficiency as a rule.

METHODOLOGY: SIMULATION

For this study, hypothetical representative models were simulated in EnergyPlus using DesignBuilder interface to calculate cooling and lighting energy with variable window design parameters, namely window size in terms of window-to-wall ratio, and orientation.

The Daylighting:Detailed method in EnergyPlus calculates daylighting illuminance levels and then determines to what extent the electric lighting can be reduced. The daylight illuminance level in a zone depends on many factors, including sky condition; sun position; calculation point; location, size, and glass transmittance of windows; window shading devices; and reflectance of interior surfaces. Reduction of electric lighting depends on daylight illuminance level, illuminance set point, fraction of zone controlled and type of lighting control (EnergyPlus Input Output Reference). Each perimeter zone has one reference point located at the geometric centre of the zone at which horizontal illuminance is calculated. It is assumed that the photocells that control the overhead electric lighting respond to the light levels at the specified reference points.

The models have been simulated for commercial office space with working hours from 10:00 a.m. to 06:00 p.m.; weekends and holidays are considered as unoccupied days. The density of people is 0.16 people/m^2. In other words, each person has 6.25m^2 of floor space. The setpoint temperature for cooling is set at 24 degC.

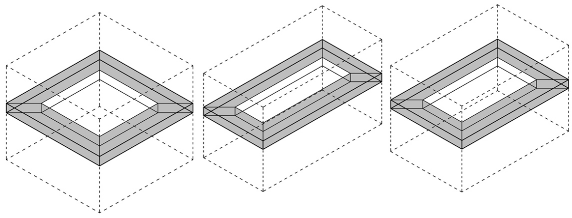
In order to represent the commercial building practices that are, more or less, energy intensive, the models are totally conditioned with no natural ventilation. The HVAC system used is Constant Volume DX system.

The design illuminance has been set at 500 lux (for office use). The work plane height is 0.8m. In order to measure the electrical lighting savings due to daylighting, light control sensors have been used in the perimeter zones of the models. The lighting control is linear type where the lights dim continuously and linearly from maximum electrical power, maximum light output to minimum electrical power, minimum light output as the daylight illuminance increases. With further increase in daylight, the lights are switched off (EnergyPlus InputOutputReference). The luminaire type used for general office lighting is suspended fluorescent with the lighting power density of 14 W/m^2.

The construction assembly and materials is same as the general trend followed in Ahmedabad, external 280 thick burnt clay brick wall with inside and outside surfaces lightweight Portland cement plastered. The roof and floor have been considered as adiabatic in order to simulate the model as an intermediate floor of a multi-storey building.

Reference Model: Parameters and Variables

The models are based on a preliminary study done for obtaining typical floor plate area figures for commercial-office spaces in Ahmedabad. From the predominantly occurring floor plate areas for commercial office use three floor plate areas of 600m2, 1200m2 and 2000m2 were taken as representative of small, medium and large office spaces. Floor height is 3m. Each of these floor plates is varied in terms of three aspect ratios of 1:1, 1:2 and 2:3. For aspect ratios 1:2 and 2:3, the model is oriented E-W axis with N and S walls as longer walls.



	Aspect Ratio **1:1**	Aspect Ratio **1:2**	Aspect Ratio **2:3**
600 m^2	24.5x24.5x3	17.3x34.6x3	20x30x3
1200 m^2	34.6x34.6x3	24.5x49x3	28.3x42.4x3
2000 m^2	44.7x44.7x3	31.6x63.2x3	36.5x54.8x3

Table 1, Parameters for simulation models (shaded area represents perimeter zones)

All these 9 cases are then simulated with WWRs of 5, 10, 20, 30, 40, 50, 60, 70, 80 and 90 and orientations of *n, e, w, s, ne, nw, ns, ew, se, sw, new, nes, swn, sew, news*, for all possible permutations of these. It is important to note here that the permutations are limited to only one WWR in the case of openings on more than one wall. For instance, 80% WWR on *news* would mean 80% WWR on *n, s, e* and *w* walls; there is no variation in WWR within one single case/model. All permutations make a total of 1350 models. The preferred height of the window is 1.5m with sill at 0. 8m. Window, sill and lintel heights vary as the WWR increases.

Each of these models is divided into core and perimeter zones (4.5m deep from external wall) for the purpose of daylighting simulation wherein each perimeter zone that has windows also has a light control sensor. For thermal analysis the model behaves as a single, controlled zone. The glazing type is taken as 6mm clear glass with SHGC 0.815, VLT 0.881 and U-value 6.144 W/m2k. Windows do not have any shading device.

The simulation runs in EnergyPlus were done using the EnergyPlus weather file of Ahmedabad with two time steps per hour. For each of the 1350 models, the output is given as annual data for the electrical consumption due to lighting and cooling. For the purpose of this study, these are termed as lighting and chiller loads respectively. Chiller load is an alternative term used for Chiller Electricity (kWh) which is one of the DesignBuilder output variables defined as total chiller fuel consumption (DesignBuilder User Manual). It represents the amount of cooling energy that needs to be provided by the chiller to offset gains from envelop, equipment, lighting and occupancy. Lighting load is defined as the electricity consumed by electrical lighting. A third term called total load represents the sum total of cooling and lighting loads.

Observations from Simulation results

Graphs were plotted to understand the performance for each of the cases for chiller vs. lighting loads. It was observed that all one-wall-opening cases from example *n*, *e*, *w* and *s* performed better than the multi-wall-openings (Figure 1). Hence, the chiller load reached its maximum in cases with openings on all four walls, *news*. This was true for all floor areas and all aspect ratios. But the situation was reversed for lighting loads, where more number of walls having openings resulted in decrease in electrical lighting consumption and the one-wall-opening cases were the worst performing.

In cases of small windows sizes with WWR less than 20%, the orientation of windows did not have an appreciable impact on total loads but became significant when the window sizes increased (Figure 2). North orientation was the best performing in terms of total loads.

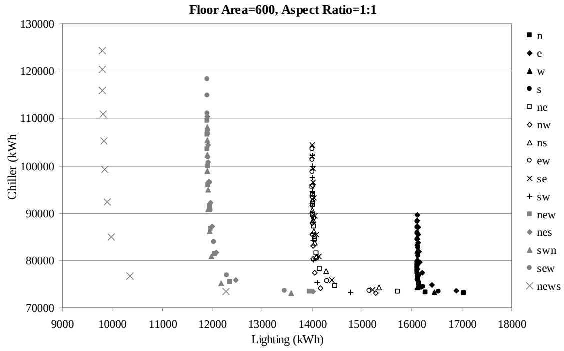


Figure 1, Chiller Vs Lighting Load performance for different orientations

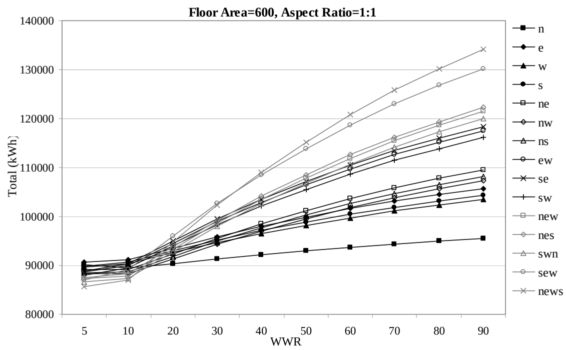


Figure 2, Impact of WWR on Total Load

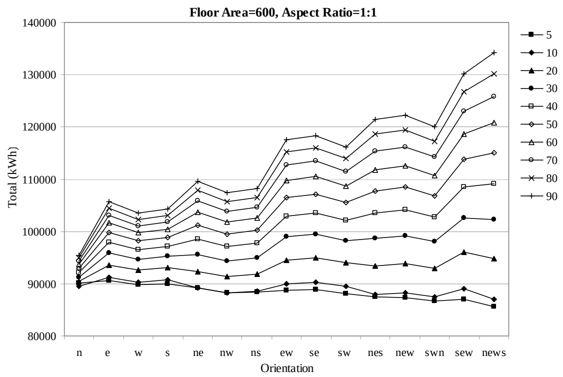


Figure 3, Impact of orientation on Total Load

However, for a given orientation, the total loads did not show a considerable increment with increase in window size. For all other primary orientations *e*, *w* and *s*, total loads increase as window size increases (Figure 3). For window sizes greater than 20% WWR, north is the best and east is the worst performing with west and south ranking second and third respectively. Based on this observation it was apparent that among the cases with openings on two walls, *nw* would be the best and *se* would be the worst. This corroborated with the simulation results (Figure 2). Observations show that aspect ratio 1:2 shows minimum lighting loads for all the cases that have windows on *n* and *s* – for openings greater than 10% the percentage increment in lighting loads ranges from 5-10% for aspect ratio 2:3 and 10-20% for 1:1. Trend is reversed for openings on *e* and *w*.

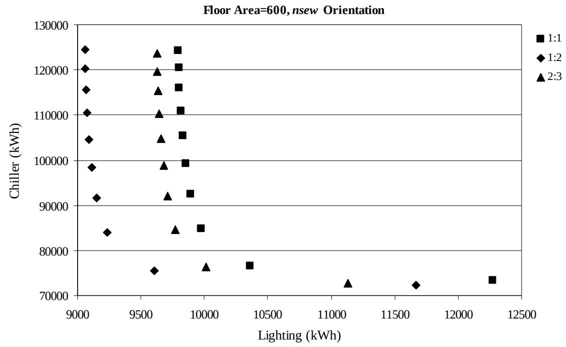


Figure 4, Impact of Aspect ratio on Chiller and Lighting load

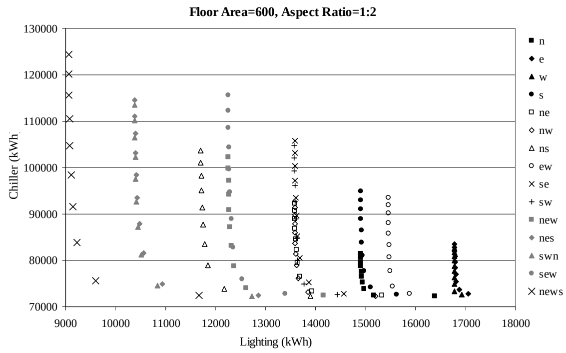


Figure 5, Split in performance of different orientations due to aspect ratio

It was noted that some shifts start emerging in lighting loads as aspect ratio is varied from 1:1 to 1:2 (Figure 5). As the floor plate is elongated along the E-W axis, all cases that include openings on the north and south walls start performing better. This is because the north and south walls become longer and windows on these walls start providing daylight to a larger perimeter zone thereby increasing savings in electrical lighting.

It was also obeserved that chiller loads dominate the total loads as it represents both sensible and latent heat gains. Therefore the percentage contribution of lighting loads to the total loads is merely 6.8% - 20.2%. This percentage is the least for small floor areas, large openings, longer plans and more number of openings. The opposite is true for cooling loads.

STATISTICAL ANALYSIS

A Multiple Regression Analysis (MRA) was performed on the data obtained from the parametric simulation runs described earlier. MRA has often been used to derive equations to calculate electric energy and peak demand as well as to understand the impact of various design parameters on building energy perfomance (Sullivan et al., 1985, 1987) The objective was to understand the data better and to derive a simplified algebraic form expressing the relationship between loads and the input variables. It was decided to divide the entire dataset into two parts – one with window size of WWR smaller than 20% and the other with WWR greater than or equal to 20%. The simulated results showed appreciable variations in loads between these two groups and therefore it was important to segregate the data in order to get more precise equations for each.

The dependant variables analysed were Chiller Load (CL), Lighting Load (LL) and Total Load (TL), where TL = CL + LL. It was important to study TL along with CL and LL because it was found that the lighting and cooling loads had a negative correlation – for a series of parametric runs one decreases as the other increases. Also, the lighting loads were marginal or negligible as compared to the cooling loads. Hence, totals load was a means to analyse the possibilities of over-all energy efficiency in the simulated cases whereas part loads provided a comparative analysis between the electricity consumption for cooling and lighting towards understanding the trade-offs between the two primary components of building electricity demand.

The four independent variables have already been explained. They are Floor Area (FA), Aspect Ratio (AR), Window-to-Wall Ratio (WWR) and Orientation (OR). OR represents a group of independent variables to indicate 15 orientations (n, e, w, s, ne, nw, ns, ew, se, sw, new, nes, swn, sew, news). For the purpose of this analysis, the default orientation is taken as corresponding to zero values for all 15 orientations, representing a model with no openings. The orientation that holds true will be attributed a value of 1 and others will be zero. At a given instant 14 values will be zero and one will be 1. For example, n=1 implies windows only on the north wall while ns=1 implies windows on north as well as south wall with same WWR on both walls.

The general form of the derived regression expression is as follows:

$$L = k + \beta_1 FA + \beta_2 WWR + \boldsymbol{\beta_o} \, \mathbf{OR} + \boldsymbol{\beta_{FWO}} \, FA \cdot WWR \cdot \mathbf{OR} + \boldsymbol{\beta_{FAO}} \, FA \cdot AR \cdot \mathbf{OR} + \boldsymbol{\beta_{FWAO}} \, FA \cdot WWR \cdot AR \cdot \mathbf{OR} \quad (1)$$

where

L = Load (TL, CL, LL)

k = constant

β = regression coefficients

FA = Floor area

WWR = Window-to-wall ratio

AR = Aspect ratio (when aspect ratio is 1:1, 2:3, and 1:2, AR=1, 1.5, and 2, respectively)

$\mathbf{OR} = [\text{ n, e, w, s, ne, nw, nw, ew, se, sw, new, nes, swn, sew, news }]_{15x1}$

$\boldsymbol{\beta_o} = [\, \beta_3, \beta_4, \beta_5 \ldots \beta_{17} \,]_{1x15}$

$\boldsymbol{\beta_{FWO}} = [\, \beta_{18}, \beta_{19}, \beta_{20} \ldots \beta_{32} \,]_{1x15}$

$\boldsymbol{\beta_{FAO}} = [\, \beta_{33}, \beta_{34}, \beta_{35} \ldots \beta_{47} \,]_{1x15}$

$\boldsymbol{\beta_{FWAO}} = [\, \beta_{48}, \beta_{49}, \beta_{50} \ldots \beta_{62} \,]_{1x15}$

Note: The equation stands valid for schedules, templates and other input data specified under Methodology. The values of k and β are given in Table 4.

The equation consists of seven components. The first is the constant which is the basic minimum load constant with all the other variables changing. Second component represents the impact of floor area on load. From Table 4 the value of β_1 is positive for all cases. This means that all three loads will increase as the floor area increases for small as well as large window sizes. Third component of the equation shows the impact of WWR. Values of β_2 are negative for lighting load and positive for the other two. This indicates that the total and chiller loads would increase with increase in window size whereas the lighting loads would decrease. However, the decrease in lighting loads in case of small openings is more substantial than in case of large openings. For instance, increasing window size from 10% to 20% WWR would have greater savings as compared to increasing it from 40% to 50%, making a small window marginally bigger is more effective when it comes to electrical lighting savings than making a medium or large-sized window larger. Increase in total and cooling loads with increase in window size is slightly more in case of smaller openings than in larger ones. Also, the increase in cooling loads is always more than total, especially for small openings, because total loads also have the lighting load component.

The last three components of the equation are permutations of the independent variables; these are termed as interaction variables and represent the combined impact of floor area, aspect ratio, WWR and orientation on load.

In order to understand the impact of WWR on loads, equation (1) was differentiated over WWR to derive the following expression:

$$\delta L/\delta WWR = \beta_2 + \boldsymbol{\beta_{FWO}}\, FA\cdot\mathbf{OR} + \boldsymbol{\beta_{FWO}}\, FA\cdot AR\cdot\mathbf{OR} \quad (2)$$

where δL/δWWR can be defined as the increment in load for a unit increment in WWR. With this equation the impact of change in WWR on load can be calculated for a particular orientation and for a given floor area and aspect ratio. For instance, to understand the impact of WWR for north orientation the following equation can be derived from equations (1) and (2):

$$\delta L/\delta WWR_n = \beta_2 + \beta_{18}\, FA + \beta_{48}\, FA\cdot AR \quad (3)$$

Similarly impact of window size for other orientations can be calculated. Figures 6-8 show gradiant γ (δL/δWWR) graphs for all aspect ratios and orientations.

Observations from Regression analysis

From Figures 6-8 it is clear that as the aspect ratio changes and as the floor plate becomes longer along the E-W axis, the difference between γ_{min} and γ_{max} become more pronounced. This implies that the range of variation in loads becomes much wider with better cases performing even better and worse cases performing much worse as compared to aspect ratio 1:1. This is especially true of the γ gradient curves for total load as they become more dynamic with change in aspect ratio. Also, this change is more pronounced for openings with WWR<20 as compared to larger window sizes. For the latter, chiller and total loads have almost the same gradient across all aspect ratios. This means that both loads are affected to the same degree with variation in window size for a given orientation. On the contrary, there is a substantial difference in the gradiant curves for the same loads in case of small openings. This is because for small openings the lighting load gradiant varies dynamically with change in window size as against the same curve for large windows.

Observations from Figures 6-8 have been summed up for easy reference in Table 2. The table shows γ_{min} and γ_{max} for different aspect ratios, orientations and large and small windows sizes. The window orientations within each aspect ratio column have been divided into four sets. The first set consists of cases with openings on one wall only (*n, e, w, s*); the second set consists of openings on two walls (*ne, nw, ns, ew, se, sw*) and the third has cases with openings on three walls (*new, nes, swn, sew*). The last set comprises of all 15 orientations. γ_{min} signifies minimal variation in loads with change in window size and γ_{max} indicates maximum variation in loads. In the following description former is referred to as the best case and the latter as the worst.

For openings on one wall, north is generally the best performing across all aspect ratios and south and east are the worst cases. For small openings, the total load increases by 125 units for every unit increase in WWR in the north whereas in east it increases by 214. The decrease in lighting load per unit increase in WWR in the north is 107 while it drops down to 60 in south. For large openings (WWR>20) lighting load does not vary considerably with increase in

AR		1:1							
No. of window walls		1		2		3		Overall	
TL	WWR <20	n, w	e	nw	se	new	sew	nw	se
	WWR ≥20	n	e	nw	se	swn	sew	n	news
CL	WWR <20	n	e	nw	se	new	sew	n	news
	WWR ≥20	n	e	nw	se	swn	sew	n	news
LL	WWR <20	n	s	nw, ne	se, sw	nes, sew	new	news	s
	WWR ≥20	e	s	ne	ns	new	swn	news	s
		γmin	γmax	γmin	γmax	γmin	γmax	γmin	γmax

AR		2:3							
No. of window walls		1		2		3		Overall	
TL	WWR <20	n	e	ne	se	new	sew	n	sew
	WWR ≥20	n	s	nw	se	new	sew	n	news
CL	WWR <20	n	s	nw	se	new	sew	n	news
	WWR ≥20	n	s	nw	se	new	sew	n	news
LL	WWR <20	n	w	ne	sw	nes	sew	news	w
	WWR ≥20	n	w	ne	sw	nes	sew	news	w
		γmin	γmax	γmin	γmax	γmin	γmax	γmin	γmax

AR		1:2							
No. of window walls		1		2		3		Overall	
TL	WWR <20	n	e	ne	sw	new	sew	n	sew
	WWR ≥20	n	s	nw	se	new	sew	n	news
CL	WWR <20	n	s	ne	se	new	sew	n	news
	WWR ≥20	n	s	ne	se	new	sew	n	news
LL	WWR <20	n	w	ns	ew	nes	sew	news	w
	WWR ≥20	n	w	ns	sw	nes	sew	ns	w
		γmin	γmax	γmin	γmax	γmin	γmax	γmin	γmax

Table 2, δL/δWWR data for different orientations

WWR on any of the four orientations (openings on one wall only) as the required illuminance levels have been met and will only lead to glare which is not within the scope of this paper to examine..

For openings on two walls, *nw* has the minimum gradient of 117 and *se* is the worst performing case with a gradient of 291 within the third set, *new* and *nes* are generally observed to be better performing as against *sew* which has the maximum gradient of 283. It is important to note here that for lighting load, better performing cases have more than one north and/or south window walls.

CONCLUSION

The study shows that in hot and dry Indian climatic conditions windows with WWR less than 20% perform very differently than larger windows. The former provide more possibilities for savings in chiller as well as lighting electricity with the help of thoughtful sizing and orientation. Other window design variables would also have a significant impact on energy savings. These measures have a far greater impact on heat gains from large windows. Design parameters like shading and blinds would lead to savings but would not show variations in electrical light consumption or savings for different orientations. Studies (Johnson et al, 1984) have shown that shading devices mitigate the differences between daylight availability in north and south orientations. However, the primary savings are a result of sizing and orientation. It is also observed that windows with WWR greater than 20% do not lead to lighting energy saving and will definitely contribute significantly to heat gains irrespective of their orientation.

Moreover, building regulations give a minimum limit of window size as one-tenth of the floor area. If this minimum is expressed as window-to-wall ratio for a floor area of $600m^2$ and aspect ratio 1:1, it would mean 82% WWR for windows on only one wall, 41% WWR for windows on two walls, 27% WWR for windows on three walls and 20% when windows are distributed equally on all four walls. As a result, window sizes that are efficient will be actualised only if windows are distributed on three or more walls which is usually not the case in commercial building practices. Window size of one-tenth of floor area when distributed on one or two walls would result in large windows leading to considerable heat gains while giving only marginal savings in lighting electricity. For larger floor areas window size further increases on each wall and the minimum limit of window size if applied to only one wall would result in 100% WWR. In such cases distributing the minimum limit on all four walls is the only way to get small/medium sized windows. This means that the minimum window size specified by regulations is highly inefficient and energy intensive in cases where windows cannot be provided on more than one walls. It is therefore important and critical to revise building regulations to specify a range of window size or measures to make windows (falling outside this range) efficient.

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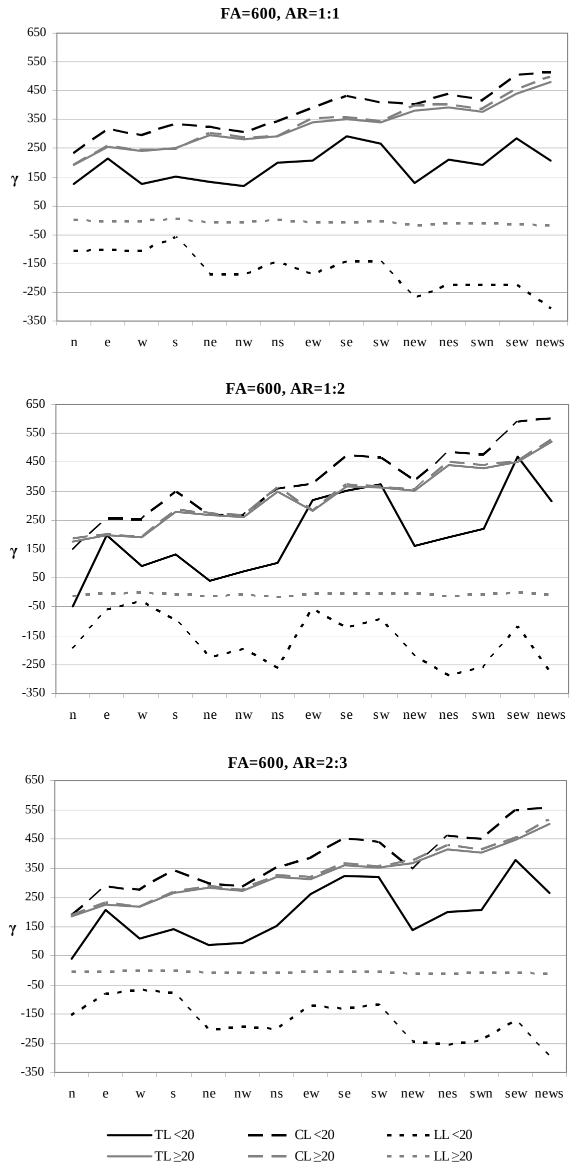
Case	WWR	Cooling Loads %								Lighting Loads %							
		E		N		S		W		E		N		S		W	
	0	0		0		0		0		0		0		0		0	
600, 1:1	5	0.4	*1.9*	-0.3	*-0.2*	0.0	*1.5*	-0.1	*1.2*	-7.2	*-10.0*	-6.5	*-10.6*	-9.3	*-11.0*	-9.6	*-11.6*
	10	1.5	*1.9*	0.2	*-0.2*	1.5	*1.5*	1.3	*1.2*	-2.9	*-10.0*	-4.4	*-10.6*	-1.9	*-11.0*	-2.1	*-11.6*
	20	3.4	*5.4*	1.4	*1.2*	3.2	*4.8*	3.0	*4.3*	-1.2	*-11.9*	-0.7	*-12.1*	-0.4	*-12.5*	0.0	*-12.8*
	30	3.1	*8.2*	1.3	*2.4*	2.9	*7.5*	2.7	*6.8*	-0.3	*-12.7*	-0.2	*-12.9*	-0.1	*-12.9*	0.0	*-13.1*
	40	2.7	*10.9*	1.2	*3.6*	2.5	*10.0*	2.4	*9.2*	-0.1	*-12.8*	-0.1	*-12.9*	-0.1	*-12.9*	0.0	*-13.1*
	50	2.3	*13.0*	1.0	*4.6*	2.1	*11.9*	2.1	*11.1*	-0.1	*-12.9*	0.0	*-13.0*	0.0	*-13.0*	0.0	*-13.1*
	60	2.1	*14.8*	1.0	*5.5*	1.9	*13.6*	1.9	*12.8*	0.0	*-13.0*	0.0	*-13.0*	0.0	*-13.0*	0.0	*-13.1*
	70	1.8	*16.0*	0.9	*6.3*	1.7	*14.7*	1.7	*13.9*	0.0	*-13.0*	0.0	*-13.0*	0.0	*-13.1*	0.0	*-13.1*
	80	1.5	*17.5*	0.8	*7.1*	1.4	*16.2*	1.4	*15.4*	0.0	*-13.0*	0.0	*-13.0*	0.0	*-13.1*	0.0	*-13.1*
	90	1.4	*18.6*	0.7	*7.7*	1.3	*17.2*	1.3	*16.5*	0.0	*-13.0*	0.0	*-13.1*	0.0	*-13.1*	0.0	*-13.1*
600, 1:2	5	0.2	*1.3*	-0.5	*-0.4*	0.0	*2.1*	0.0	*1.0*	-5.8	*-6.8*	-9.5	*-16.2*	-13.7	*-16.6*	-6.5	*-7.3*
	10	1.2	*1.3*	0.1	*-0.4*	2.2	*2.1*	1.0	*1.0*	-1.1	*-6.8*	-7.4	*-16.2*	-3.3	*-16.6*	-0.9	*-7.3*
	20	2.4	*3.8*	2.0	*1.6*	4.7	*7.0*	2.1	*3.1*	-0.3	*-7.6*	-1.3	*-19.1*	-0.9	*-20.1*	0.0	*-7.8*
	30	2.1	*5.7*	1.9	*3.4*	4.2	*10.7*	1.9	*4.9*	-0.1	*-7.7*	-0.2	*-21.1*	-0.2	*-21.2*	0.0	*-7.9*
	40	1.9	*7.6*	1.7	*5.1*	3.6	*14.5*	1.7	*6.6*	0.0	*-7.8*	-0.1	*-21.2*	-0.1	*-21.3*	0.0	*-7.9*
	50	1.6	*9.1*	1.5	*6.6*	3.1	*17.1*	1.5	*8.1*	0.0	*-7.8*	-0.1	*-21.3*	-0.1	*-21.3*	0.0	*-7.9*
	60	1.5	*10.4*	1.4	*7.9*	2.8	*19.4*	1.4	*9.3*	0.0	*-7.8*	0.0	*-21.4*	0.0	*-21.4*	0.0	*-7.9*
	70	1.3	*11.4*	1.3	*9.0*	2.4	*20.7*	1.2	*10.3*	0.0	*-7.9*	0.0	*-21.4*	0.0	*-21.5*	0.0	*-7.9*
	80	1.1	*12.5*	1.1	*10.1*	2.1	*22.9*	1.1	*11.4*	0.0	*-7.9*	0.0	*-21.4*	0.0	*-21.5*	0.0	*-7.9*
	90	1.0	*13.3*	1.0	*11.0*	1.9	*24.3*	1.0	*12.3*	0.0	*-7.9*	0.0	*-21.4*	0.0	*-21.5*	0.0	*-7.9*
600, 2:3	5	0.2	*1.6*	-0.8	*-0.3*	-0.2	*1.8*	-0.2	*1.1*	-6.7	*-8.2*	-10.8	*-14.0*	-13.0	*-14.2*	-8.6	*-8.9*
	10	1.3	*1.6*	0.5	*-0.3*	2.0	*1.8*	1.2	*1.1*	-1.6	*-8.2*	-3.5	*-14.0*	-1.4	*-14.2*	-0.3	*-8.9*
	20	2.8	*4.4*	1.7	*1.4*	4.0	*5.9*	2.4	*3.5*	-0.4	*-9.2*	-0.6	*-16.3*	-0.4	*-16.7*	0.0	*-9.7*
	30	2.5	*6.7*	1.6	*2.9*	3.5	*9.1*	2.2	*5.5*	-0.1	*-9.5*	-0.1	*-17.1*	-0.1	*-17.1*	0.0	*-9.8*
	40	2.1	*8.9*	1.4	*4.4*	3.0	*12.3*	1.9	*7.5*	-0.1	*-9.6*	-0.1	*-17.2*	-0.1	*-17.2*	0.0	*-9.8*
	50	1.9	*10.6*	1.3	*5.6*	2.6	*14.5*	1.7	*9.0*	0.0	*-9.6*	0.0	*-17.3*	0.0	*-17.3*	0.0	*-9.8*
	60	1.7	*12.1*	1.2	*6.8*	2.4	*16.6*	1.5	*10.4*	0.0	*-9.7*	0.0	*-17.3*	0.0	*-17.3*	0.0	*-9.8*
	70	1.5	*13.1*	1.1	*7.7*	2.0	*17.8*	1.3	*11.4*	0.0	*-9.7*	0.0	*-17.3*	0.0	*-17.4*	0.0	*-9.8*
	80	1.2	*14.4*	0.9	*8.6*	1.8	*19.6*	1.2	*12.6*	0.0	*-9.7*	0.0	*-17.4*	0.0	*-17.4*	0.0	*-9.8*
	90	1.1	*15.3*	0.9	*9.4*	1.6	*20.8*	1.1	*13.5*	0.0	*-9.7*	0.0	*-17.4*	0.0	*-17.4*	0.0	*-9.8*
1200, 1:1	5	0.3	*1.4*	-0.2	*-0.2*	-0.1	*1.0*	-0.2	*0.8*	-5.3	*-7.4*	-4.6	*-8.0*	-6.9	*-8.2*	-7.2	*-8.7*
	10	1.1	*1.4*	0.0	*-0.2*	1.1	*1.0*	1.0	*0.8*	-2.2	*-7.4*	-3.5	*-8.0*	-1.4	*-8.2*	-1.6	*-8.7*
	20	2.5	*3.9*	1.0	*0.8*	2.4	*3.5*	2.2	*3.1*	-0.9	*-8.7*	-0.5	*-8.9*	-0.3	*-9.2*	0.0	*-9.4*
	30	2.3	*6.1*	0.9	*1.7*	2.2	*5.5*	2.0	*5.0*	-0.2	*-9.2*	-0.1	*-9.4*	-0.1	*-9.4*	0.0	*-9.5*
	40	2.0	*8.2*	0.9	*2.6*	1.9	*7.4*	1.8	*6.8*	-0.1	*-9.3*	0.0	*-9.4*	0.0	*-9.4*	0.0	*-9.5*
	50	1.8	*9.8*	0.8	*3.4*	1.6	*8.9*	1.6	*8.3*	-0.1	*-9.4*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*
	60	1.6	*11.3*	0.7	*4.1*	1.5	*10.3*	1.5	*9.7*	0.0	*-9.4*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*
	70	1.4	*12.3*	0.7	*4.7*	1.3	*11.3*	1.3	*10.7*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*
	80	1.2	*13.6*	0.6	*5.3*	1.1	*12.5*	1.1	*11.8*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*
	90	1.1	*14.5*	0.5	*5.8*	1.0	*13.4*	1.0	*12.7*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*	0.0	*-9.5*
1200, 1:2	5	0.2	*1.0*	-0.7	*-0.4*	-0.3	*1.4*	0.0	*0.6*	-3.6	*-4.9*	-8.8	*-12.1*	-11.1	*-12.3*	-4.8	*-5.7*
	10	0.8	*1.0*	0.3	*-0.4*	1.7	*1.4*	0.7	*0.6*	-1.4	*-4.9*	-3.6	*-12.1*	-1.4	*-12.3*	-1.0	*-5.7*
	20	1.8	*2.7*	1.5	*1.1*	3.5	*4.9*	1.5	*2.2*	-0.6	*-5.6*	-0.6	*-13.9*	-0.4	*-14.3*	0.0	*-6.0*
	30	1.6	*4.3*	1.4	*2.4*	3.1	*7.7*	1.4	*3.5*	-0.1	*-5.9*	-0.1	*-14.6*	-0.1	*-14.6*	0.0	*-6.1*
	40	1.4	*5.7*	1.2	*3.7*	2.7	*10.5*	1.2	*4.8*	-0.1	*-5.9*	-0.1	*-14.7*	-0.1	*-14.7*	0.0	*-6.1*
	50	1.2	*6.9*	1.1	*4.8*	2.3	*12.6*	1.1	*5.8*	0.0	*-6.0*	0.0	*-14.7*	0.0	*-14.7*	0.0	*-6.1*
	60	1.1	*7.9*	1.1	*5.8*	2.1	*14.4*	1.0	*6.8*	0.0	*-6.0*	0.0	*-14.8*	0.0	*-14.8*	0.0	*-6.1*
	70	1.0	*8.7*	0.9	*6.6*	1.8	*15.6*	0.9	*7.6*	0.0	*-6.0*	0.0	*-14.8*	0.0	*-14.8*	0.0	*-6.1*
	80	0.9	*9.6*	0.8	*7.4*	1.6	*17.2*	0.8	*8.4*	0.0	*-6.0*	0.0	*-14.8*	0.0	*-14.8*	0.0	*-6.1*
	90	0.8	*10.3*	0.8	*8.1*	1.4	*18.4*	0.7	*9.0*	0.0	*-6.0*	0.0	*-14.8*	0.0	*-14.8*	0.0	*-6.1*
1200, 2:3	5	0.1	*1.0*	-0.4	*-0.3*	-0.1	*1.2*	-0.1	*0.7*	-5.3	*-6.3*	-6.1	*-10.0*	-8.6	*-10.4*	-6.0	*-6.8*
	10	1.0	*1.0*	0.1	*-0.3*	1.3	*1.2*	0.8	*0.7*	-1.1	*-6.3*	-4.2	*-10.0*	-1.9	*-10.4*	-0.9	*-6.8*
	20	2.1	*3.2*	1.2	*0.9*	3.0	*4.2*	1.8	*2.5*	-0.3	*-7.0*	-0.7	*-11.4*	-0.4	*-11.8*	0.0	*-7.3*
	30	1.9	*4.9*	1.2	*2.1*	2.7	*6.7*	1.6	*4.1*	-0.1	*-7.1*	-0.2	*-12.1*	-0.1	*-12.1*	0.0	*-7.3*
	40	1.7	*6.6*	1.1	*3.2*	2.3	*9.1*	1.4	*5.5*	0.0	*-7.2*	-0.1	*-12.2*	-0.1	*-12.2*	0.0	*-7.3*
	50	1.5	*8.0*	1.0	*4.1*	2.0	*10.9*	1.3	*6.8*	0.0	*-7.2*	0.0	*-12.2*	0.0	*-12.2*	0.0	*-7.3*
	60	1.3	*9.2*	0.9	*5.0*	1.8	*12.5*	1.2	*7.9*	0.0	*-7.3*	0.0	*-12.3*	0.0	*-12.3*	0.0	*-7.3*
	70	1.2	*10.1*	0.8	*5.7*	1.6	*13.7*	1.1	*8.7*	0.0	*-7.3*	0.0	*-12.3*	0.0	*-12.3*	0.0	*-7.3*
	80	1.0	*11.1*	0.7	*6.5*	1.4	*15.1*	0.9	*9.7*	0.0	*-7.3*	0.0	*-12.3*	0.0	*-12.3*	0.0	*-7.3*
	90	0.9	*11.9*	0.7	*7.1*	1.3	*16.1*	0.8	*10.4*	0.0	*-7.3*	0.0	*-12.3*	0.0	*-12.3*	0.0	*-7.3*
2000, 1:1	5	0.2	*1.0*	-0.2	*1.0*	-0.1	*0.8*	-0.2	*0.6*	-4.2	*-5.9*	-3.6	*-6.3*	-5.5	*-6.6*	-5.7	*-6.9*
	10	0.8	*1.0*	0.0	*1.0*	0.9	*0.8*	0.8	*0.6*	-1.8	*-5.9*	-2.8	*-6.3*	-1.1	*-6.6*	-1.3	*-6.9*
	20	2.0	*3.0*	0.8	*0.6*	1.9	*2.7*	1.8	*2.4*	-0.7	*-6.9*	-0.5	*-7.0*	-0.3	*-7.2*	0.0	*-7.4*
	30	1.8	*4.8*	0.7	*1.4*	1.7	*4.3*	1.6	*3.9*	-0.2	*-7.2*	-0.1	*-7.3*	-0.1	*-7.3*	0.0	*-7.5*
	40	1.6	*6.5*	0.7	*2.0*	1.5	*5.9*	1.4	*5.4*	-0.1	*-7.3*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.5*
	50	1.5	*7.8*	0.6	*2.7*	1.3	*7.1*	1.3	*6.6*	0.0	*-7.3*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.5*
	60	1.3	*9.1*	0.6	*3.2*	1.2	*8.3*	1.2	*7.7*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.5*
	70	1.2	*10.0*	0.5	*3.7*	1.1	*9.1*	1.1	*8.6*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.5*
	80	1.0	*11.0*	0.5	*4.2*	0.9	*10.1*	0.9	*9.5*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.5*
	90	0.9	*11.8*	0.4	*4.6*	0.8	*10.8*	0.8	*10.3*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.4*	0.0	*-7.5*
2000, 1:2	5	0.1	*0.7*	-0.3	*-0.3*	-0.2	*1.0*	-0.1	*0.5*	-2.9	*-4.0*	-5.3	*-9.3*	-8.1	*-9.6*	-3.9	*-4.7*
	10	0.6	*0.7*	0.0	*-0.3*	1.2	*1.0*	0.5	*0.5*	-1.2	*-4.0*	-4.2	*-9.3*	-1.7	*-9.6*	-0.8	*-4.7*
	20	1.4	*2.1*	1.1	*0.8*	2.7	*3.8*	1.2	*1.7*	-0.4	*-4.6*	-0.7	*-10.5*	-0.4	*-10.9*	0.0	*-4.8*
	30	1.3	*3.4*	1.1	*1.9*	2.5	*6.1*	1.1	*2.8*	-0.1	*-4.7*	-0.2	*-11.2*	-0.1	*-11.2*	0.0	*-4.9*
	40	1.2	*4.5*	1.0	*2.9*	2.2	*8.3*	1.0	*3.8*	0.0	*-4.8*	0.0	*-11.2*	-0.1	*-11.2*	0.0	*-4.9*
	50	1.0	*5.5*	0.9	*3.8*	1.9	*10.1*	0.9	*4.7*	0.0	*-4.8*	0.0	*-11.3*	0.0	*-11.3*	0.0	*-4.9*
	60	0.9	*6.4*	0.9	*4.6*	1.7	*11.6*	0.8	*5.5*	0.0	*-4.8*	0.0	*-11.3*	0.0	*-11.3*	0.0	*-4.9*
	70	0.8	*7.1*	0.8	*5.3*	1.5	*12.7*	0.7	*6.1*	0.0	*-4.9*	0.0	*-11.3*	0.0	*-11.3*	0.0	*-4.9*
	80	0.7	*7.8*	0.7	*5.9*	1.3	*14.0*	0.7	*6.8*	0.0	*-4.9*	0.0	*-11.3*	0.0	*-11.3*	0.0	*-4.9*
	90	0.6	*8.4*	0.6	*6.5*	1.2	*15.0*	0.6	*7.3*	0.0	*-4.9*	0.0	*-11.3*	0.0	*-11.3*	0.0	*-4.9*
2000, 2:3	5	0.1	*0.8*	-0.3	*-0.3*	-0.1	*0.9*	-0.2	*0.5*	-3.9	*-5.0*	-4.5	*-7.9*	-6.9	*-8.2*	-5.1	-5.5
	10	0.7	*0.8*	0.0	*-0.3*	1.0	*0.9*	0.7	*0.5*	-1.2	*-5.0*	-3.6	*-7.9*	-1.4	*-8.2*	-0.5	-5.5
	20	1.7	*2.5*	1.0	*0.7*	2.3	*3.3*	1.4	*1.9*	-0.3	*-5.5*	-0.6	*-8.9*	-0.3	*-9.2*	0.0	-5.8
	30	1.5	*3.9*	0.9	*1.6*	2.1	*5.3*	1.3	*3.2*	-0.1	*-5.7*	-0.1	*-9.4*	-0.1	*-9.4*	0.0	-5.8
	40	1.3	*5.3*	0.9	*2.5*	1.9	*7.2*	1.2	*4.4*	0.0	*-5.7*	0.0	*-9.4*	0.0	*-9.4*	0.0	-5.8
	50	1.2	*6.4*	0.8	*3.3*	1.6	*8.7*	1.0	*5.4*	0.0	*-5.7*	0.0	*-9.5*	0.0	*-9.5*	0.0	-5.8
	60	1.1	*7.4*	0.7	*4.0*	1.5	*10.1*	1.0	*6.3*	0.0	*-5.8*	0.0	*-9.5*	0.0	*-9.5*	0.0	-5.8
	70	1.0	*8.2*	0.7	*4.6*	1.3	*11.1*	0.9	*7.0*	0.0	*-5.8*	0.0	*-9.5*	0.0	*-9.5*	0.0	-5.8
	80	0.8	*9.0*	0.6	*5.2*	1.1	*12.3*	0.8	*7.8*	0.0	*-5.8*	0.0	*-9.5*	0.0	*-9.5*	0.0	-5.8
	90	0.7	*9.7*	0.5	*5.7*	1.0	*13.1*	0.7	*8.4*	0.0	*-5.8*	0.0	*-9.5*	0.0	*-9.5*	0.0	-5.8

*Table 3, % change in Cooling and Lighting Loads (CL%, LL%) for **e**, **n**, **s**, **w** orientations; non-italicised numbers show % difference for each case as compared to the case preceding it, italicised numbers show % difference for each case as compared to the base case which is defined as having 'no windows' for each of the six conditions.*



*Figures 6, 7 and 8, Graphs showing **γ**=δL/δWWR, change in Load per unit change in WWR for different orientations within each aspect ratio*

		WWR < 20						WWR ≥ 20					
		Total Load		Cooling Load		Lighting Load		Total Load		Cooling Load		Lighting Load	
Variable	Coefficient	beta	sig.	beta	sig.	beta	sig.	beta	sig.	beta	sig.	beta	sig.
(Constant)	k	3003.688	.000	3129.546	.000	-125.858	.564	5054.207	.000	2938.500	.001	2115.706	.000
FA	β1	147.929	.000	117.033	.000	30.897	.000	146.311	.000	117.183	.000	29.127	.000
WWR	β2	232.822	.000	280.082	.000	-47.261	.015	206.040	.000	207.922	.000	-1.883	.240
n	β3	-3901.726	.000	-2468.022	.000	-1433.705	.000	-10455.786	.000	-6572.329	.000	-3883.457	.000
e	β4	-2780.018	.000	-1824.612	.000	-955.406	.001	-7930.442	.000	-4431.021	.000	-3499.421	.000
w	β5	-3102.959	.000	-2030.722	.000	-1072.237	.000	-8638.455	.000	-5063.868	.000	-3574.587	.000
s	β6	-3334.116	.000	-1790.654	.000	-1543.463	.000	-6649.971	.000	-2731.928	.005	-3918.043	.000
ne	β7	-4346.577	.000	-2044.340	.000	-2302.237	.000	-7383.329	.000	-2329.160	.016	-5054.169	.000
nw	β8	-4659.870	.000	-2238.975	.000	-2420.895	.000	-8090.151	.000	-2960.722	.002	-5129.429	.000
ns	β9	-4900.125	.000	-2008.004	.000	-2892.121	.000	-6101.463	.000	-628.581	.515	-5472.882	.000
ew	β10	-3526.140	.000	-1585.397	.000	-1940.743	.000	-5578.789	.000	-833.484	.388	-4745.306	.000
se	β11	-3770.582	.000	-1358.624	.000	-2411.958	.000	-3596.844	.000	1491.756	.122	-5088.600	.000
sw	β12	-4084.420	.000	-1553.112	.000	-2531.308	.000	-4299.245	.000	865.305	.370	-5164.550	.000
new	β13	-5095.614	.000	-1806.187	.000	-3289.427	.000	-5031.377	.000	1268.605	.189	-6299.982	.000
nes	β14	-5336.294	.000	-1575.623	.000	-3760.671	.000	-3048.832	.001	3594.607	.000	-6643.438	.000
swn	β15	-5649.939	.000	-1769.939	.000	-3880.001	.000	-3750.780	.000	2968.588	.002	-6719.369	.000
sew	β16	-4520.561	.000	-1120.718	.000	-3399.842	.000	-1245.937	.168	5089.162	.000	-6335.099	.000
news	β17	-6086.169	.000	-1337.657	.000	-4748.512	.000	-697.945	.440	7191.974	.000	-7889.920	.000
FA·WWR·n	β18	.107	.044	.059	.108	.048	.187	.009	.480	-.020	.161	.029	.000
FA·WWR·e	β19	-.004	.939	.166	.000	-.170	.000	.177	.000	.181	.000	-.004	.343
FA·WWR·w	β20	-.124	.020	.099	.007	-.223	.000	.142	.000	.147	.000	-.004	.338
FA·WWR·s	β21	.103	.053	.066	.070	.037	.319	.033	.013	.003	.814	.029	.000
FA·WWR·ne	β22	.004	.945	.179	.000	-.176	.000	.193	.000	.200	.000	-.008	.085
FA·WWR·nw	β23	-.118	.027	.110	.003	-.228	.000	.158	.000	.165	.000	-.008	.084
FA·WWR·ns	β24	.110	.038	.079	.031	.031	.392	.048	.000	.022	.116	.026	.000
FA·WWR·ew	β25	-.231	.000	.216	.000	-.447	.000	.326	.000	.367	.000	-.041	.000
FA·WWR·se	β26	-.001	.977	.186	.000	-.188	.000	.217	.000	.224	.000	-.007	.096
FA·WWR·sw	β27	-.124	.020	.117	.002	-.240	.000	.182	.000	.189	.000	-.007	.094
FA·WWR·new	β28	-.223	.000	.230	.000	-.452	.000	.342	.000	.386	.000	-.044	.000
FA·WWR·nes	β29	.006	.909	.199	.000	-.193	.000	.232	.000	.243	.000	-.011	.015
FA·WWR·swn	β30	-.116	.029	.129	.000	-.246	.000	.197	.000	.208	.000	-.011	.015
FA·WWR·sew	β31	-.228	.000	.237	.000	-.465	.000	.366	.000	.410	.000	-.044	.000
FA·WWR·news	β32	-.220	.000	.249	.000	-.470	.000	.382	.000	.429	.000	-.048	.000
FA·AR·n	β33	.941	.000	.691	.000	.250	.136	2.293	.000	2.047	.000	.246	.024
FA·AR·e	β34	.202	.403	.286	.085	-.085	.613	2.481	.000	1.788	.000	.693	.000
FA·AR·w	β35	-.137	.569	.221	.183	-.358	.033	2.432	.000	1.848	.000	.583	.000
FA·AR·s	β36	-.876	.000	-.278	.095	-.598	.000	.938	.004	.857	.013	.082	.451
FA·AR·ne	β37	.162	.501	.068	.682	.094	.573	.091	.778	.320	.354	-.229	.035
FA·AR·nw	β38	-.208	.389	-.030	.855	-.177	.290	.034	.916	.373	.280	-.338	.002
FA·AR·ns	β39	-.921	.000	-.505	.003	-.417	.013	-1.452	.000	-.612	.076	-.840	.000
FA·AR·ew	β40	-.942	.000	-.429	.010	-.514	.002	.229	.477	.120	.727	.109	.317
FA·AR·se	β41	-1.677	.000	-.924	.000	-.753	.000	-1.246	.000	-.853	.013	-.393	.000
FA·AR·sw	β42	-2.015	.000	-.991	.000	-1.024	.000	-1.312	.000	-.810	.019	-.502	.000
FA·AR·new	β43	-.979	.000	-.647	.000	-.333	.048	-2.161	.000	-1.348	.000	-.813	.000
FA·AR·nes	β44	-1.722	.000	-1.150	.000	-.572	.001	-3.635	.000	-2.321	.000	-1.314	.000
FA·AR·swn	β45	-2.061	.000	-1.218	.000	-.843	.000	-3.703	.000	-2.279	.000	-1.424	.000
FA·AR·sew	β46	-2.816	.000	-1.637	.000	-1.179	.000	-3.495	.000	-2.519	.000	-.977	.000
FA·AR·news	β47	-2.862	.000	-1.864	.000	-.999	.000	-5.886	.000	-3.987	.000	-1.899	.000
FA·WWR·AR·n	β48	-.289	.000	-.140	.000	-.149	.000	-.030	.001	-.007	.450	-.023	.000
FA·WWR·AR·e	β49	-.027	.483	-.102	.000	.075	.006	-.096	.000	-.096	.000	.001	.837
FA·WWR·AR·w	β50	.055	.159	-.071	.009	.126	.000	-.084	.000	-.087	.000	.003	.379
FA·WWR·AR·s	β51	-.033	.405	.025	.346	-.058	.034	.044	.000	.064	.000	-.020	.000
FA·WWR·AR·ne	β52	-.160	.000	-.101	.000	-.059	.030	-.045	.000	-.043	.000	-.003	.392
FA·WWR·AR·nw	β53	-.074	.057	-.066	.015	-.009	.748	-.034	.000	-.033	.000	-.001	.857
FA·WWR·AR·ns	β54	-.165	.000	.028	.295	-.193	.000	.094	.000	.117	.000	-.023	.000
FA·WWR·AR·ew	β55	.186	.000	-.029	.273	.216	.000	-.100	.000	-.123	.000	.023	.000
FA·WWR·AR·se	β56	.099	.012	.067	.013	.032	.242	.027	.002	.027	.004	.000	.990
FA·WWR·AR·sw	β57	.180	.000	.098	.000	.082	.003	.039	.000	.037	.000	.002	.492
FA·WWR·AR·new	β58	.053	.175	-.028	.301	.081	.003	-.050	.000	-.069	.000	.020	.000
FA·WWR·AR·nes	β59	-.033	.399	.070	.010	-.103	.000	.078	.000	.081	.000	-.003	.295
FA·WWR·AR·swn	β60	.048	.215	.101	.000	-.052	.055	.089	.000	.091	.000	-.001	.710
FA·WWR·AR·sew	β61	.312	.000	.140	.000	.172	.000	.023	.009	.001	.941	.022	.000
FA·WWR·AR·news	β62	.180	.000	.143	.000	.037	.169	.073	.000	.054	.000	.019	.000
R square		1.000		1.000		1.000		1.000		1.000		.998	
Adjusted R sq.		1.000		1.000		1.000		.999		.999		.998	
Standard error		498.598		343.117		346.225		2028.513		2126.926		683.533	

Table 4, Coefficient (β) and k and Significance values for regression variables along with R square and standard error for each regression