

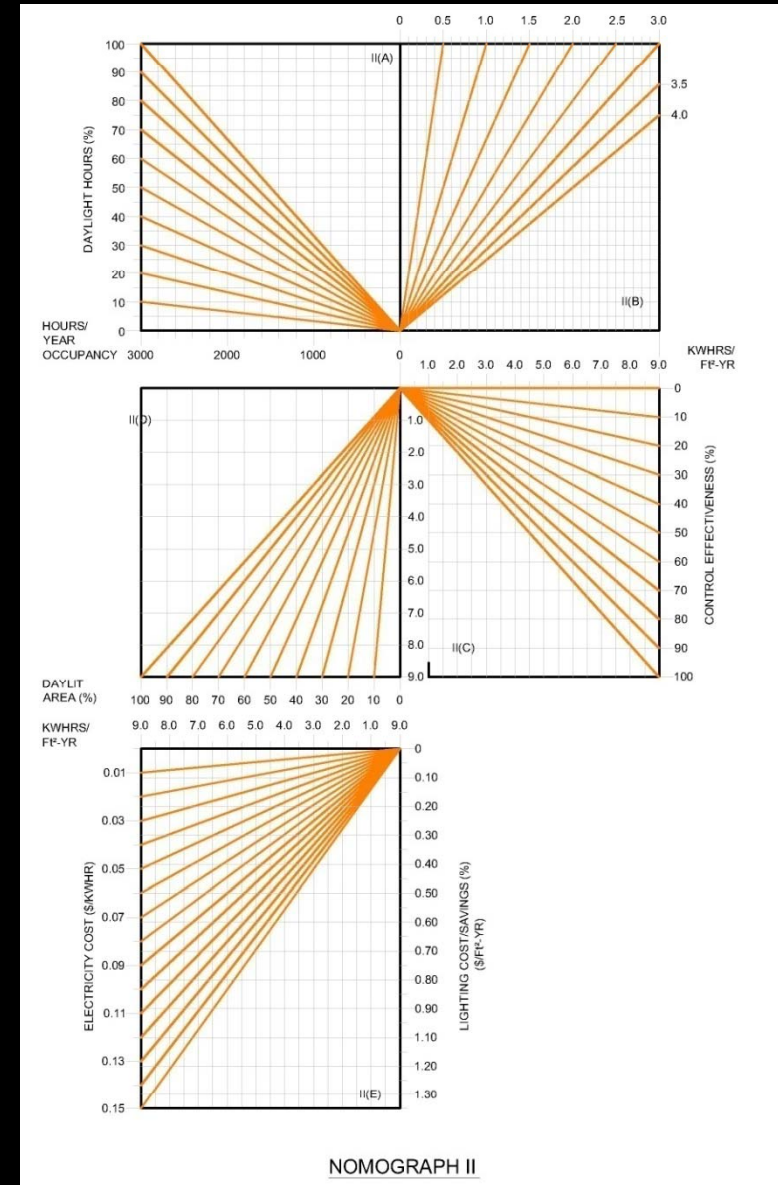
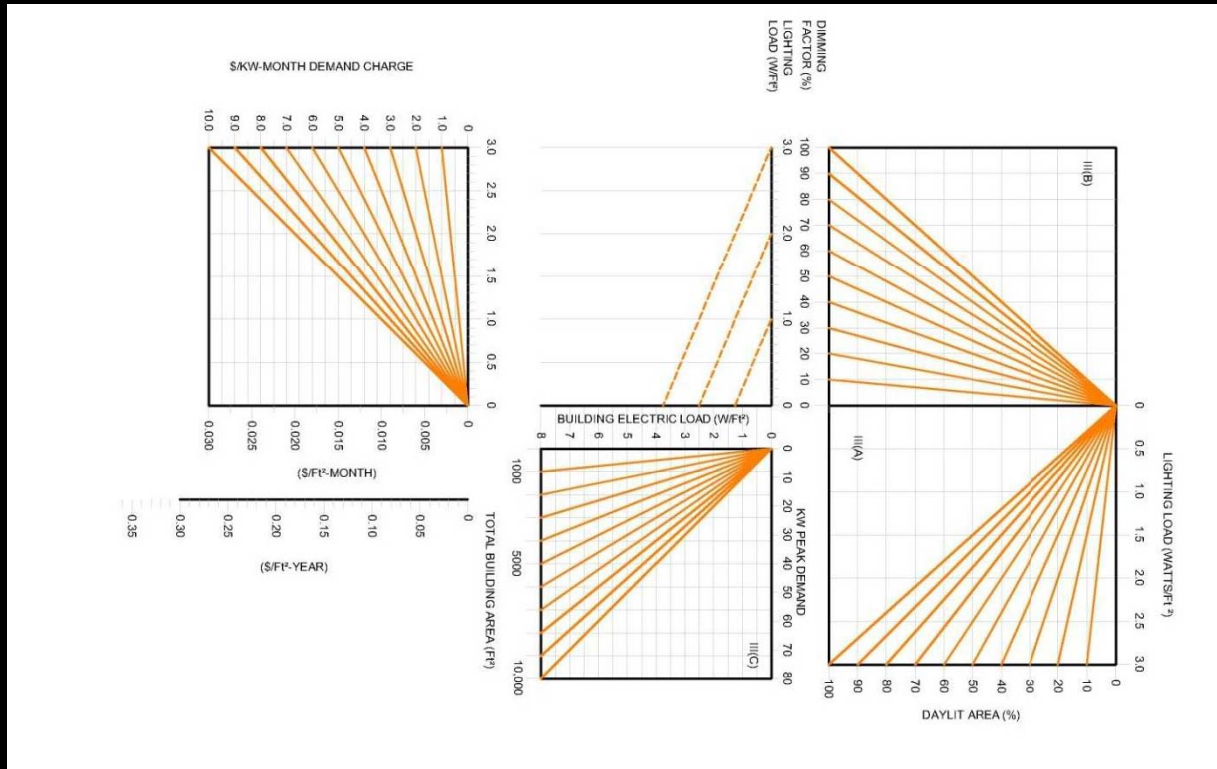
# DAYLIGHTING NOMOGRAPHS REVISITED

RADIANCE WORKSHOP, October 23 2009

ROHIT MANUDHANE | CHRISTOPH REINHART  
Harvard Graduate School of Design

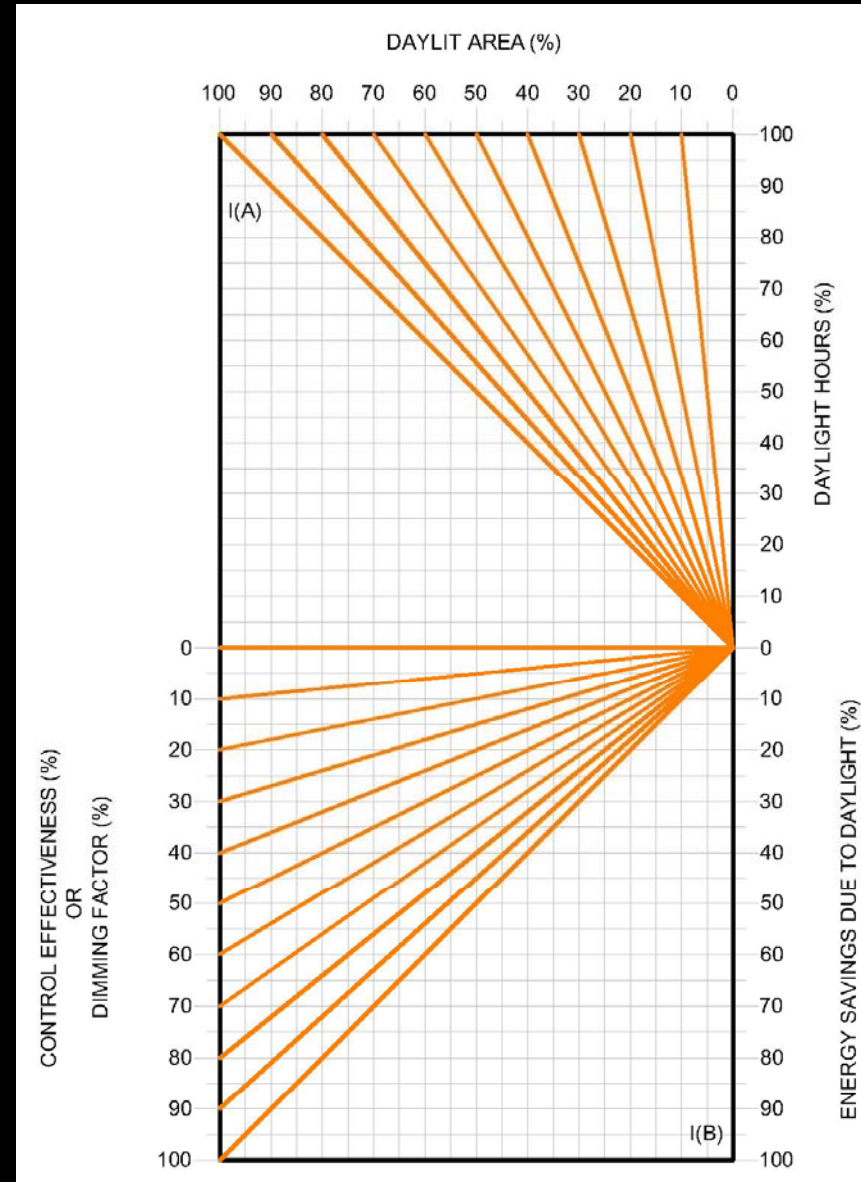
# LBL DAYLIGHTING NOMOGRAPHS

- Originated from the 1984 paper titled LBL Daylighting Nomographs by Selkowitz and Gabel
- Validated using DOE 2 measurements



# USING THE NOMOGRAPHS

- Determine potential impact of daylighting in a commercial building.
- Flexibility in:
  - Latitude of location
  - Occupancy hours and schedule
  - Total building floor area
  - Daylight floor area
  - Visible Light transmittance of glazing
  - Glazing area
  - Choice of dimming or one step controls
  - Maximum dimming factor



Harvard Graduate School of Design

# USING THE NOMOGRAPHS

Worksheet.xlsx - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Acrobat

Clipboard Font Alignment Number Styles Cells Editing

Input (i) or Output (o) value for the specified Nomographs										Worksheet Item no.	Description of Worksheet Item	Base Case	Case 1	Case 2	Case 3	Case 4	
Charts S.1 - S.7													Houston	Boston	Mumbai		
I	II	III	IV	1	2	3	4	5	6	7							
				i	i						1	Latitude of Building Location	29.75	42.35			
				i	i						2	Daily Occupancy Schedule	8am to 6pm	8am to 6pm			
								i	i	i	3	Gross Area per Floor (Ft <sup>2</sup> )	3000	3000			
								i	i	i	4	Typical Floor Shape: Length to Width Ratio	3:2	3:2			
						i	i				5a	Lighting Control Type	Dimming	Dimming			
						i	i				5b	Illumination Level (fc)	50	50			
						i	i				5c	Side Lighting Glass Area Fraction	0.42	0.42			
												Top Lighting Glass Area Fraction	None	None			
						i	i				5d	Side Lighting Glass Visible Transmittance (TVIS)	0.8	0.8			
												Top Lighting Glass Visible Transmittance (TVIS) X Well Factor	None	None			
											6	Annual Hours of Occupancy	2500	2500			
	i										7	Installed Lighting Load (Watts/Ft <sup>2</sup> )	1	1			
	i	i									8	Electricity Cost (\$/kWh)	0.11	0.076			
			i								9	Gross Total Building Area (Ft <sup>2</sup> )	15000	15000			
											10	Non-Lighting Electric Loads (Watts/Ft <sup>2</sup> )	2	2			
											11	Peak Demand Rate (\$/kW-month)	?	?			
i	i			o	o						12	Daylit Hours (%)	0.95	0.93	0.96		
i	i	i						o	o	o	13	Total Daylit Area (%) 10 feet perimeter zone	62	62			
i	i					o	o				14	Control Effectiveness (%)	18	18			
i		i									15	Dimming Factor (%)	85	85			
o											16	Annual Energy Savings due to Daylight (%)					
o											17	Daylight Peak Load Savings (%)					
											18						

Case 3 Case 2 Case 1 Sheet2 Sheet3

Tuesday, October 20, 2009

Ready

Thesis Radiance Workshop... Control effectiveness... Worksheet.xlsx

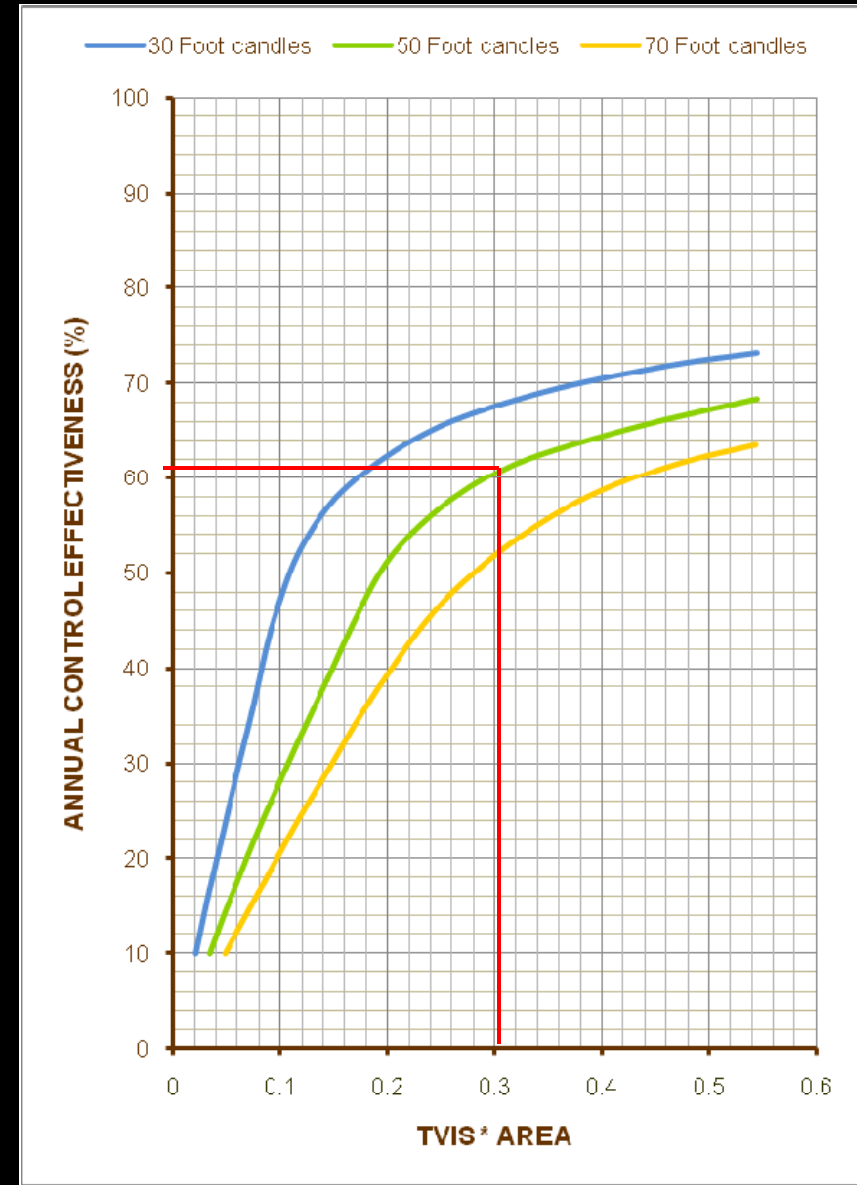
9:00 AM

# USING THE NOMOGRAPHS

- Daylight hours: 95%
- Daylit area: 62%
- Threshold Illumination level: 50 foot candles
- TVIS \* Area: 0.3
- Annual Control Effectiveness: 61%

Worksheet .xlsx - Microsoft Excel

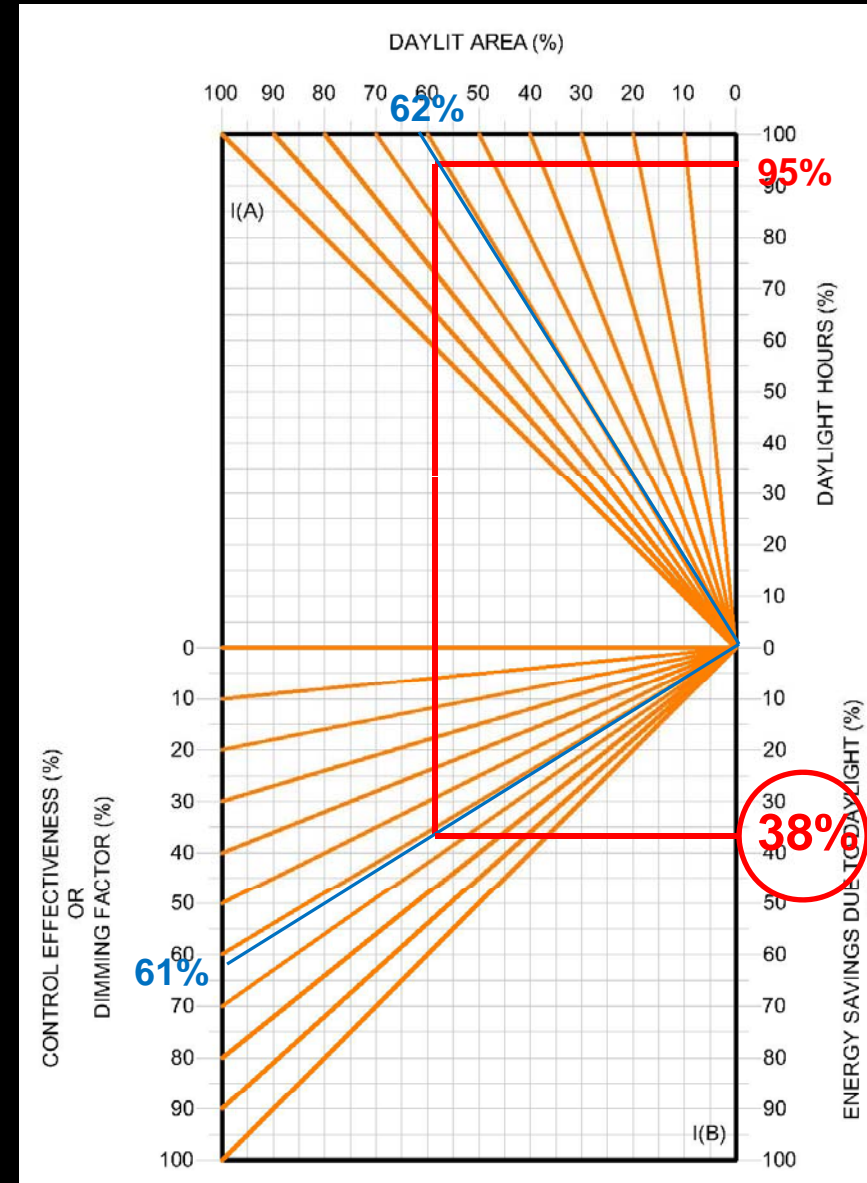
Input (i) or Output (o) value for the specified	Nomographs							Charts S.1 - S.7	Worksheet Item no.	Description of Worksheet Item	Base Case	Case 1	Case 2	Case 3	Case 4
	I	II	III	IV	1	2	3	4	5	6	7	Houston	Boston	Mumbai	
1												29.75	42.35		
2												8am to 6pm	8am to 6pm		
3												3000	3000		
4												3.2	3.2		
5a												Dimming	Dimming		
5b												50	50		
5c												0.42	0.42		
												None	None		
												0.8	0.8		
												None	None		
6												2500	2500		
7												1	1		
8												0.11	0.076		
9												15000	15000		
10												2	2		
11												?	?		
12												0.95	0.93	0.96	
13												62	62		
14												18	18		
15												85	85		
16															
17															
18															



# USING THE NOMOGRAPHS

- Daylight hours: 95%
- Daylit area: 62%
- Threshold Illumination level: 50 foot candles
- TVIS \* Area: 0.3
- Annual Control Effectiveness: 61%

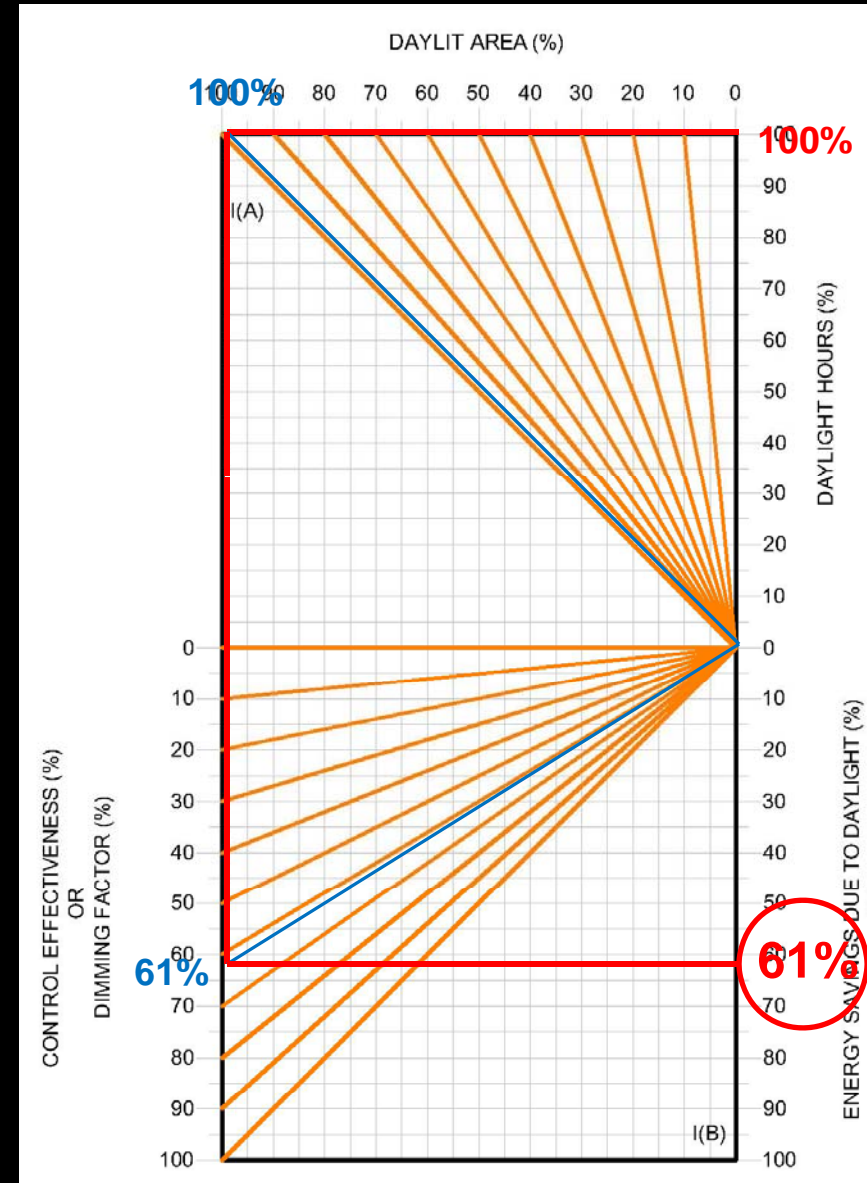
Input (i) or Output (o) value for the specified	Nomographs							Charts S.1 - S.7	Worksheet Item no.	Description of Worksheet Item	Base Case	Case 1	Case 2	Case 3	Case 4
	I	II	III	IV	1	2	3	4	5	6	7	Houston	Boston	Mumbai	
1												29.75	42.35		
2												8am to 6pm	8am to 6pm		
3												3000	3000		
4												3.2	3.2		
5a												Dimming	Dimming		
5b												50	50		
5c												0.42	0.42		
												None	None		
												0.8	0.8		
												None	None		
6												2500	2500		
7												1	1		
8												0.11	0.076		
9												15000	15000		
10												2	2		
11												?	?		
12												0.95	0.93	0.96	
13												62	62		
14												18	18		
15												85	85		
16															
17															



# USING THE NOMOGRAPHS

- Daylight hours: 100%
- Daylit area: 100%
- Threshold Illumination level: 50 foot candles
- TVIS \* Area: 0.3
- Annual Control Effectiveness: **61%**

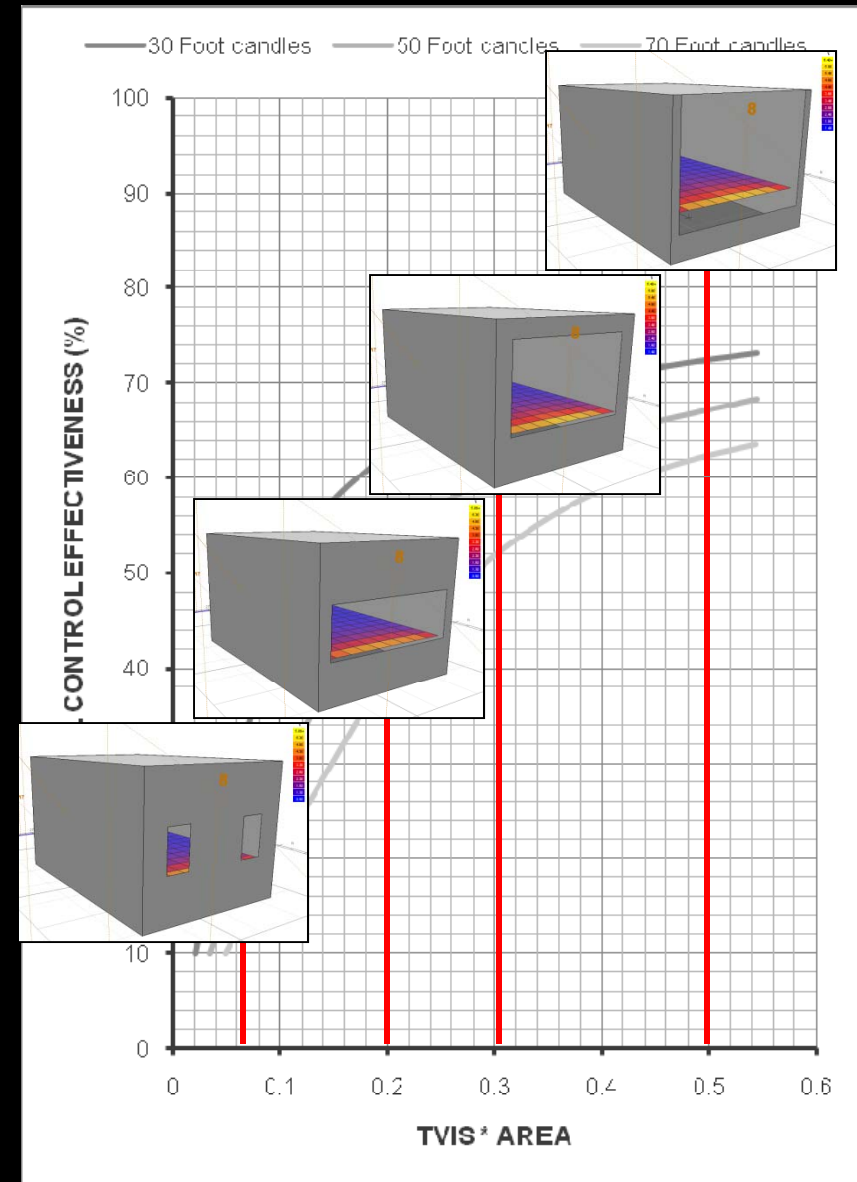
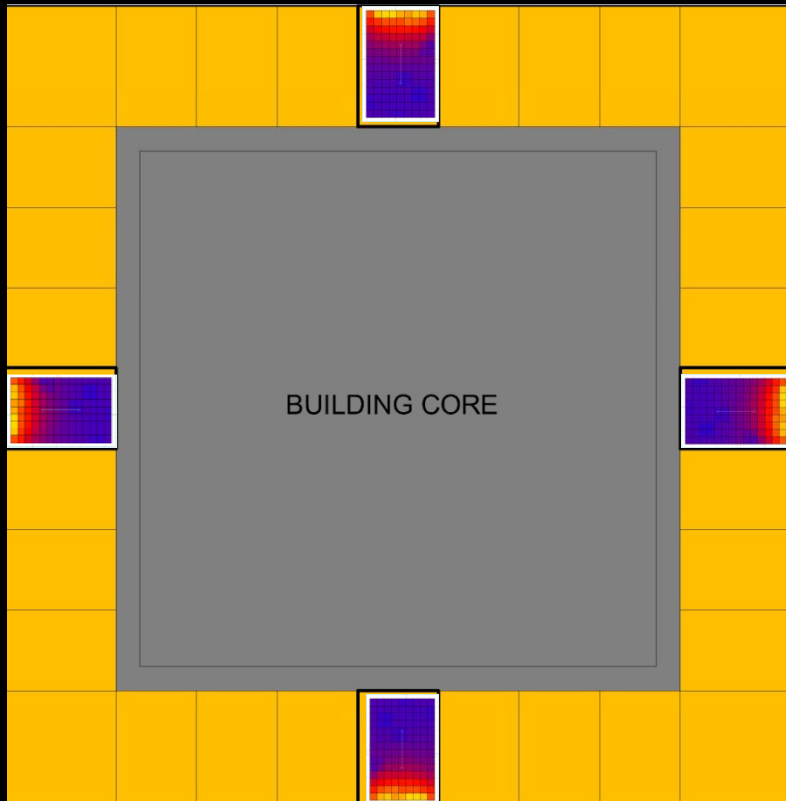
Input (i) or Output (o) value for the specified Nomographs	Charts S.1 - S.7	Worksheet Item no.	Description of Worksheet Item	Base Case	Case 1	Case 2	Case 3	Case 4
		1	Latitude of Building Location	29.75	42.35			
		2	Daily Occupancy Schedule	8am to 6pm	8am to 6pm			
		3	Gross Area per Floor (Ft <sup>2</sup> )	3000	3000			
		4	Typical Floor Shape: Length to Width Ratio	3.2	3.2			
		5a	Lighting Control Type	Dimming	Dimming			
		5b	Illumination Level (fc)	50	50			
		5c	Side Lighting Glass Area Fraction	0.42	0.42			
			Top Lighting Glass Area Fraction	None	None			
		5d	Side Lighting Glass Visible Transmittance (TVIS)	0.8	0.8			
			Top Lighting Glass Visible Transmittance (TVIS) X Well Factor	None	None			
		6	Annual Hours of Occupancy	2500	2500			
		7	Installed Lighting Load (Watts/Ft <sup>2</sup> )	1	1			
		8	Electricity Cost (\$/kWh)	0.11	0.076			
		9	Gross Total Building Area (Ft <sup>2</sup> )	15000	15000			
		10	Non-Lighting Electric Loads (Watts/Ft <sup>2</sup> )	2	2			
		11	Peak Demand Rate (\$/kW-month)	?	?			
		12	Daylit Hours (%)	0.95	0.93	0.96		
		13	Total Daylit Area (%) 10 feet perimeter zone	62	62			
		14	Control Effectiveness (%)	18	18			
		15	Dimming Factor (%)	85	85			
		16	Annual Energy Savings due to Daylight (%)					
		17	Daylight Peak Load Savings (%)					



# RECREATING NOMOGRAPH RESULTS IN RADIANCE/ DAYSIM

The Nomograph parameters:

- Occupancy hours: 0800 to 1800
- Lighting Power Density: 1W/ sq ft
- No individual lighting controls, no blinds

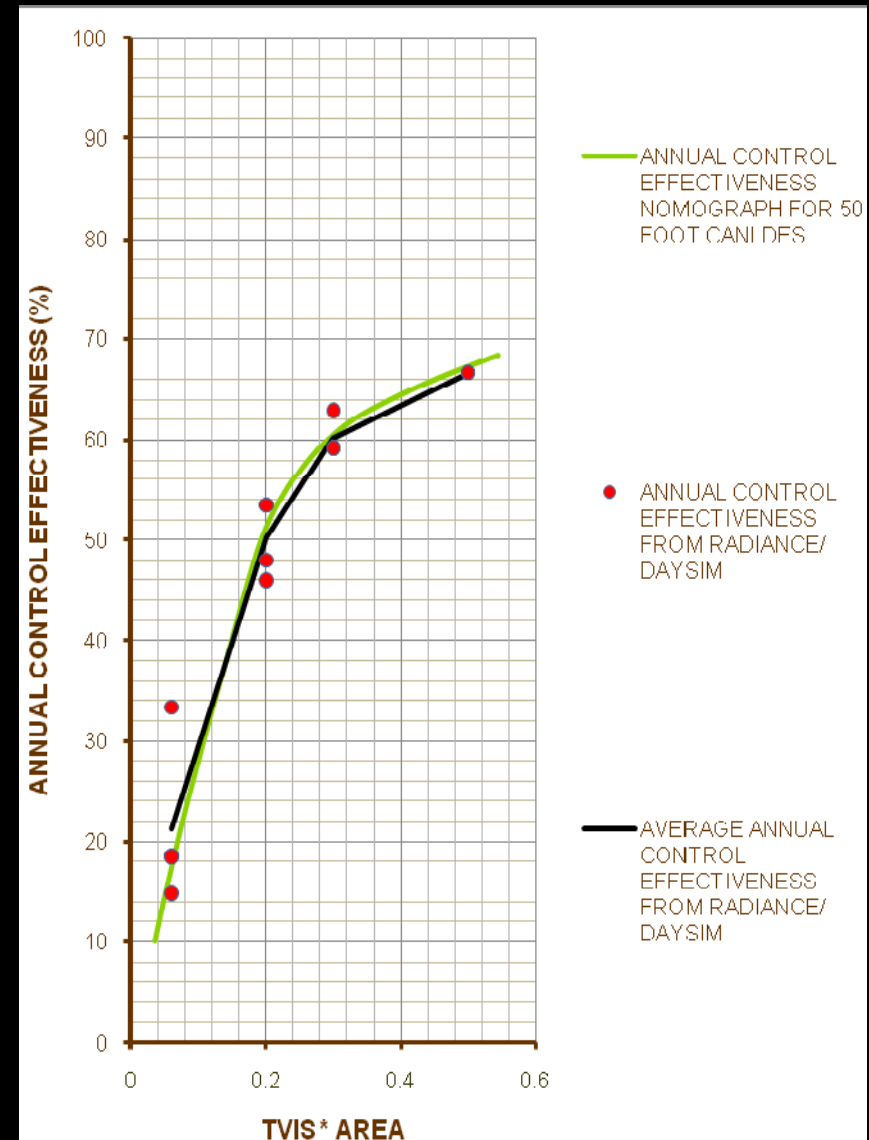




# RECREATING NOMOGRAPH RESULTS IN RADIANCE/ DAYSIM

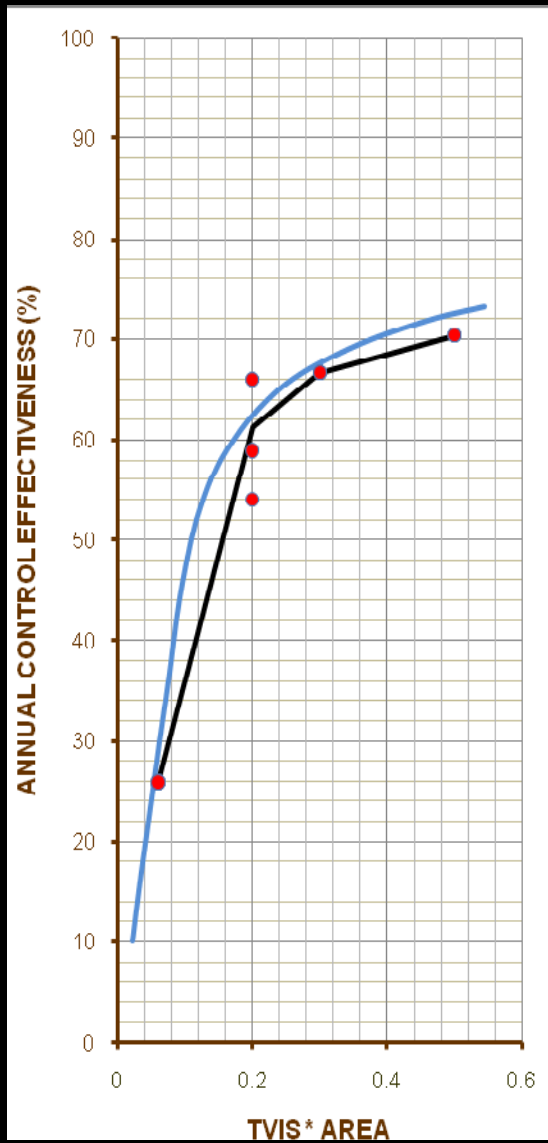
## The Nomograph parameters:

- Occupancy hours: 0800 to 1800
- Lighting Power Density: 1W/ sq ft
- Lighting user: No individual controls
- Blind user: No blinds installed
- Threshold Illumination level: 50 foot candles

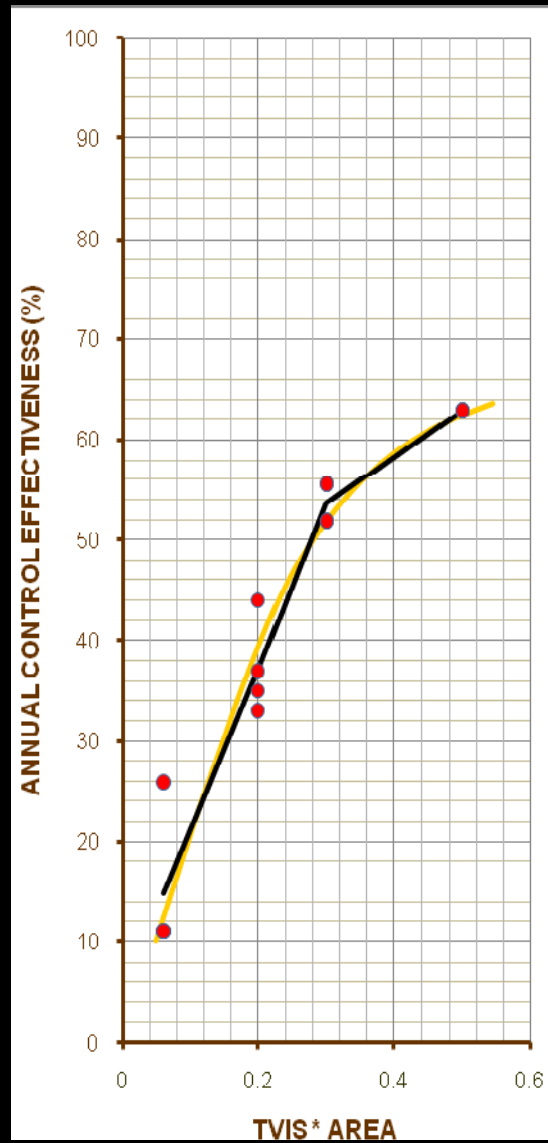


50 foot candles

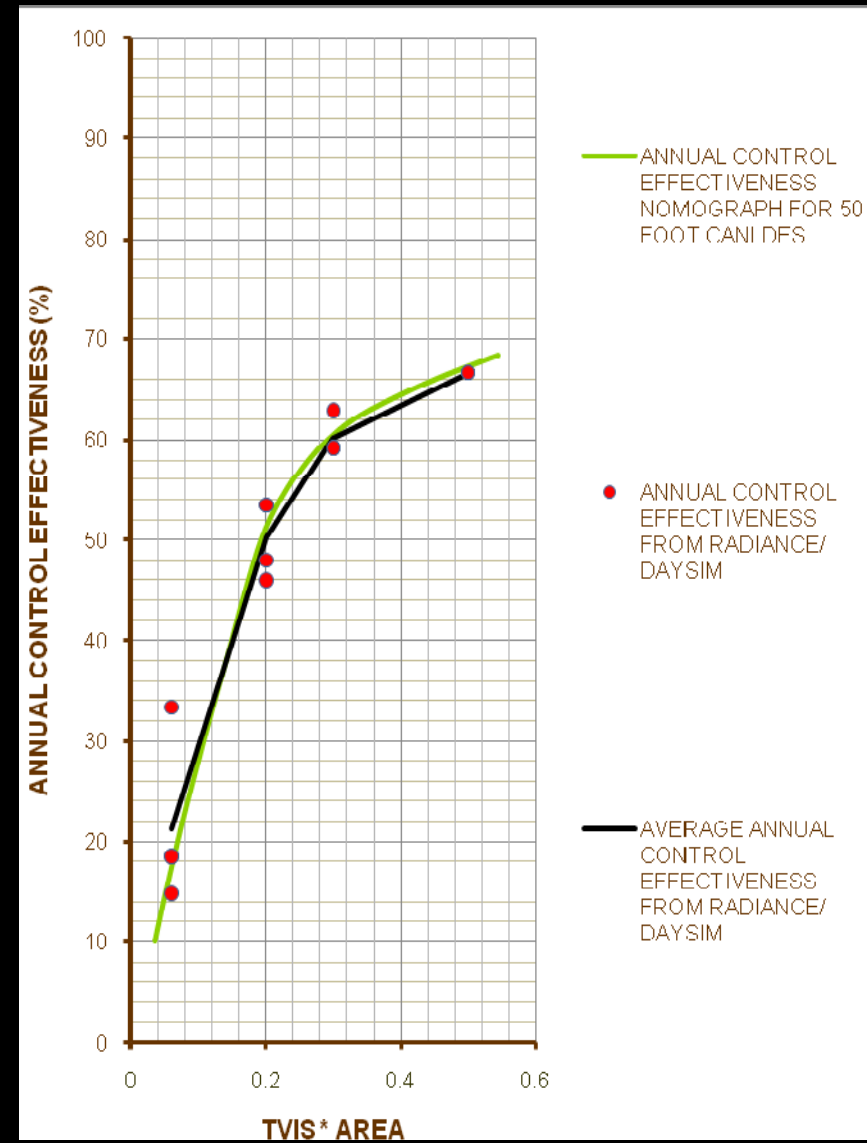
# RECREATING NOMOGRAPH RESULTS IN RADIANCE/ DAYSIM



30 foot candles



70 foot candles



50 foot candles

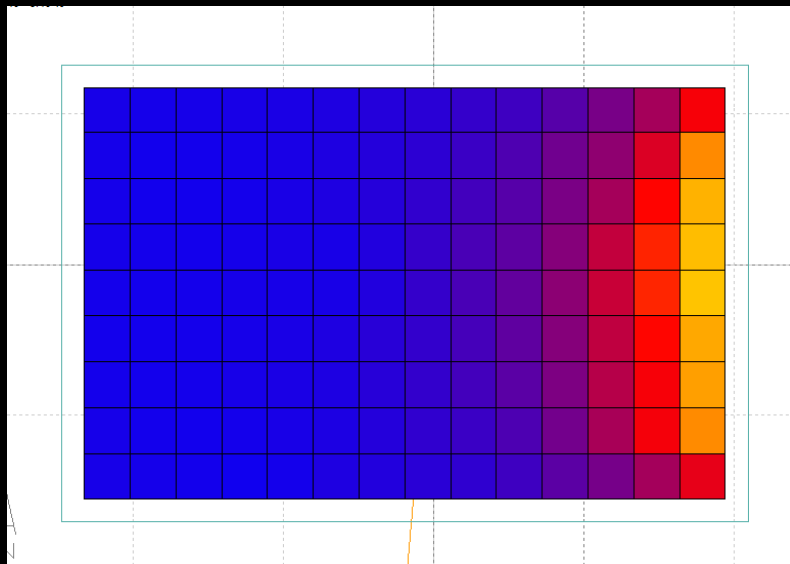
# ENERGY SAVINGS FROM DAYLIGHTING TODAY

## The Nomograph parameters (1984):

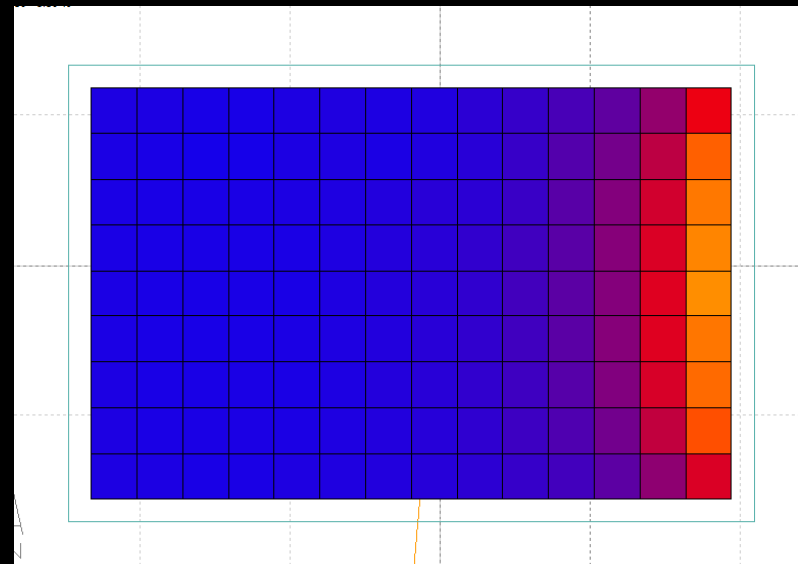
- Lighting user: No individual controls
- Blind user: No blinds installed
- Reference: Lights always on

## Parameters for practices today:

- Lighting user: **Individual controls (Switches)**
- Blind user: **Blinds (inevitable)**
- **Lighting controls: Photo sensor controlled dimming system (How efficient?)**
- Reference: Lights under individual controls

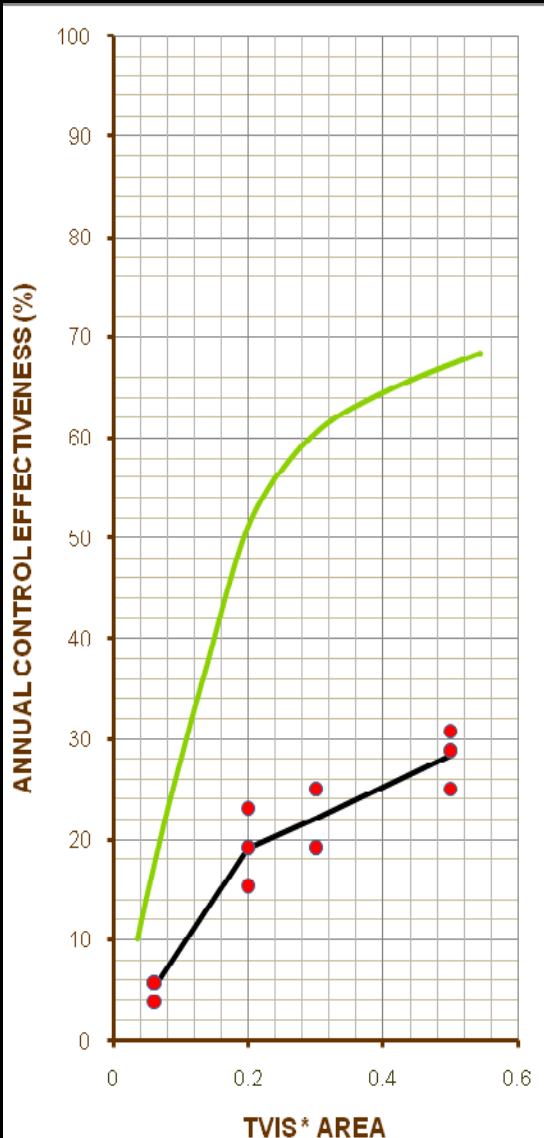


Daylight Autonomy Analysis with the above parameters



Daylight Autonomy Analysis with the above parameters

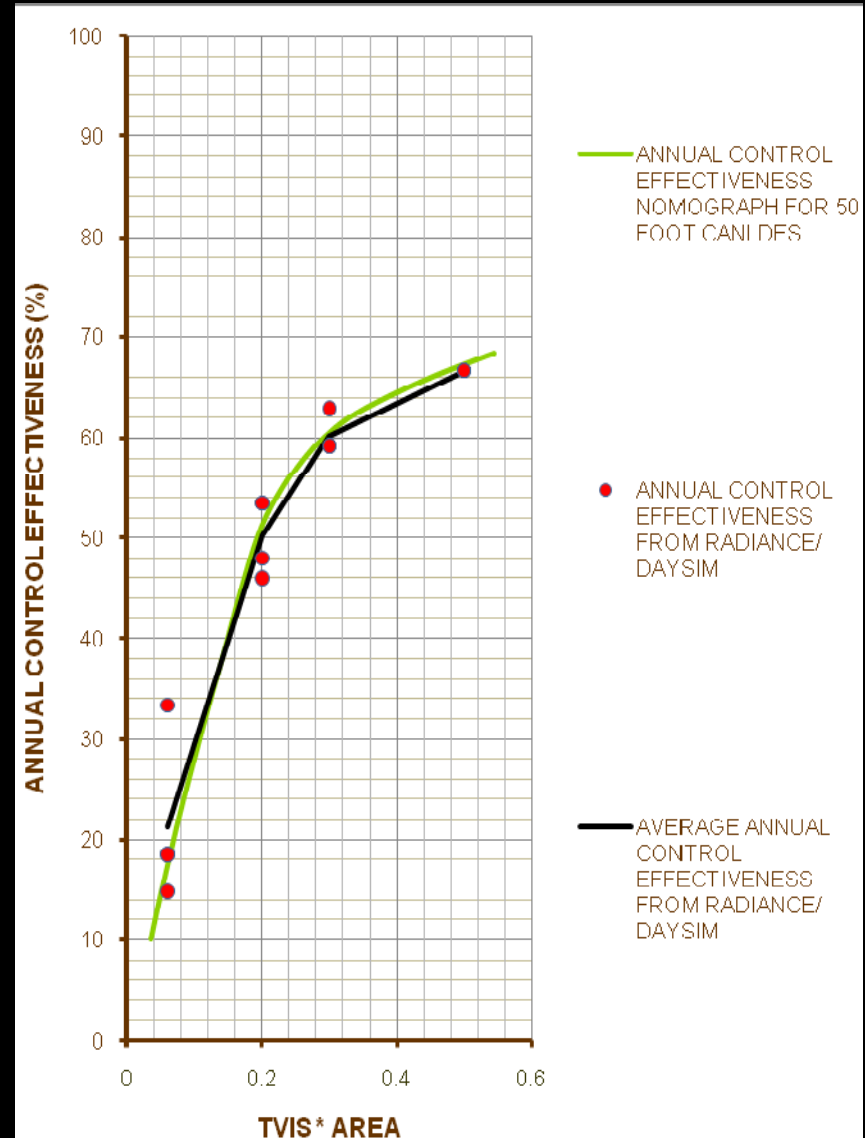
# ENERGY SAVINGS DUE TO OCCUPANT BEHAVIOR:



Private office, standard lighting system

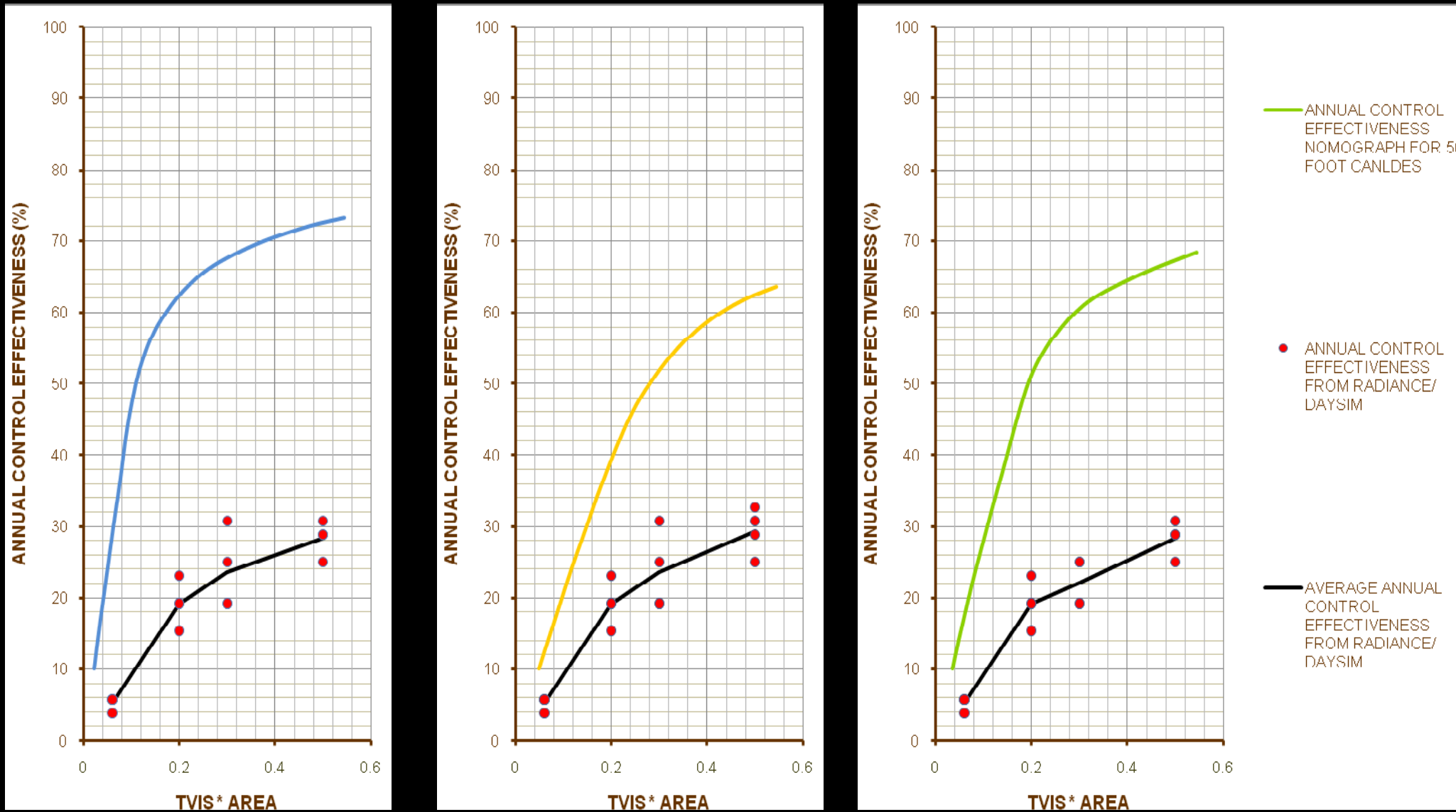
Blinds  
Yes  
Blind control  
Occupant  
Lighting system  
On/ Off  
Lighting control  
Average Occupant

Blinds  
No  
Blind control  
NA  
Lighting system  
Dimming  
Lighting control  
None



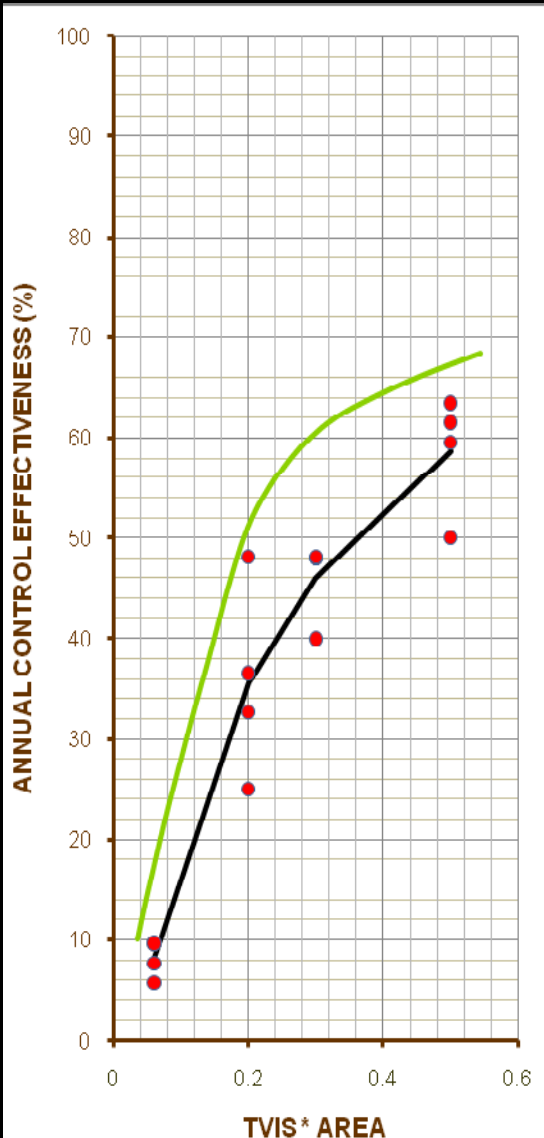
LBL Nomograph conditions

# ENERGY SAVINGS DUE TO OCCUPANT BEHAVIOR:



Blinds Yes | Blind control Occupant | Lighting system On / Off | Lighting control Average Occupant

# ENERGY SAVINGS DUE TO LIGHTING CONTROL SYSTEMS:

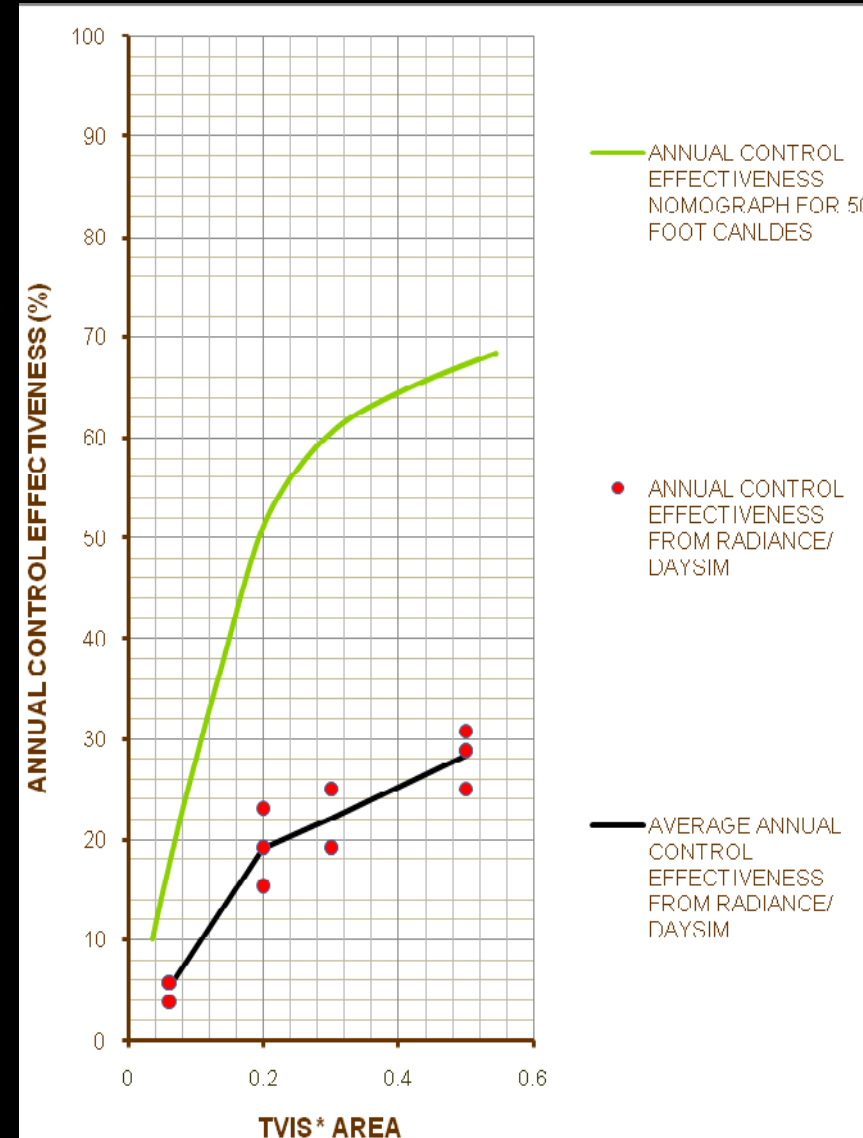


Blinds  
Yes  
Blind control  
Occupant  
Lighting system:  
Dimming  
Lighting control  
Average occupant

Blinds  
Yes  
Blind control  
Occupant  
Lighting system:  
On/ Off  
Lighting control  
Average Occupant

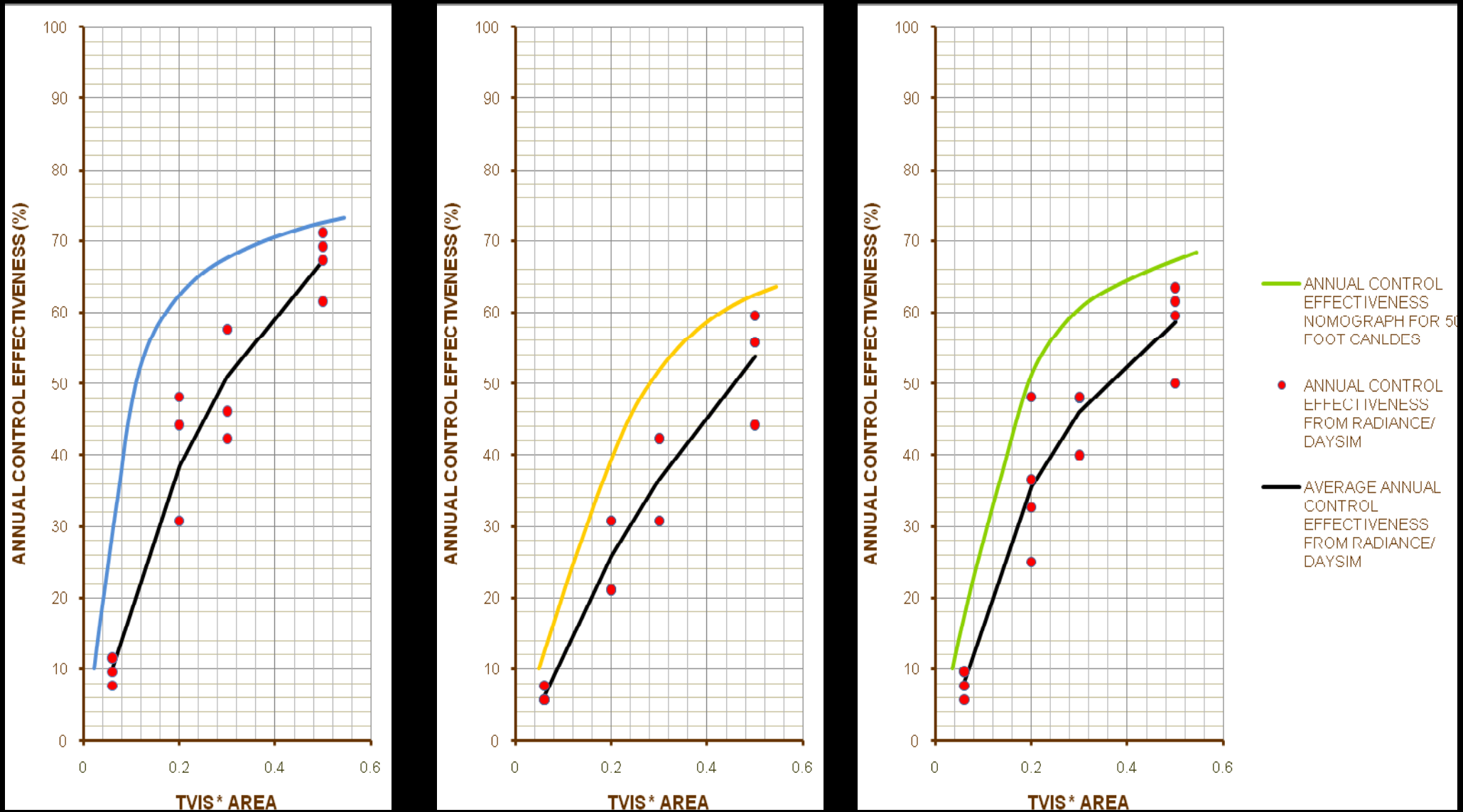


Private office, photo sensor controlled dimming stem



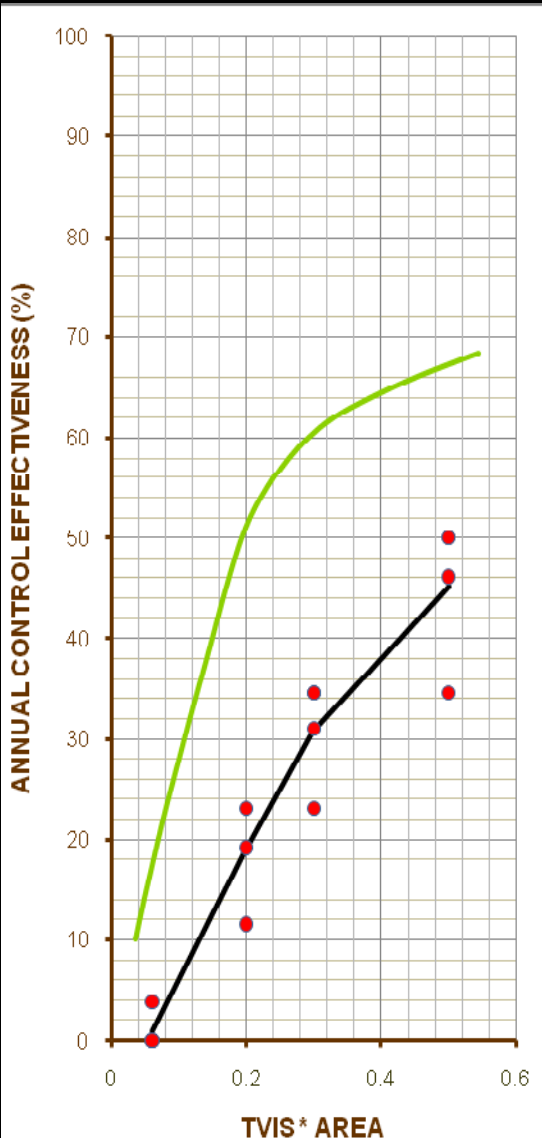
Private office, standard lighting system

# ENERGY SAVINGS DUE TO LIGHTING CONTROL SYSTEMS:



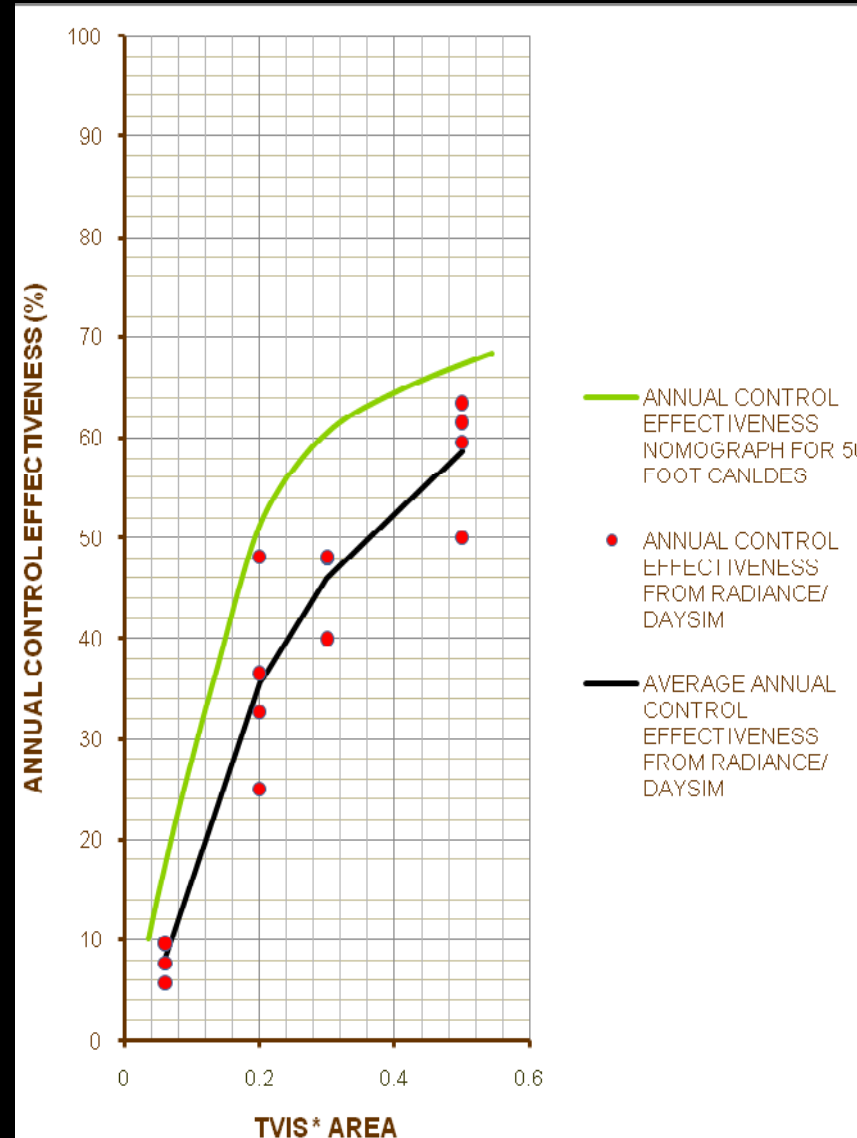
Blinds Yes | Blind control Occupant | Lighting system Dimming | Lighting control Average Occupant

# ENERGY SAVINGS DUE TO OCCUPANTS:



Blinds  
Yes  
Blind control  
Occupant  
Lighting system:  
Dimming  
Lighting control  
None

Blinds  
Yes  
Blind control  
Occupant  
Lighting system:  
Dimming  
Lighting control  
Average Occupant



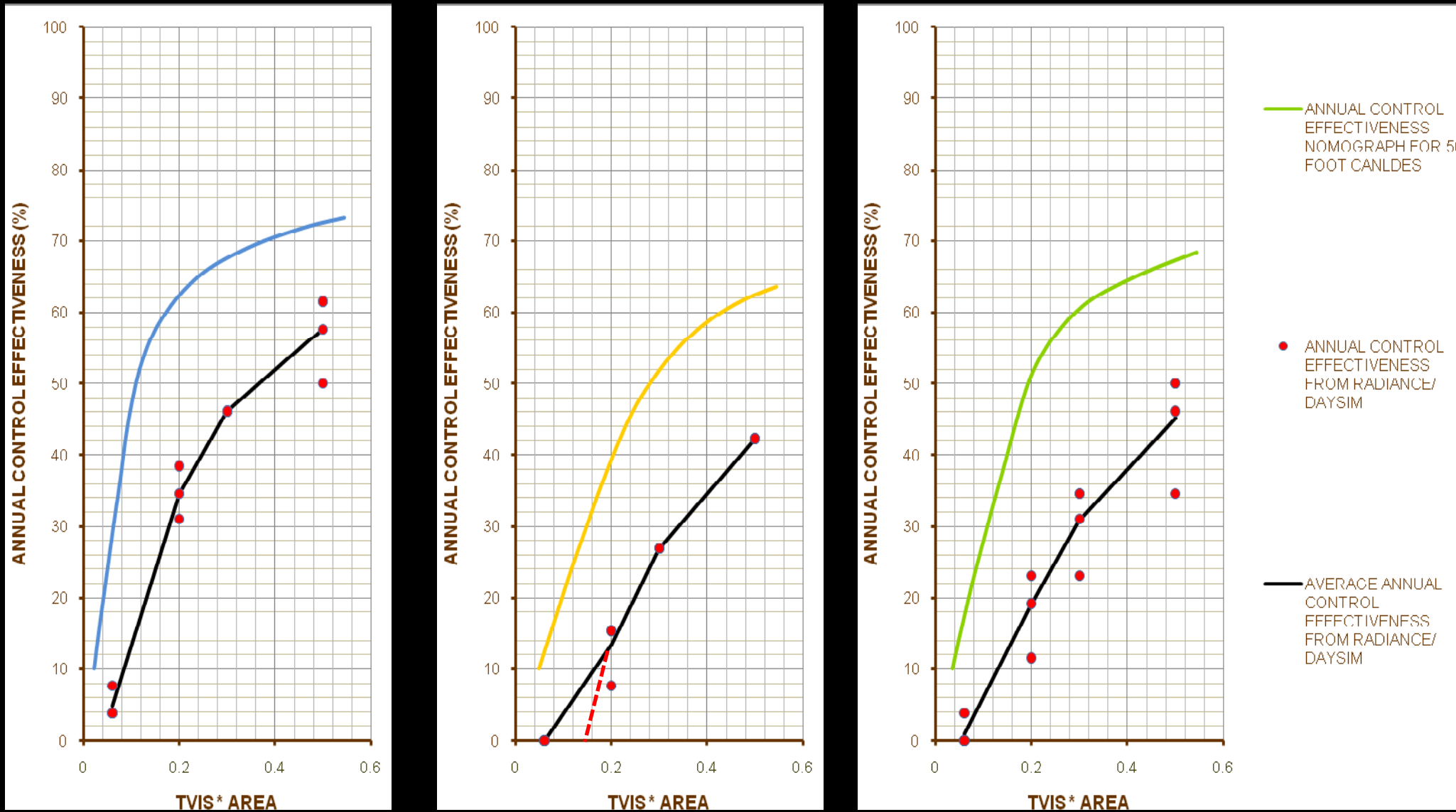
— ANNUAL CONTROL EFFECTIVENESS NOMOGRAPH FOR 50 FOOT CANDLES  
● ANNUAL CONTROL EFFECTIVENESS FROM RADIANCE/ DAYSIM  
— AVERAGE ANNUAL CONTROL EFFECTIVENESS FROM RADIANCE/ DAYSIM

Open plan office, photo sensor controlled dimming system

Private office, standard lighting system



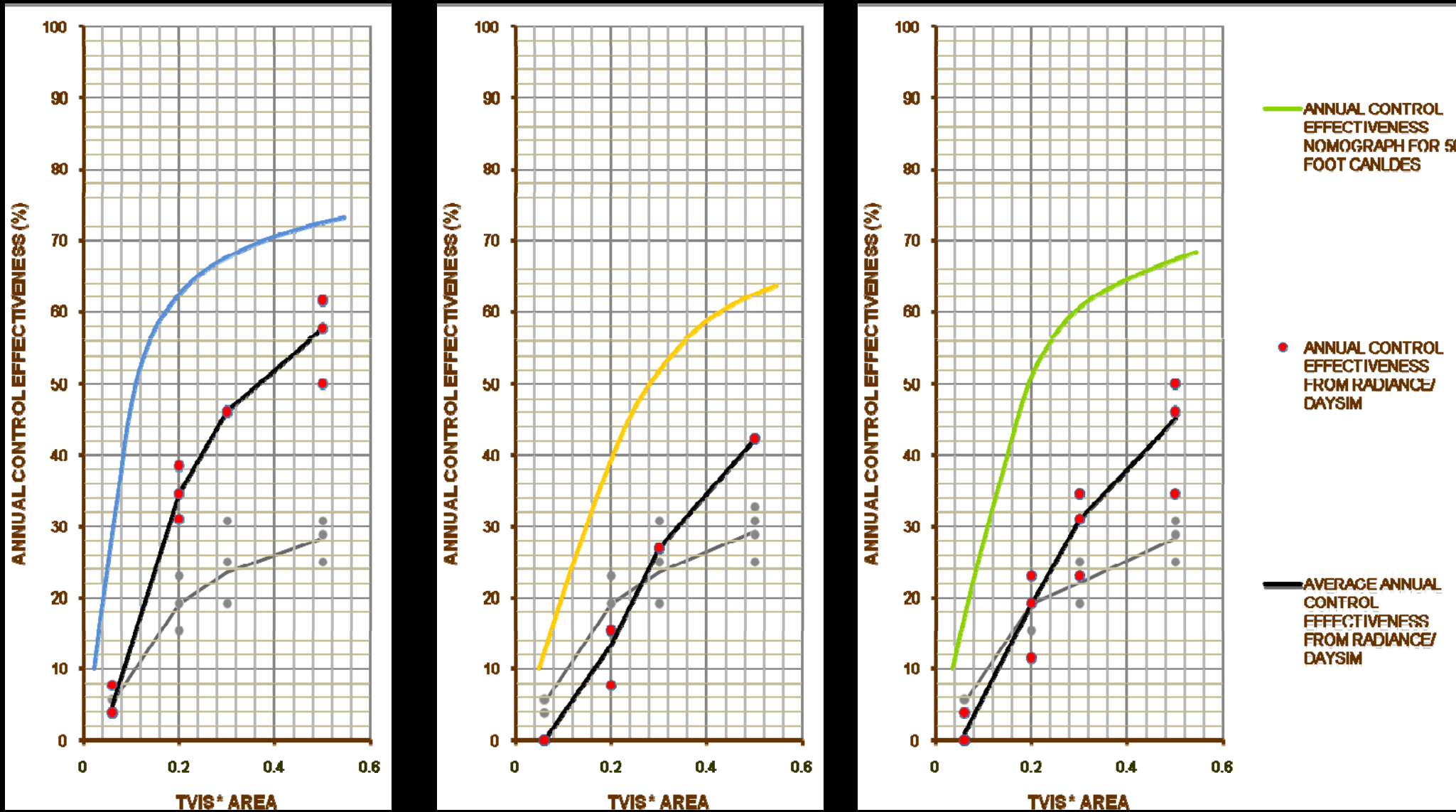
# ENERGY SAVINGS DUE TO LIGHTING CONTROL SYSTEMS:



Blinds Yes | Blind control Occupant | Lighting system Dimming | Lighting control None | Open plan office

Harvard Graduate School of Design

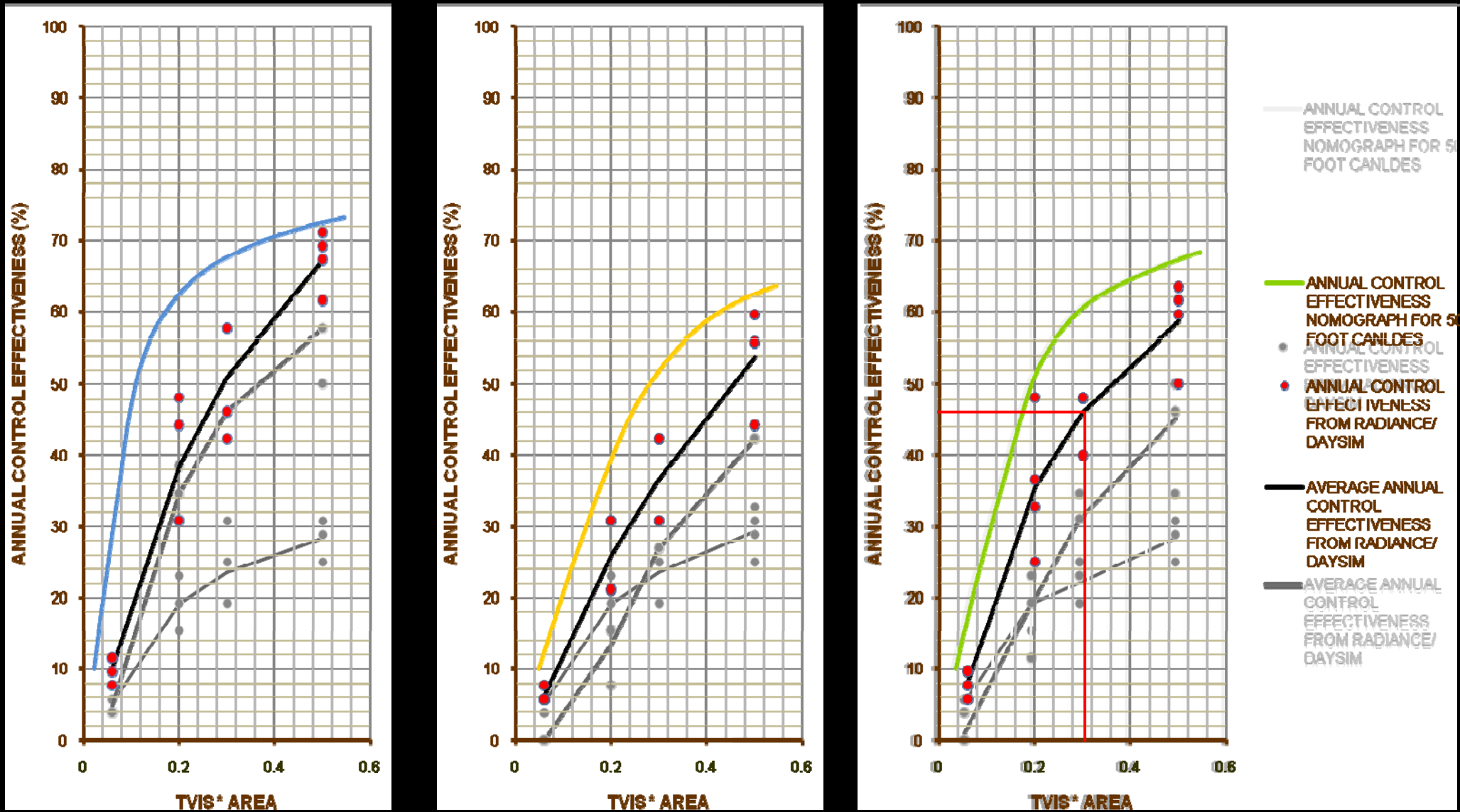
# ENERGY SAVINGS DUE TO OCCUPANT BEHAVIOR:



Blinds Yes | Blind control Occupant | Lighting system Dimming | Lighting control None | Open plan office

Blinds Yes | Blind control Occupant | Lighting system On/ Off | Lighting control Average Occupant | Private Office

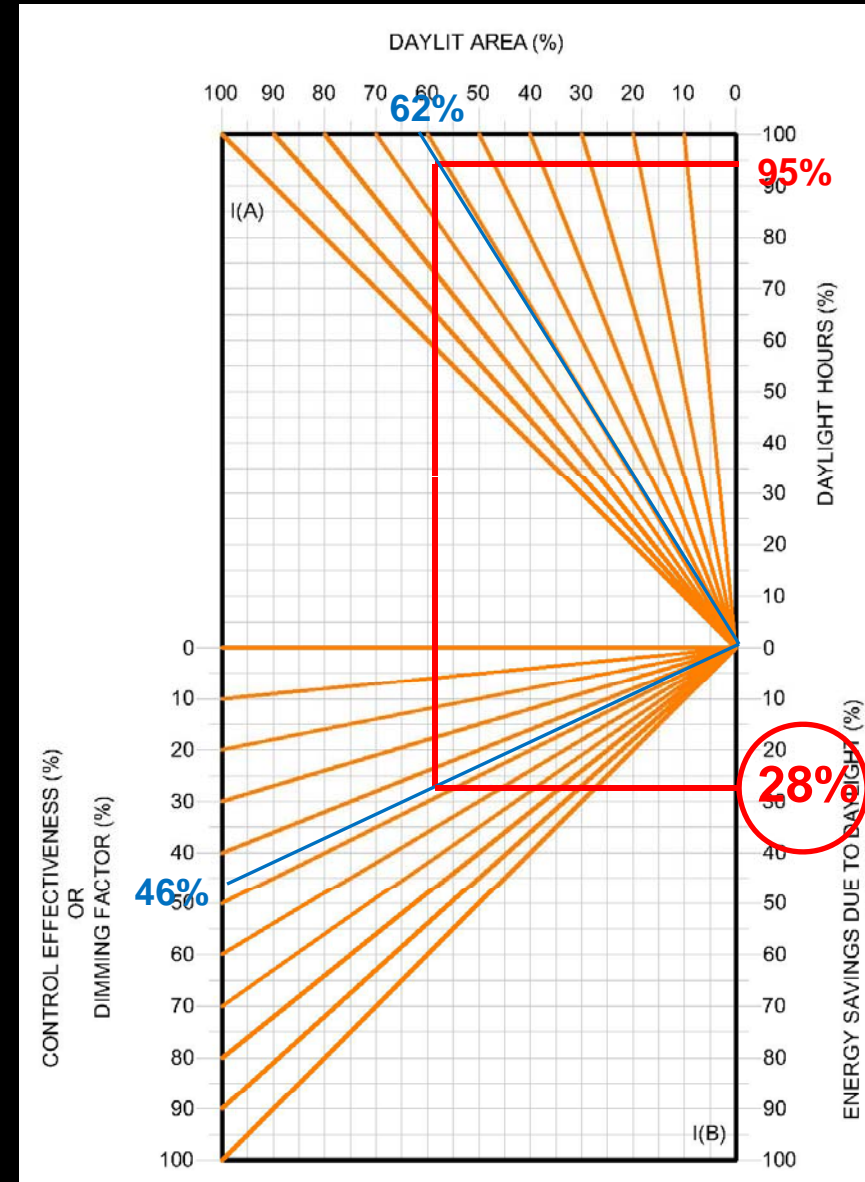
# ENERGY SAVINGS DUE TO OCCUPANT BEHAVIOR:



Blinds Yes | Blind control Occupant | Lighting system Dimming | Lighting control Average Occupant | Private office  
 Blinds Yes | Blind control Occupant | Lighting system Dimming | Lighting control None | Open Plan Office  
 Blinds Yes | Blind control Occupant | Lighting system On/ Off | Lighting control Average Occupant | Private Office

# USING THE NOMOGRAPHS

- Daylight hours: 95%
- Daylit area: 62%
- Threshold Illumination level: 50 foot candles
- TVIS \* Area: 0.3
- Annual Control Effectiveness: 46%



THANK YOU

RADIANCE WORKSHOP, October 23 2009

ROHIT MANUDHANE | CHRISTOPH REINHART  
Harvard Graduate School of Design