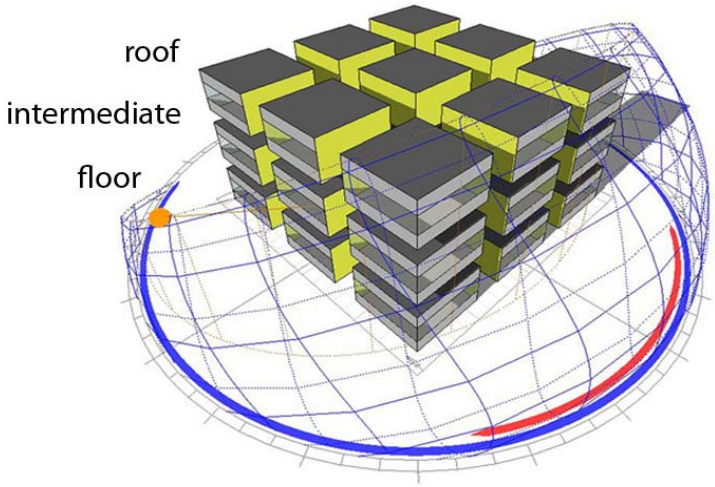
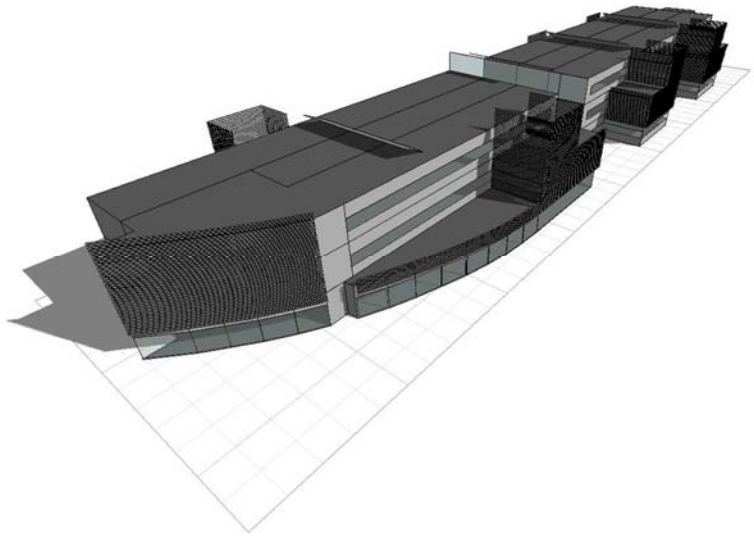
Relation between shape and energy use in low energy office buildings.





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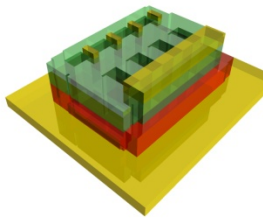
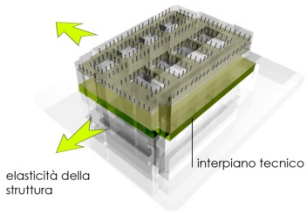
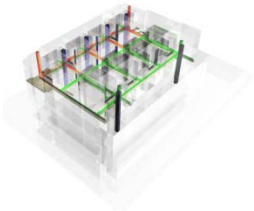
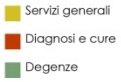
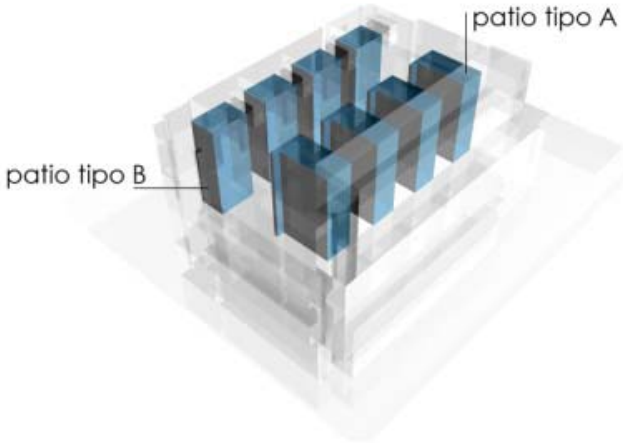
MORPHOLOGICAL ANALYSIS

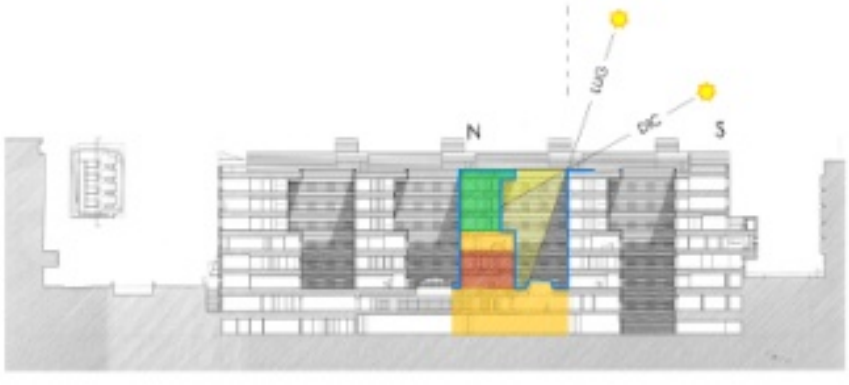


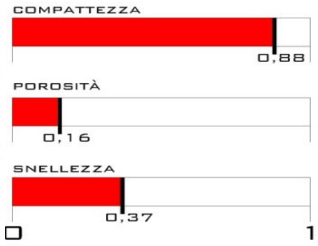












SHAPE COEFFICIENTS

(1),(2) **Compactness**

$$C = \frac{S_{eq}}{S_g} = 4{,}836\frac{V_t^{2/3}}{S_g} \leq 1$$

$$S_g / V_t \ (m^{-1})$$

(3) **Slenderness**

$$e = \frac{h}{d} = \frac{h}{\sqrt{\left(\frac{S_0}{\pi} + h^2\right)}}$$

(4) **Wall/Volume**

$$S_w / V_t \ (m^{-1})$$

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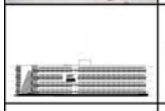
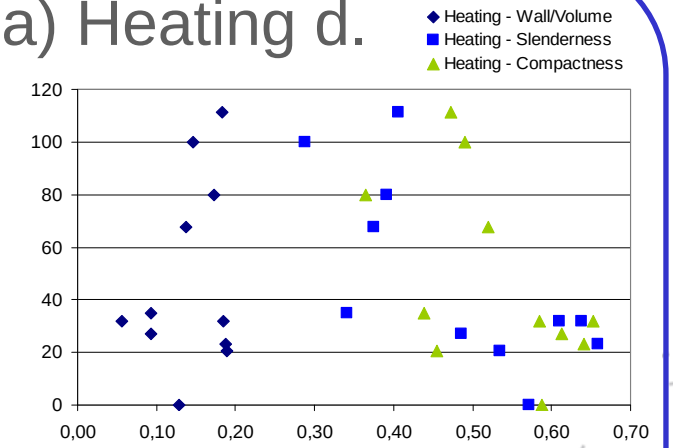
CASE STUDIES

THERMAL DEMAND

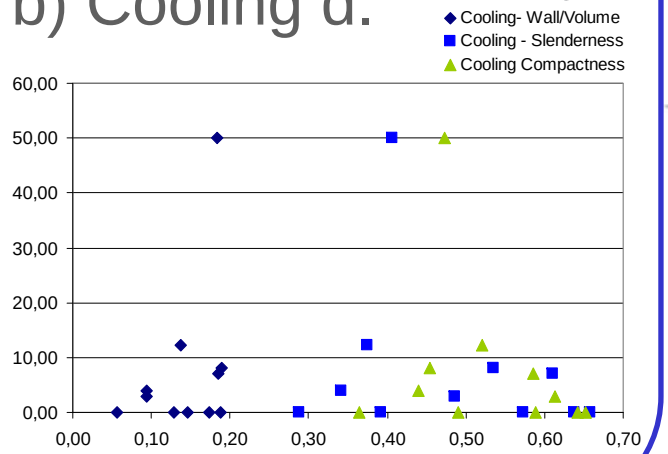
Foto	3D		Heated surface (HS)	Exposed surface (EA)	Glass area (GA)	window/wall ratio (GA/HS)	Double-facade*	Superwindow	Double facade**	Earth coupling	Heat pump	Hybrid ventilation	Passive cooling	PV-roof	Biomass	Thermal collector	Demand controll	District heat
		**Bravida**	6300	5585,5	1080	32,30		X			X					X	X	X
		Year of constr. 2003			*A/V* 0,32													
		Location Fredrikstad			*Compactness* 0,52													
		Heating demand 67,45 KWh/m2y			*Slenderness* 0,37													
		Cooling demand 12,26 KWh/m2y			*EA/V* 0,14													
		**Hamar Radhus**	10500	6183,3	1300	31,80	X		X									
		Year of constr. 2001			*A/V* 0,26													
		Location Hamar Kommune			*Compactness* 0,59													
		Heating demand			*Slenderness* 0,57													
		Cooling demand			*EA/V* 0,13													
		**Miljøsenter**	15000	18827,3	2700	24,40		X			X				X	X	X	X
		Year of constr. 2006			*A/V* 0,22													
		Location Oslo - Blindern			*Compactness* 0,44													
		Heating demand 35 KWh/m2y			*Slenderness* 0,34													
		Cooling demand 4 KWh/m2y			*EA/V* 0,09													
		**MMS Horten**	3700	3654,1	700	27,40					X							
		Year of constr. 1996			*A/V* 0,34													
		Location Horten			*Compactness* 0,59													
		Heating demand 32 KWh/m2y			*Slenderness* 0,61													
		Cooling demand 7 KWh/m2y			*EA/V* 0,19													
		**Nydalspynten**	2700	2537,1	428,7	40,80		X					X		X	X	X	
		Year of constr. 2008			*A/V* 0,28													
		Location Oslo			*Compactness* 0,65													
		Heating demand 32 KWh/m2y			*Slenderness* 0,64													
		Cooling demand 0 KWh/m2y			*EA/V* 0,06													
		**Røstad**	3697	5121,6	1000	30,60				X	X							
		Year of constr. 2002			*A/V* 0,39													
		Location Levanger			*Compactness* 0,47													
		Heating demand 111,4 KWh/m2y			*Slenderness* 0,41													
		Cooling demand 0 KWh/m2y			*EA/V* 0,18													
		**Sig. Halvorsen**	3600	3763	600	30,60					X							
		Year of constr. 2006			*A/V* 0,42													
		Location Sandnes			*Compactness* 0,49													
		Heating demand 100,0 KWh/m2y			*Slenderness* 0,29													
		Cooling demand 0 KWh/m2y			*EA/V* 0,15													
		**Telenor Kokstad**	26800	22161,7	4800	29,00	X	X		X								X
		Year of constr. 2000			*A/V* 0,29													
		Location Bergen			*Compactness* 0,37													
		Heating demand			*Slenderness* 0,39													
		Cooling demand			*EA/V* 0,17													
		**Vestveien**	3200	3160,3	660	28,60		X		X		X	X					
		Year of constr. 2008			*A/V* 0,33													
		Location Ski			*Compactness* 0,64													
		Heating demand 23 KWh/m2y			*Slenderness* 0,66													
		Cooling demand 0 KWh/m2y			*EA/V* 0,19													
		**Prof Brochs Gt**	11450	10028	2200	28,80					X			X			X	
		Year of constr. 2009			*A/V* 0,31													
		Location Trondheim			*Compactness* 0,45													
		Heating demand 20,5 KWh/m2y			*Slenderness* 0,54													
		Cooling demand 8,2 KWh/m2y			*EA/V* 0,19													
		**Sparebank 1**	15600	8230	2138	41,80					X						X	
		Year of constr. 2010			*A/V* 0,21													
		Location Trondheim			*Compactness* 0,61													
		Heating demand 25 KWh/m2y			*Slenderness* 0,49													
		Cooling demand 3 KWh/m²y			*EA/V* 0,09													

* Double skin for reduction of energy demand
** Solar energy double skin

a) Heating d.



b) Cooling d.



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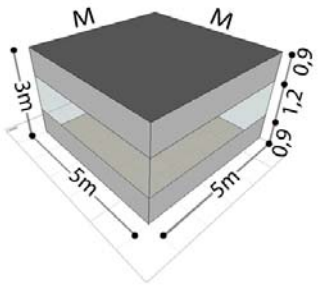
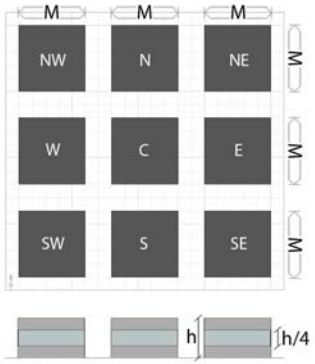
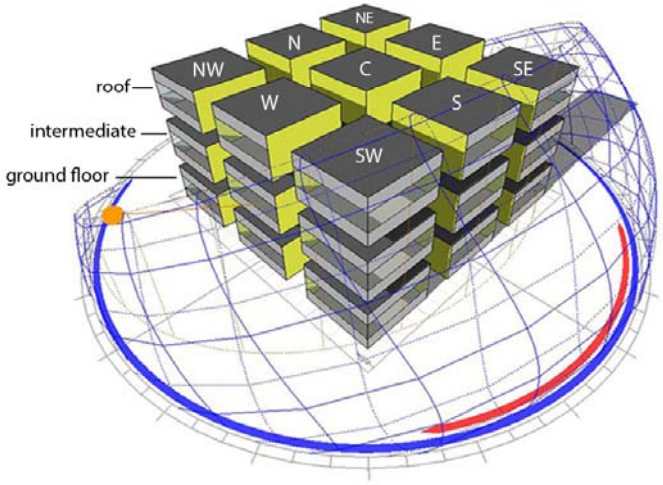
METHODOLOGY

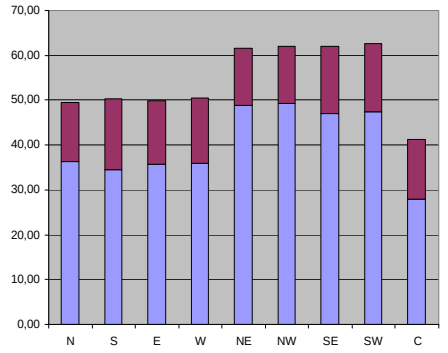
27 OFFICE UNITS



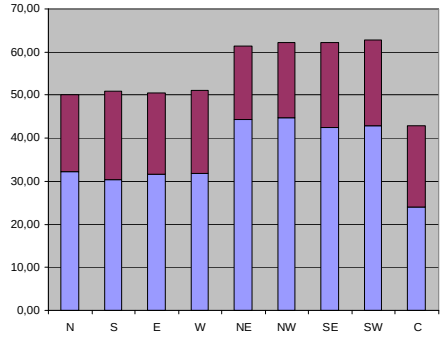




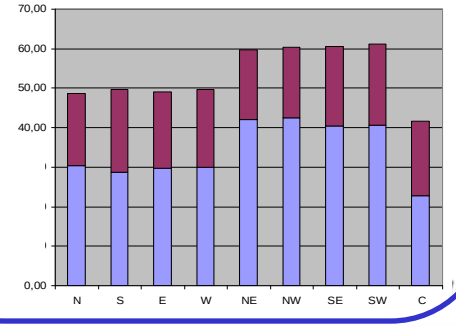
a) Ground floor



b) Intermediate fl.

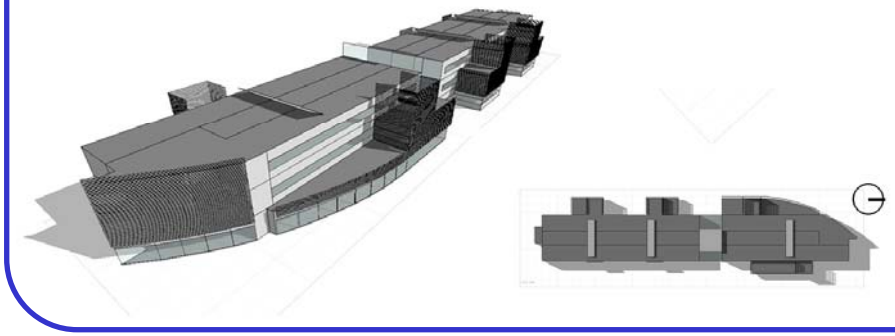


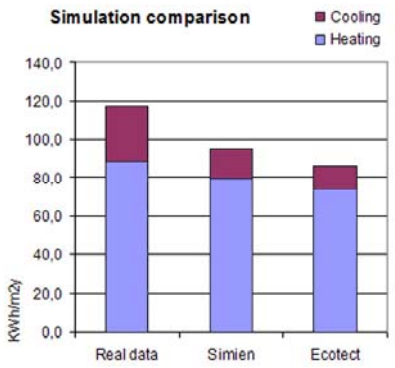
c) roof



-Corner zones: higher request for heating
-Central zones: need for cooling represent almost 50% of the total thermal demand.
-Vertical location: not really affecting

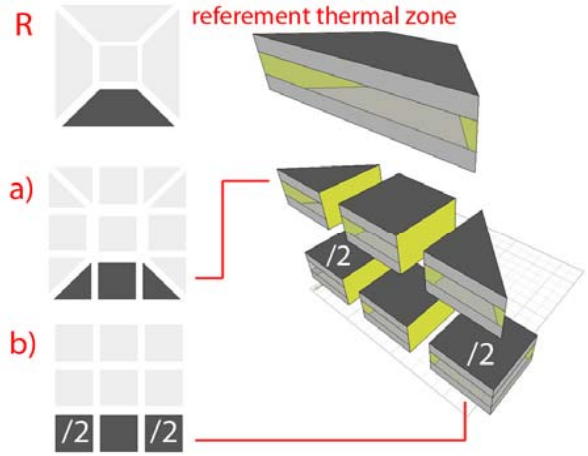
CALIBRATION

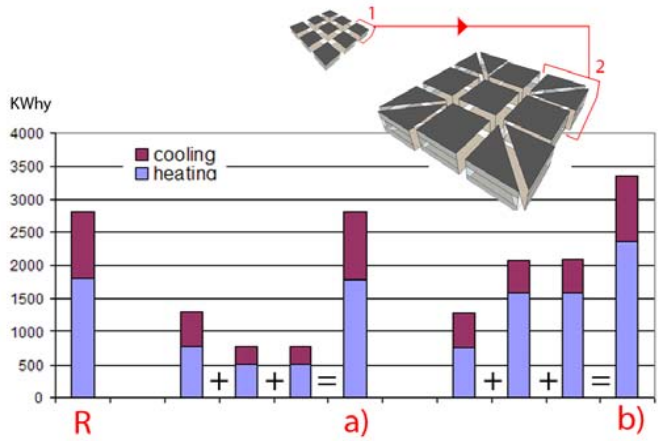




1

Comparison with SIMIEN and monitored data





2

Dividing thermal zones into units

Corners:

a) two triangular thermal zones

b) Dividing thermal demand in two

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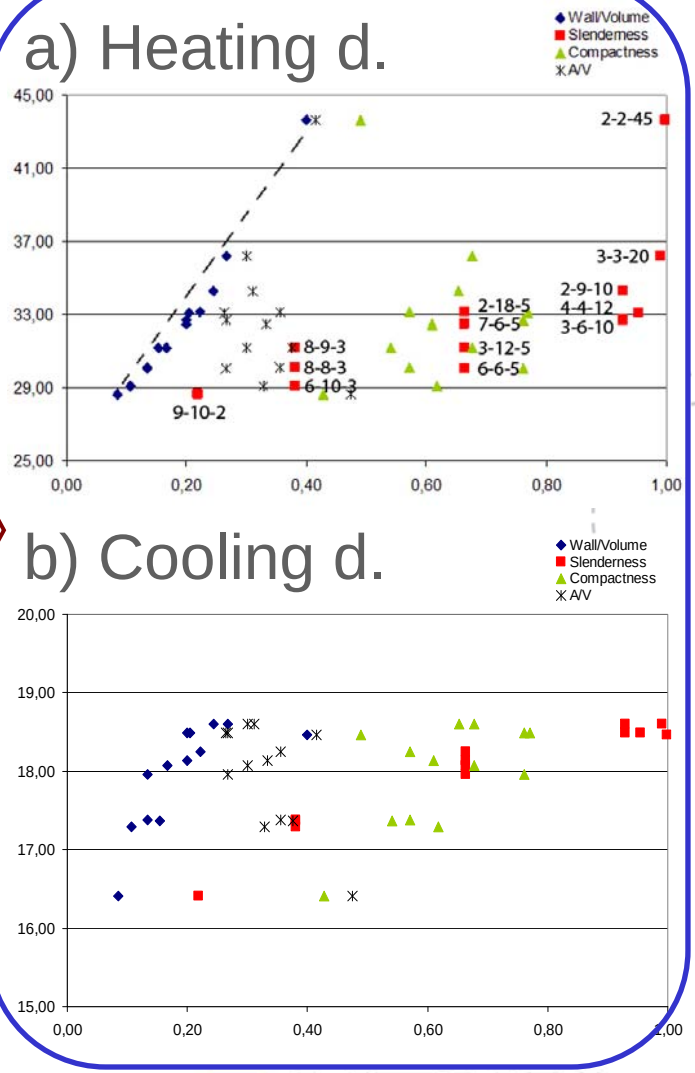
THEORETICAL MODELS

THERMAL DEMAND

		Theoretical model	Heated surface (HS)	Exposed surface (EA)	Glass area (GA)	(GA/HS)		Heating demand	Cooling demand
Deep plan		**01 - Block 6-6-5**	4500	2700	720	16,00		30,04	17,96
		N, S 16					*A/V* 0,27		
		E, W 14					*Compactness* 0,76		
		NE,NW,SE,SW 2					*Slenderness* 0,66		
		Central 112					*EA/V* 0,13		
		**02 - Block 6-10-3**	4500	2940	576	12,80		29,14	17,3
		N, S 24					*A/V* 0,33		
		E, W 12					*Compactness* 0,62		
		NE,NW,SE,SW 3					*Slenderness* 0,38		
		Central 96					*EA/V* 0,11		
		**03 - Slab 9-10-2**	4500	3390	456	10,13		28,64	16,41
		N, S 16					*A/V* 0,47		
		E, W 14					*Compactness* 0,43		
		NE,NW,SE,SW 2					*Slenderness* 0,22		
		Central 112					*EA/V* 0,08		
		**04 - Atrio 8-8-3**	4500	3300	720	16,00		30,15	17,38
		N, S 24					*A/V* 0,36		
		E, W 24					*Compactness* 0,57		
		NE,NW,SE,SW 3					*Slenderness* 0,38		
		Central 72					*EA/V* 0,13		
		**05 - Atrio 6-7-5**	4500	3600	1080	24,00		32,49	18,14
		N, S 40					*A/V* 0,33		
		E, W 30					*Compactness* 0,61		
		NE,NW,SE,SW 5					*Slenderness* 0,66		
		Central 20					*EA/V* 0,20		
		**06-Tower 4-4-12**	4500	3160	1104	24,53		33,1	18,49
		N, S 22					*A/V* 0,26		
		E, W 22					*Compactness* 0,77		
		NE,NW,SE,SW 12					*Slenderness* 0,96		
		Central 44					*EA/V* 0,20		
3M depth		**07-Tower 3-3-20**	4500	3825	1440	32,00		36,2	18,61
		N, S 20					*A/V* 0,30		
		E, W 20					*Compactness* 0,68		
		NE,NW,SE,SW 20					*Slenderness* 0,99		
		Central 20					*EA/V* 0,27		
		**08 - Bar 3-12-5**	4500	3150	900	20,00		31,17	18,08
		N, S 50					*A/V* 0,30		
		E, W 5					*Compactness* 0,68		
		NE,NW,SE,SW 5					*Slenderness* 0,66		
		Central 50					*EA/V* 0,17		
		**09 - Bar 3-6-10**	4500	3150	1080	24,00		32,73	18,48
		N, S 40					*A/V* 0,27		
		E, W 10					*Compactness* 0,76		
		NE,NW,SE,SW 10					*Slenderness* 0,93		
		Central 40					*EA/V* 0,20		
		**10 - H - 8-10-3**	4500	3570	828	18,40		31,18	17,37
		N, S 27					*A/V* 0,38		
		E, W 18					*Compactness* 0,54		
		NE,NW,SE,SW 6					*Slenderness* 0,38		
		Central 66					*EA/V* 0,15		
2M depth		**11 - Bar 2-18-5**	4500	3900	1200	26,67		33,14	18,25
		N, S 80					*A/V* 0,36		
		E, W 0					*Compactness* 0,57		
		NE,NW,SE,SW 5					*Slenderness* 0.66		
		Central 0					*EA/V* 0,22		
		**12 - Bar 2-9-10**	4500	3750	1320	29,33		34,29	18,6
		N, S 70					*A/V* 0,31		
		E, W 0					*Compactness* 0,65		
		NE,NW,SE,SW 10					*Slenderness* 0,93		
		Central 0					*EA/V* 0,24		
		**13 - Tower 2-2-45**	4500	5500	2160	48,00		43,65	18,47
		N, S 0					*A/V* 0,42		
		E, W 0					*Compactness* 0,49		
		NE,NW,SE,SW 45					*Slenderness* 0,99		
		Central 0					*EA/V* 0,40		



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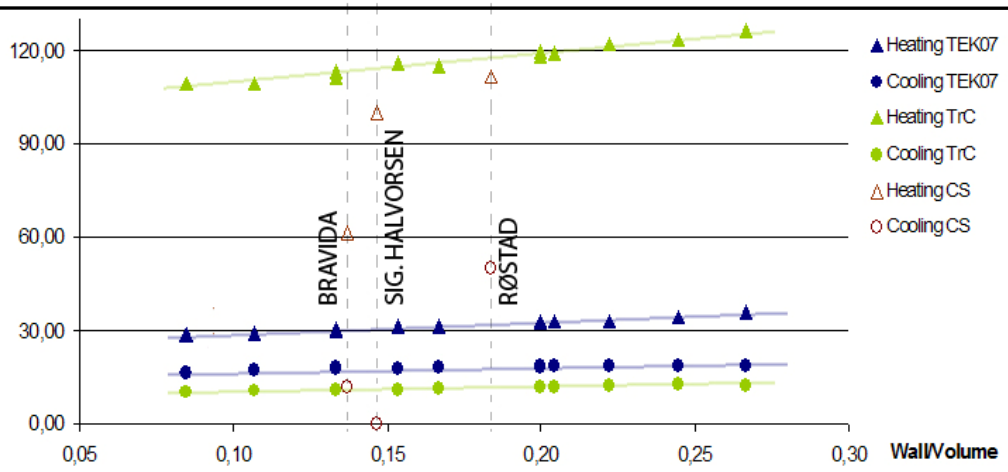
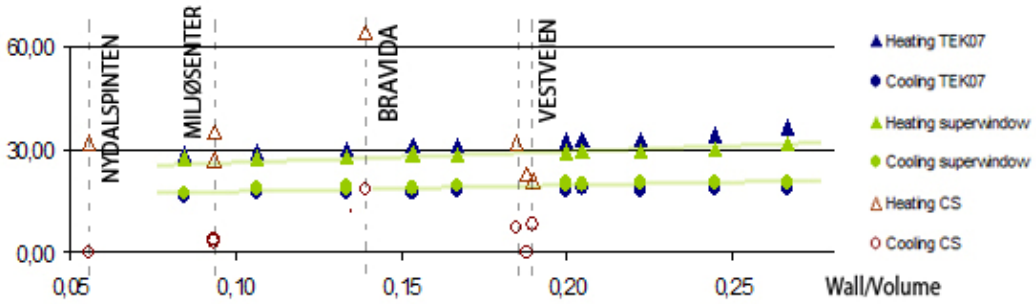
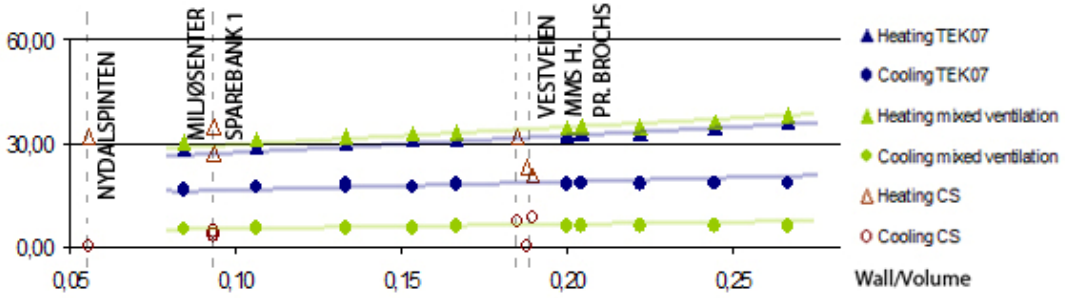
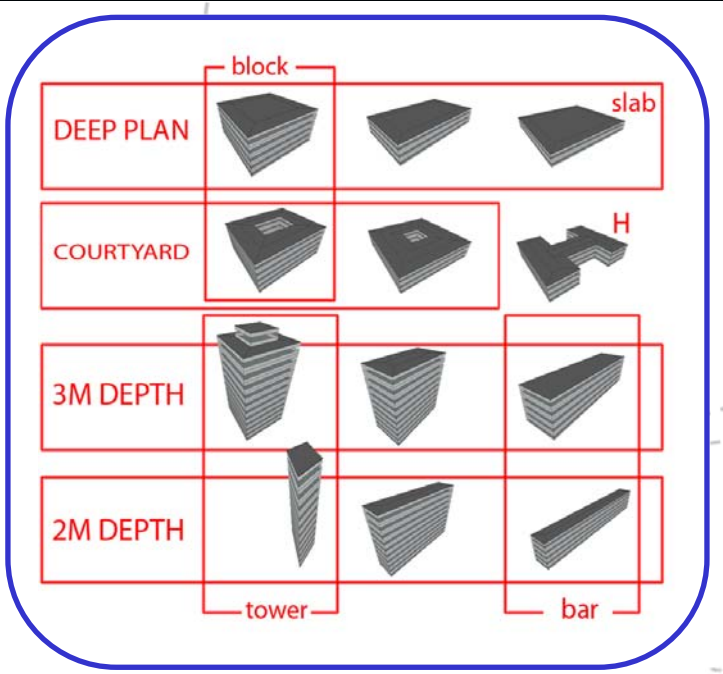
L-E STRATEGIES

TYPOLOGIES









Negligible influence of the shape ?

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HEATING AND COOLING DEMAND

STANDARDS

Unit	**Ref.**	**TEK07**	**LE**	
$W/m^2/K$	1.2	0.15	0.15	U-value external wall
$W/m^2/K$	0.60	0.13	0.13	U-value roof
$W/m^2/K$	0.50	0.18	0.18	U-value floor on ground
$W/m^2/K$	2.4	1.2	1.2	U-value windows, glasses
ach	3.0	1.5	0.6	Air-tightness
-	0.7	0.7	0.85	Heat recovery syst. efficiency
$Pers./m^2$	0.1	0.1	0.1	Occupancy
$^{\circ}C$	26	26	26	Cooling set point temperature
$^{\circ}C$	18	18	18	Heating set back temperature
W/m^2	8	8	8	Lighting load
W/m^2	11	11	11	Equipment load

compact shapes in cold climates ?

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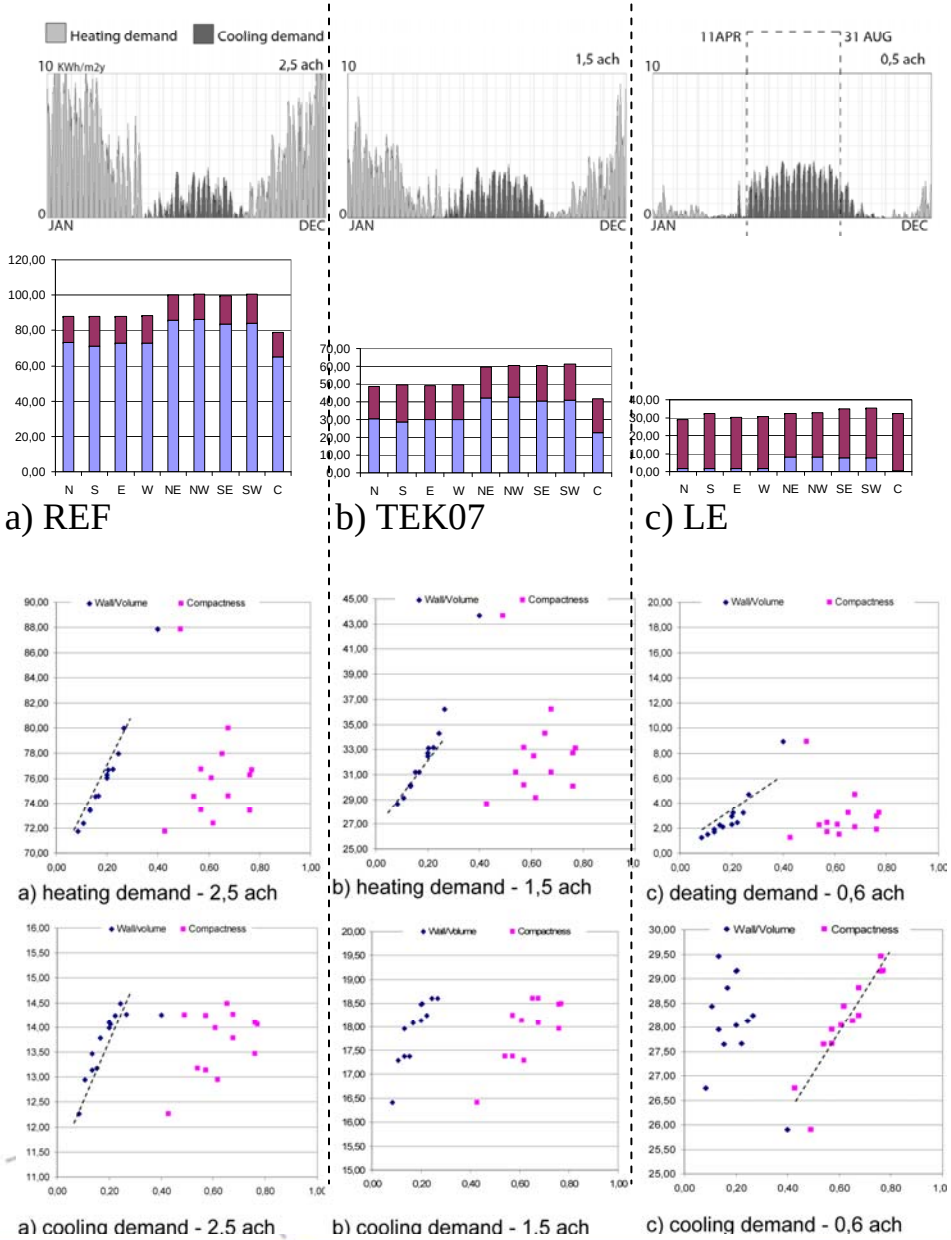
HEATING AND COOLING DEMAND

SHAPE



-Strategies for cooling

-Different behaviour of heating and cooling demand

-Morphological implications

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