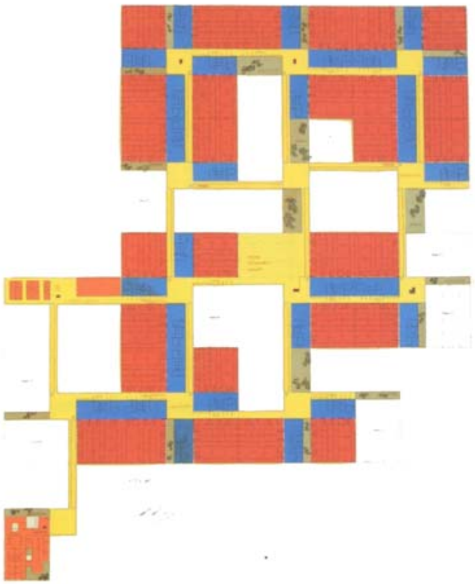
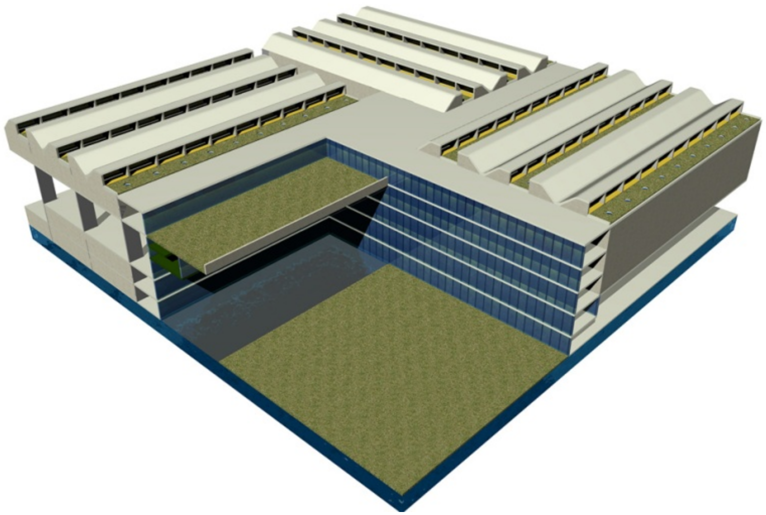


NTNU

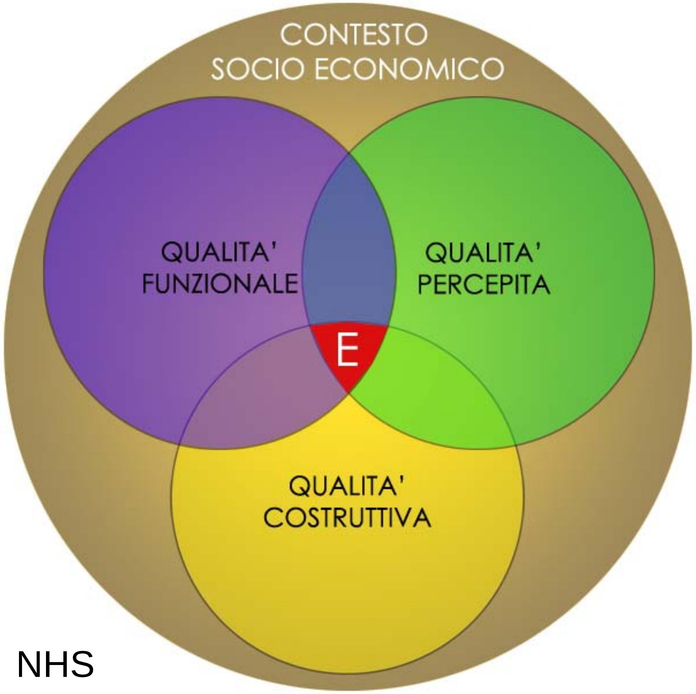
Innovation and Creativity

Morphological implications of passive control

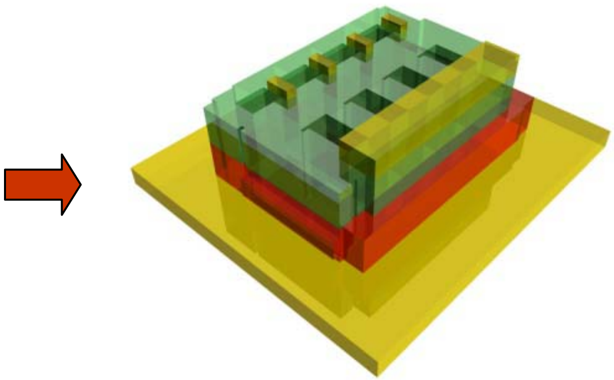


"I didn't invent anything. I just designed an hospital that can be born, live and expand itself like an open hand", Le Corbusier

Venice Hospital,1965


CONTESTO
SOCIO ECONOMICO
QUALITA'
FUNZIONALE
QUALITA'
PERCEPITA
E
QUALITA'
COSTRUTTIVA

NHS

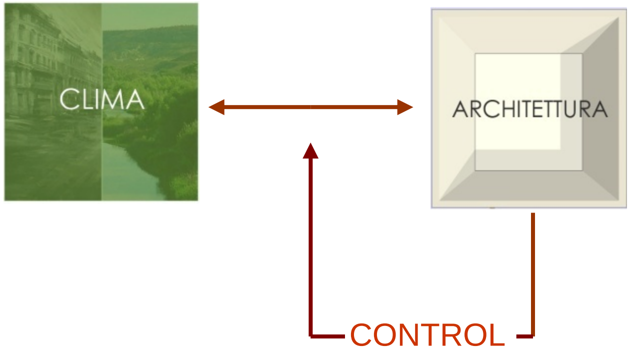


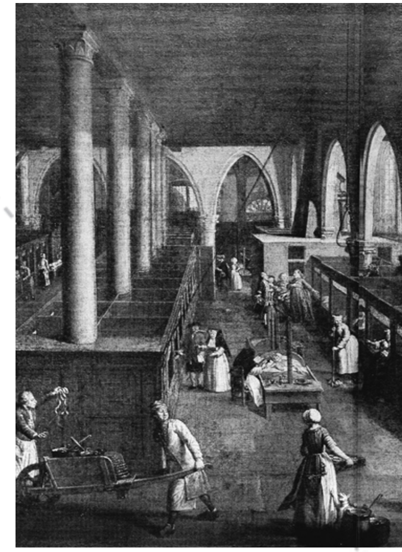
XV CENTURY

EXTERIOR / INTERIOR

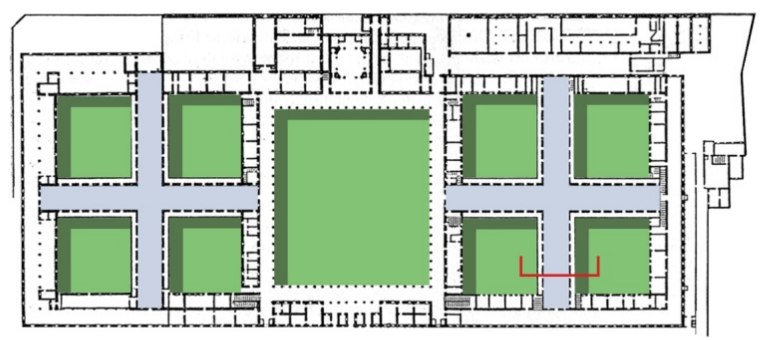
THERAPEUTIC ROLE

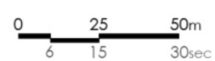
ENVIRONMENTAL DESIGN



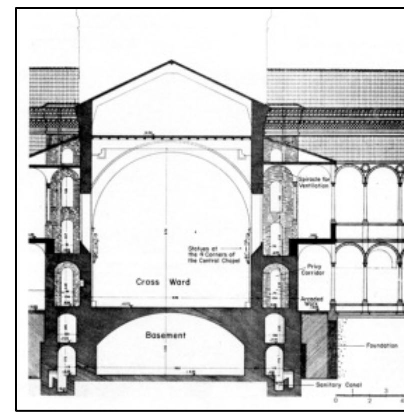


ABBAZIE OF CLUNY





OSPEDALE MAGGIORE,MILAN

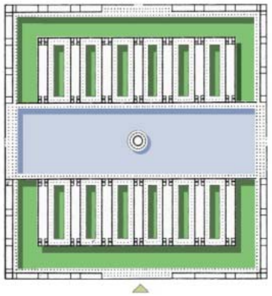


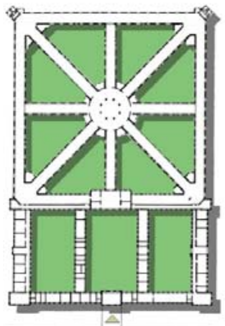
NTNU
Innovation and Creativity

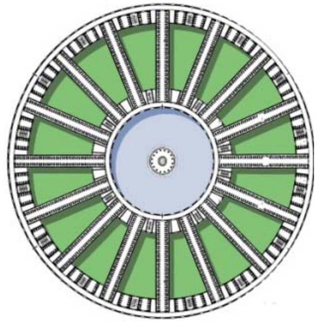
COURTYARD AND PAVILLIONS

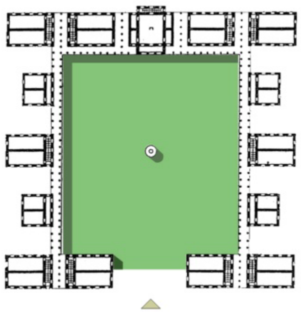
EXTERIOR/INTERIOR

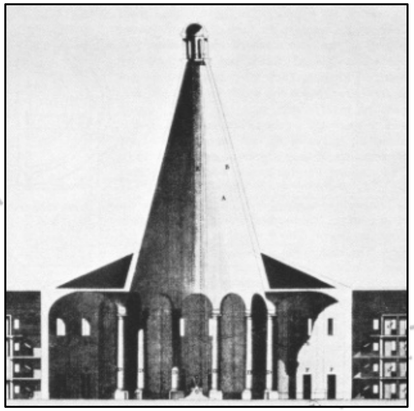
THERAPEUTIC ROLE

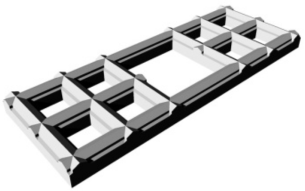

Durand

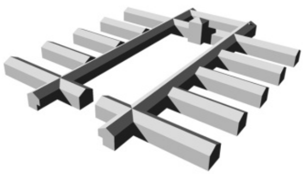

Desgodets


Poyet y Coqueau,


Royal Naval hospital







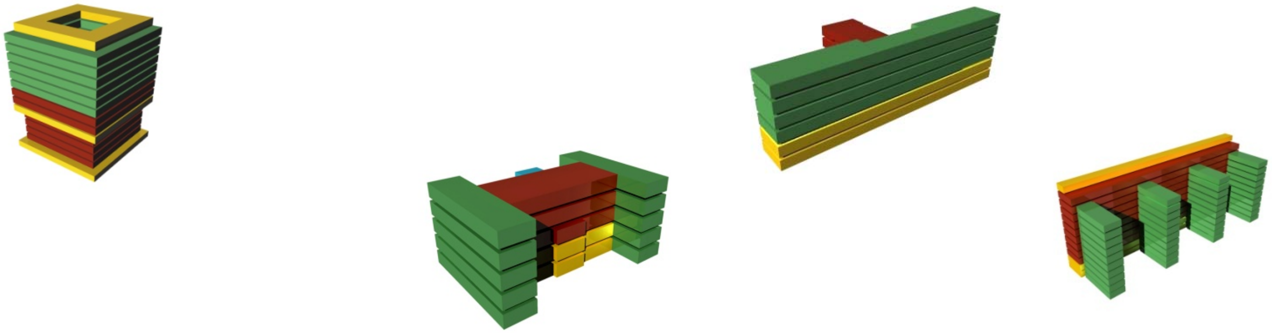
NTNU
Innovation and Creativity

COMPACT TYPOLOGIES

THREE ZONES

FUNCTIONAL PROGRAM

- General services
- Diagnosis and treatments
- Nursing wards



- Lift diffusion
- Increased cost of urban fields
- Pasteur and Koch discoveries - role of bacteria

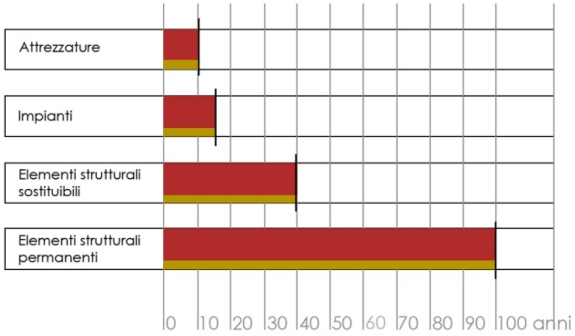
DELEGATION OF THE ENVIRONMENTAL CONTROL TO INSTALLASTIONS

NTNU
Innovation and Creativity

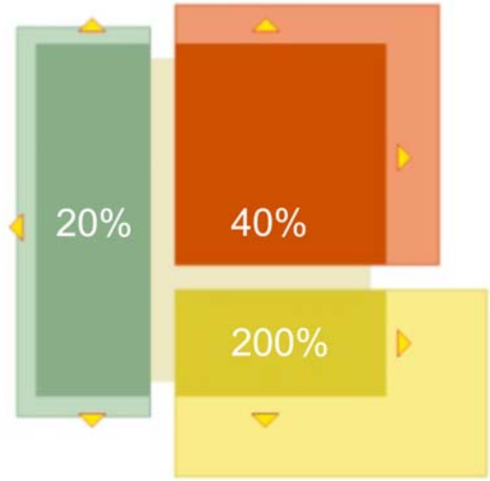
1950 - MEDICAL SCIENCE ACCELERATION

COMPLEXITY

UNPREDICTABILITY

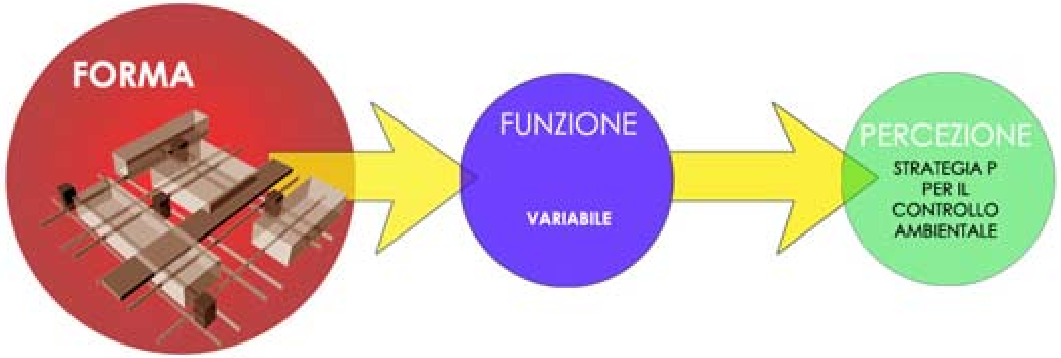


Font: F. R. Prodi, A. Stocchetti



"The study of functions doesn't represent anymore a solid base for hospitals architectural design. Functions change so often that architects will not have to aspire to the optimum between form and function. The real requirement is designing buildings that would allow functions to change"

John Weeks



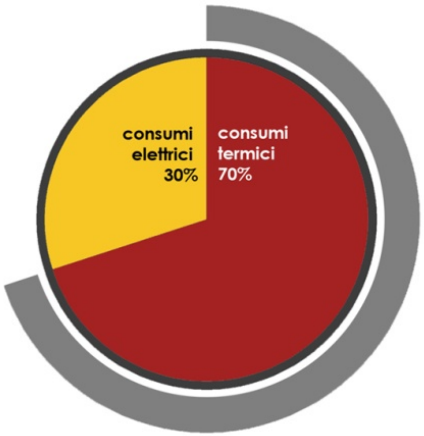
NTNU

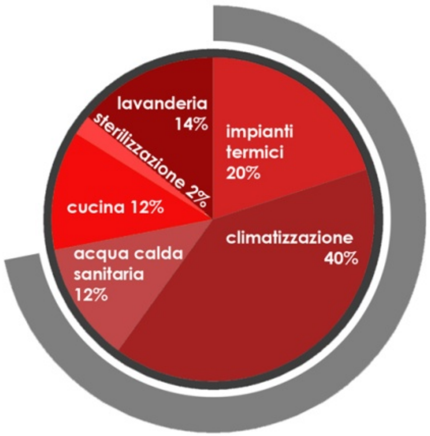
Innovation and Creativity

ENERGY CONSUMPTION

THERMAL DEMAND

ALMOST 70& OF TOTAL CONS.

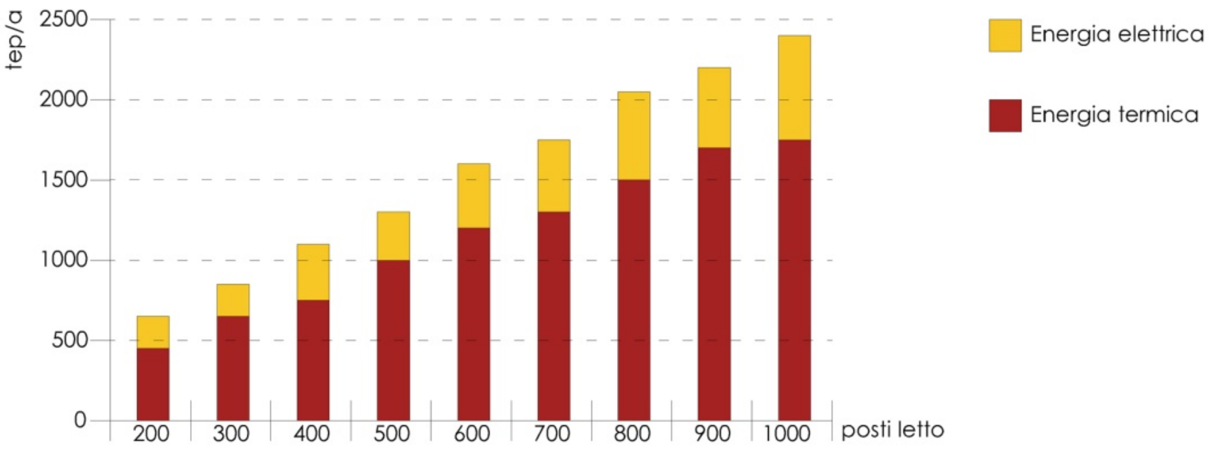




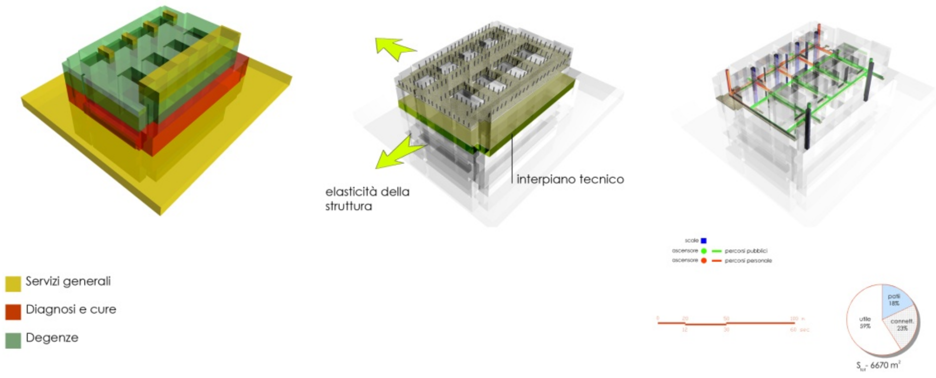
PRINCIPALI INDICATORI DI CONSUMO ENERGETICO ANNUO

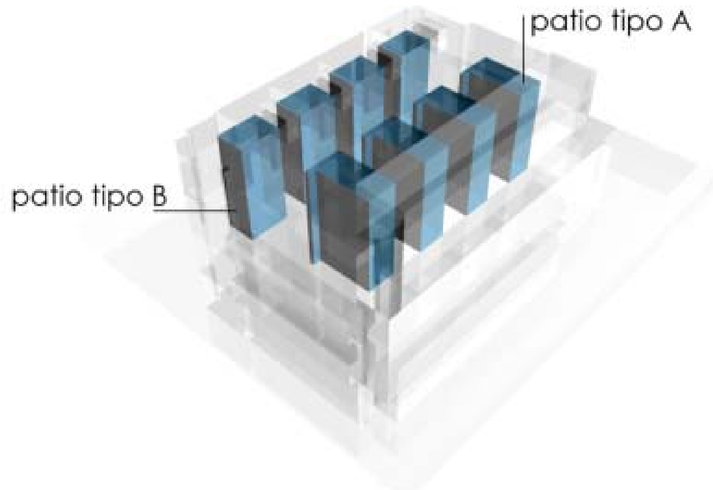
Energia termica impiegata per	Consumo tep/p.l.
Riscaldamento	1,40
Usi tecnologici	0,80
Acqua calda	0,15
Lavanderia	0,20
Preparazione alimenti	0,02
Altri usi	0,03
(2,90)	
Energia elettrica (0,70)	0,70
Totale	3,60

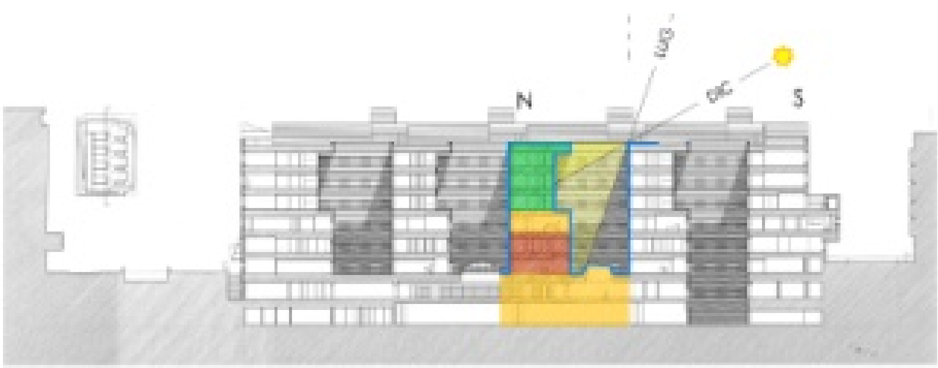
Thermal energy used for environmental comfort represents more than two thirds of the total consumption. Font: ENEA, 1996



MORPHOLOGICAL ANALYSIS







SHAPE COEFFICIENTS

ENVIRONMENTAL BEHAVIOUR

Pediatric hospital Gregorio Maranon

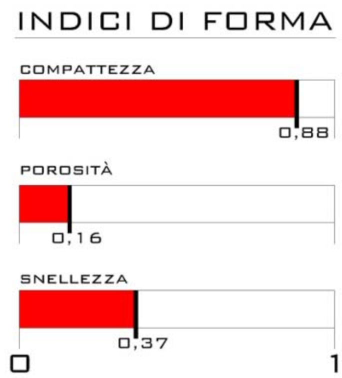
Location: **Madrid**

Architect: **Rafael Moneo**

$$C = \frac{S_{eq}}{S_g}$$

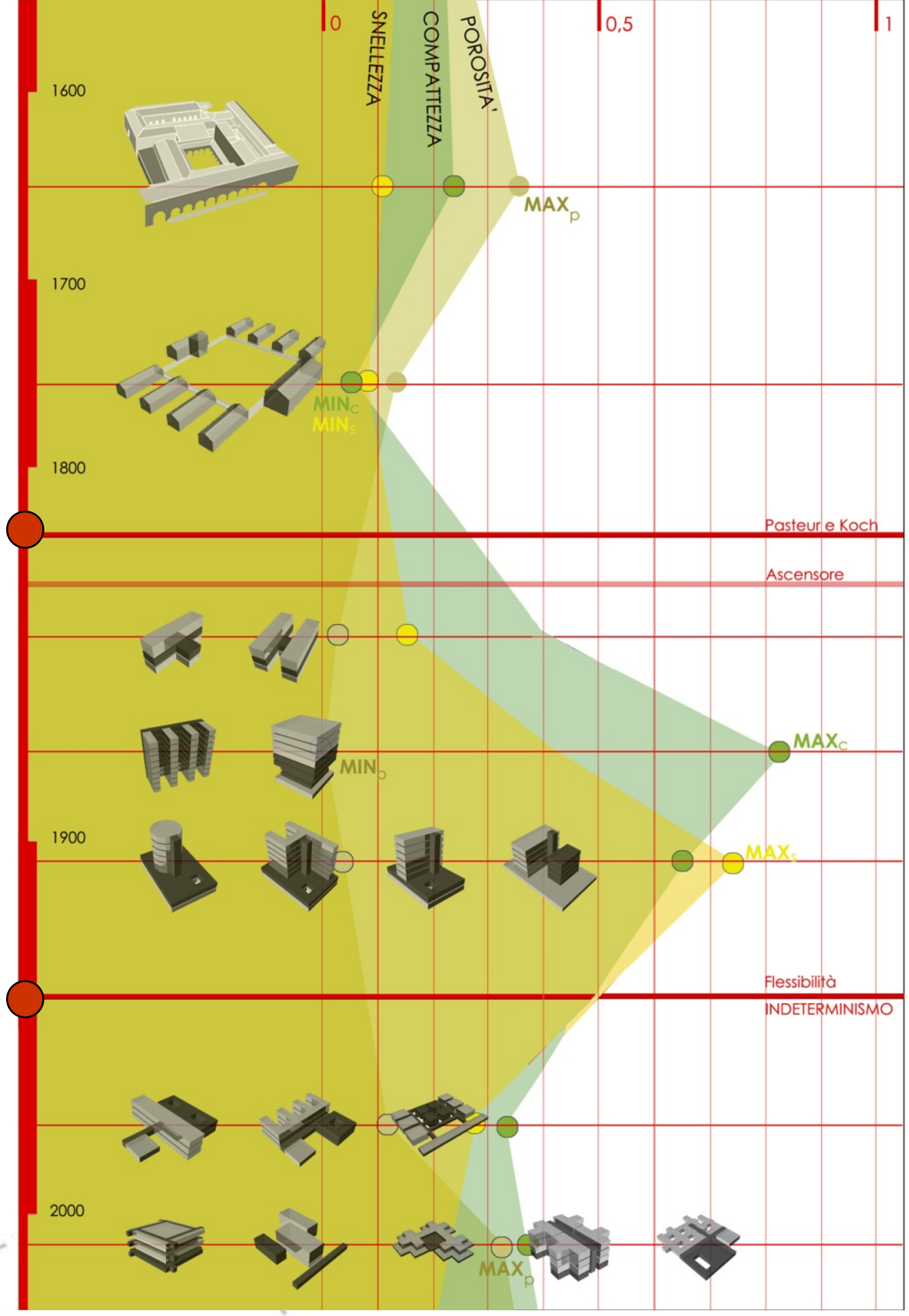
$$p = \frac{V_{ep}}{V_t}$$

$$e = \frac{h}{d}$$



NTNU

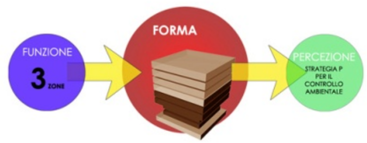
Innovation and Creativity



COURTYARD AND PAVILLION TYPOLOGIES

- **XV - XVIII CENT**

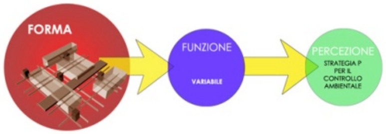
therapeutic role of natural light and ventilation



COMPACT TYPOLOGIES

- **XIX CENT.**

role of bazcteria, HVAC, lift



FLEXIBLE TYPOLOGIES

- **XX CENT.**

Medical science acceleration and functional orgnization unpredictibility.

NTNU
Innovation and Creativity

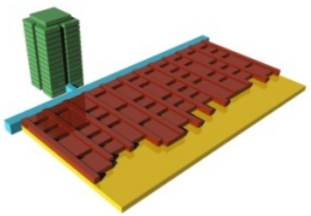
DETERMINISM

ATTEMPT OF FORECASTING CHANGE

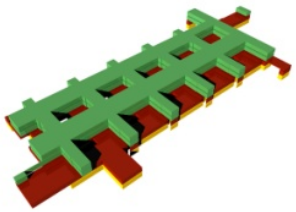
FORM OF ORGANISM

FUNCTIONAL PROGRAM

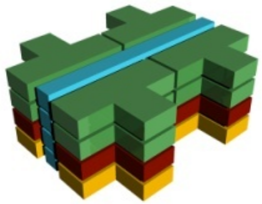
VERTICAL



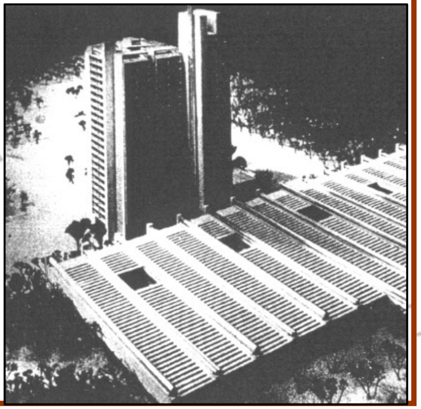
SLAB AND TOWER



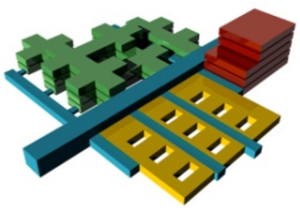
ARTICULATED SLAB

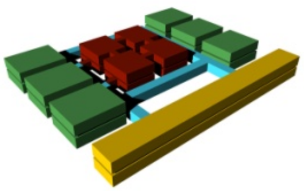


GALLERY

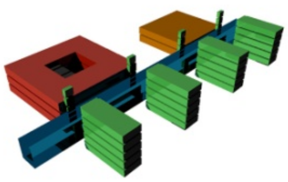


HORIZONTAL





MODULAR PLANT WITH COURTYARDS



SPINE AND PAVILLIONS

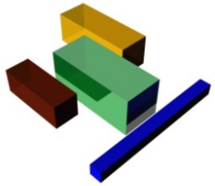
- General services
- Diagnosis and treatments
- Nursing wards

NTNU
Innovation and Creativity

INDETERMINISM

1

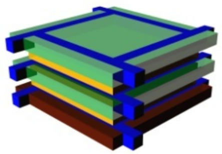
ADAPTABLE BUILDING



Isolated structures able to change indipendently

2

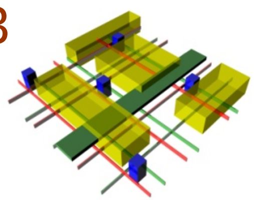
UNIVERSAL BOX



Box of big dimension – any point of the structure is able to host any sort of function

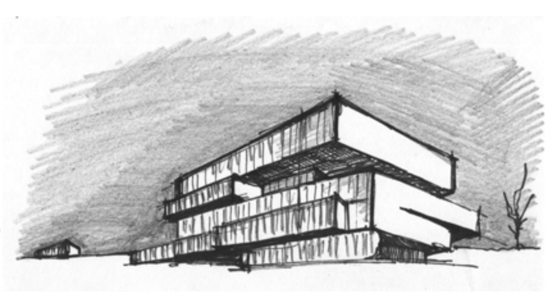
3

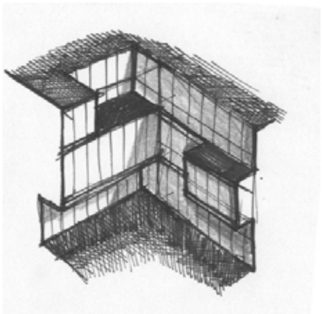
MAT BUILDING



The mail garantees growth and order

- **ORGANISM SHAPE**
- **SKIN**
- **VERTICAL PARTITIONS**
- **HORIZONTAL PARTITIONS**
- **INTERNAL PARTITIONS**
- **VERTICAL CONNECTIONS**
- **RELATIONS MAIL**
- **FUNCTIONAL BLOCKS**
- **STRUCTURE**
- **SPATIAL CELLS**



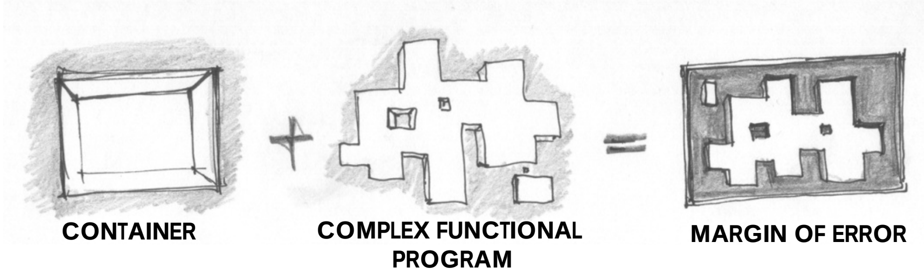


NTNU
Innovation and Creativity

INTERSTITIAL SPACES

PHYSICAL EXPRESSION

FLEXIBILITY

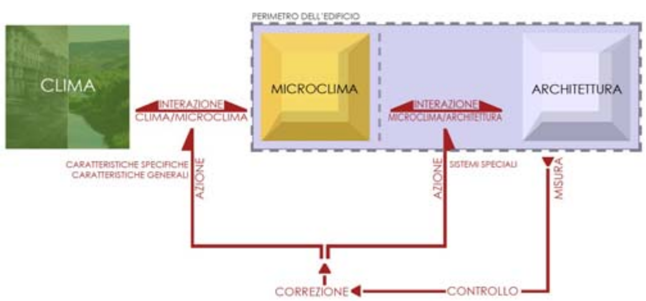


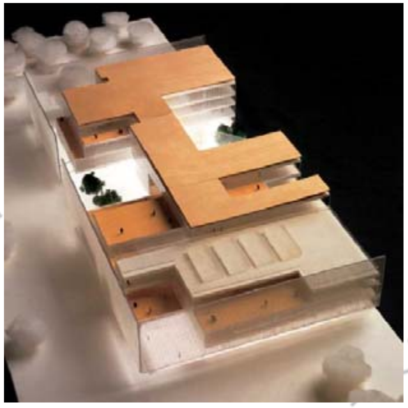
FONDAMENTAL QUALITY – COLLECTING INSIDE THE PERIMETER INTERSTITIAL SPACES, SMALL FRAGMENTS OF AIR AND DAYLIGHT WHOSE CONDITIONS MIGHT BE CONTROLLED AS AN INTERNAL SPACE

INTERSTITIAL SPACES

INDIFFERENT VERSATILE SPACE — **ZEIDLER**

AVAILABLE SPACES — **JOHN WEEKS**





MORPHOLOGICAL CHARACTERISTIC → **ENVIRONMENTAL QUALITY**

VERSATIL INTERSTITIAL SPACES INTERNAL TO THE PERIMETER

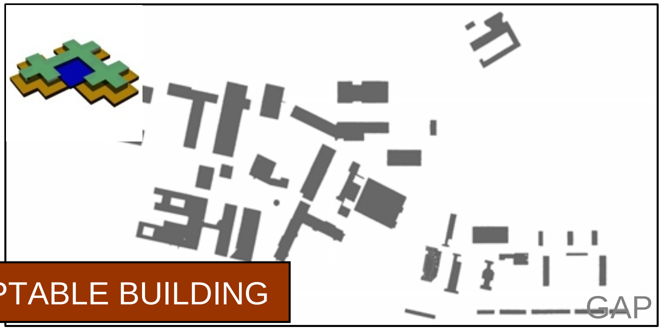
ENVIRONMENTAL SENSITIVITY FORM/CLIMATE

NTNU
Innovation and Creativity

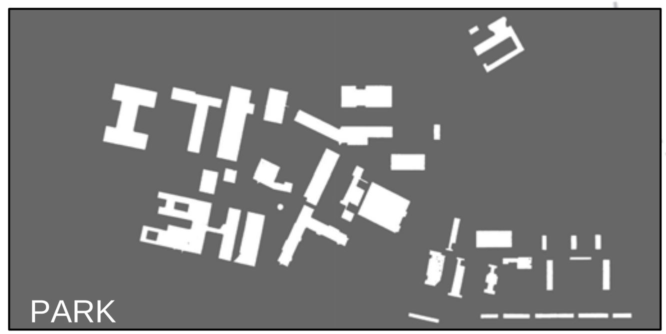
ENVIRONMENTAL CONTROL

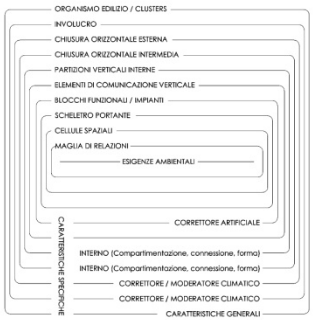
STRATEGIES

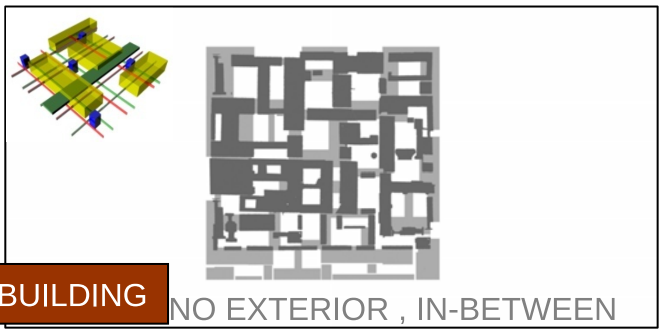
INTERSTITIAL SPACES



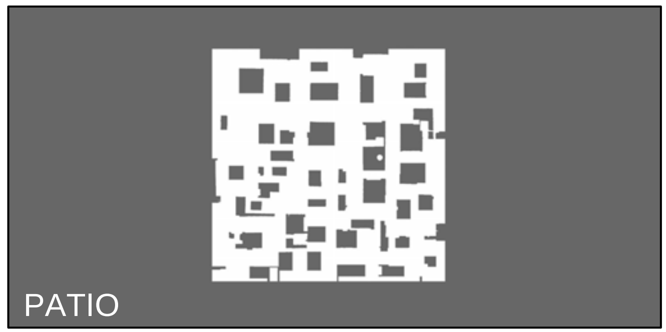
ADAPTABLE BUILDING

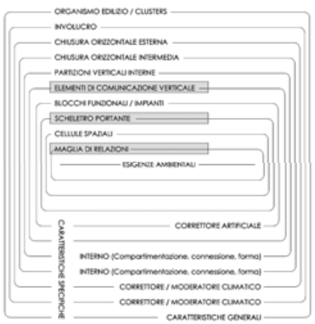


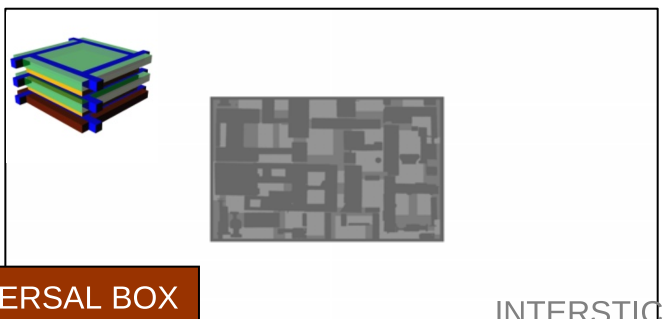




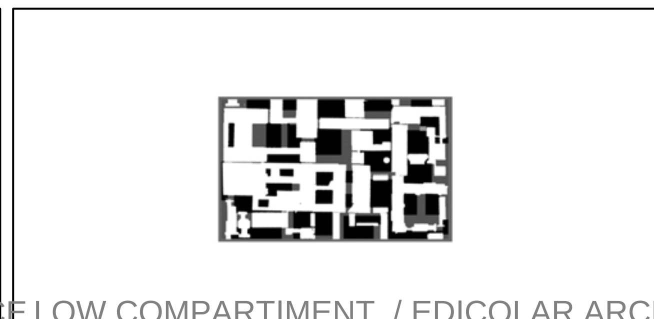
MAT BUILDING



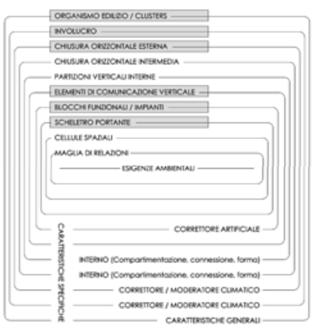




UNIVERSAL BOX



INTERSTICE LOW COMPARTIMENT. / EDICOLAR ARCH.



NTNU
Innovation and Creativity

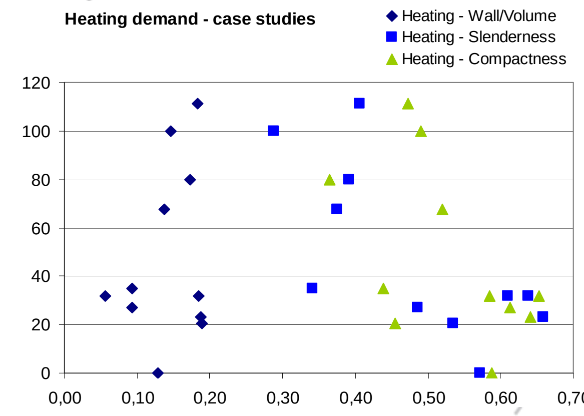
OFFICE BUILDINGS

THERMAL DEMAND

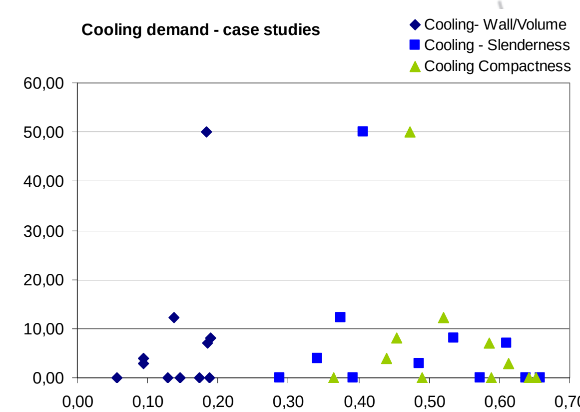
SHAPE COEFFICIENTS

Building	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/m^{2}y			*EA/V* 0,09													

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



a) Heating demand



b) Cooling demand

NTNU
Innovation and Creativity

METHODOLOGY

AGGREGATION

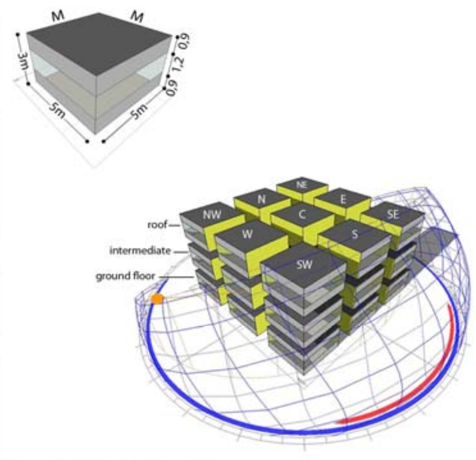
27 OFFICE UNITS

GENERAL CHARACTERISTICS	unit	theoretical models
Heated surface	m^2	4500 (180 clusters)
Glass area/heated surface	%	variable
Glass area/exposed facades	%	40,00
floor height	m	3,50

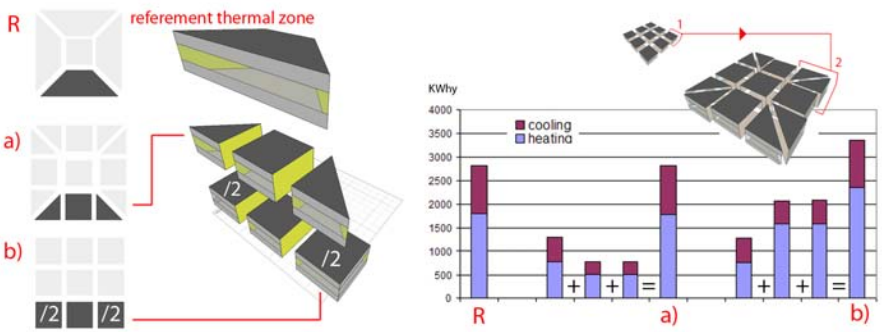
OCCUPANCY AND OPERATION	unit	font: TEK07
Occupancy	m^2/person	10,00
Hours of operation	hours	12 (MON_FRY), 0 (SAT,SUN)
HVAC		
Efficiency of heat recovery system	%	70,00
cooling set point temperature	°C	26,00
Heating set-back temperature	°C	18,00
Internal gains		
Lighting Load	W/m^2	8,00
Equipment Load	W/m^2	11,00

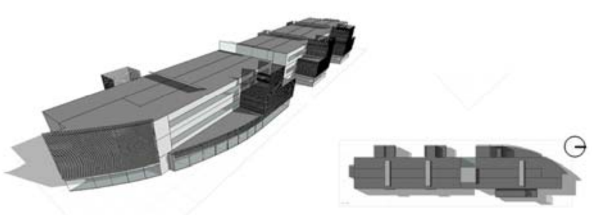
MATERIAL PROPERTIES	unit	font: TEK07
U-Value Floor	W/m^2/K	0,15
U-value roof	W/m^2/K	0,13
U-value wall	W/m^2/K	0,18
U-value window	W/m^2/K	1,20

INTERNAL COMFORT	unit	Simulation in Ecotect
Thermal		
Clothing	clo	1.0
Humidity	%	60
Air speed	m/s	0,5
Lighting		
Lighting level	lux	500
Infiltration rate		
Air tightness	ach	1,5 (TEC07)
Wind sensitivity	ach	0,25

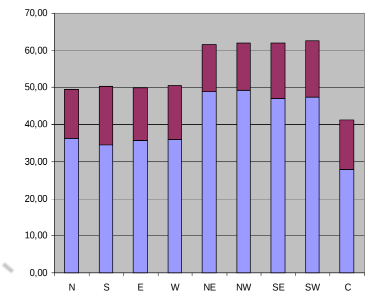


Climate: Oslo; Lat. 59.9°, Lng. 10,6°

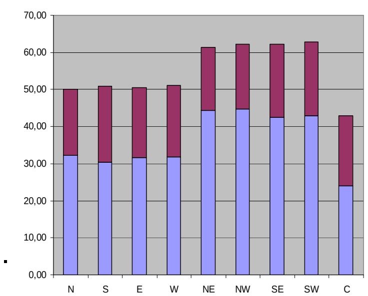




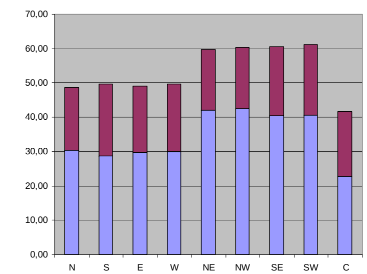
a) floor



b) interm.



c) roof

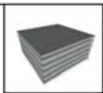
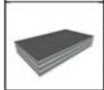
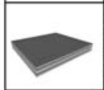
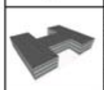
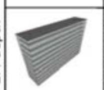
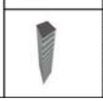


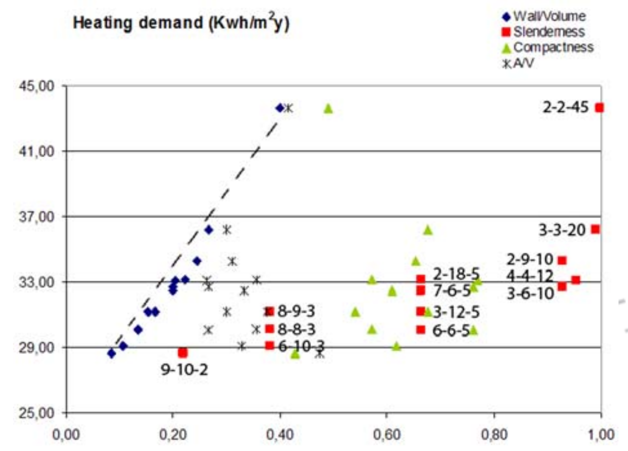
NTNU
Innovation and Creativity

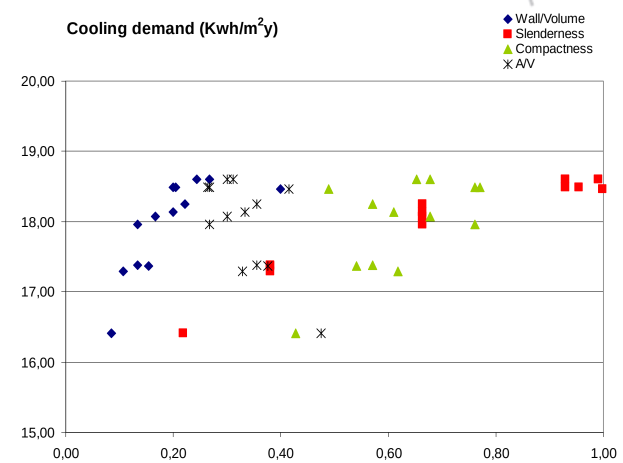
THEORETICAL MODELS

THERMAL DEMAND

SHAPE COEFFICIENTS

		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		





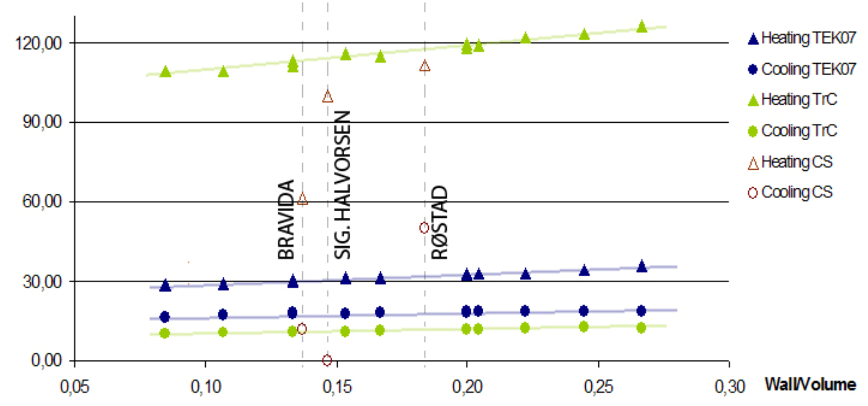
$S_w / V_t \ (m^{-1})$

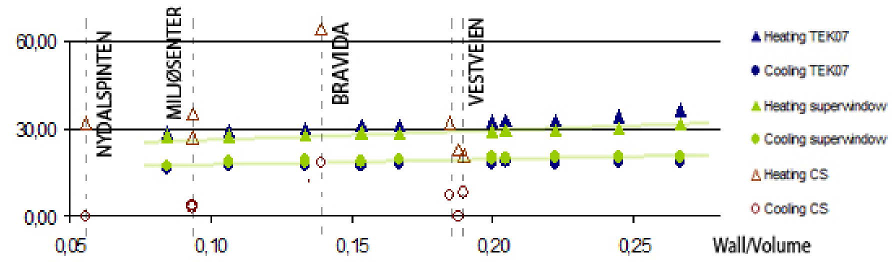
NTNU
Innovation and Creativity

RESULTS

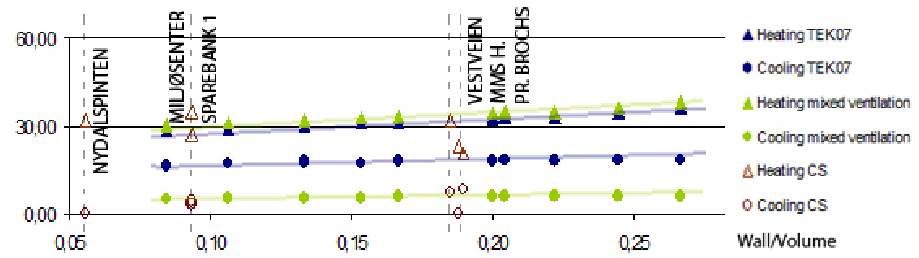
STRATEGIES

AND SHAPE IMPLICATIONS



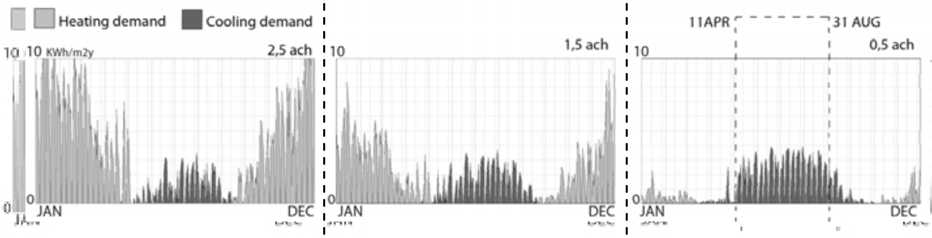


Implications of the shape on the thermal demand are negligible if compared with those ones due to the adoption of a certain low energy strategy



NTNU
Innovation and Creativity

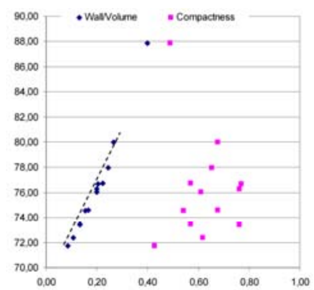
TEK07 – LE standards



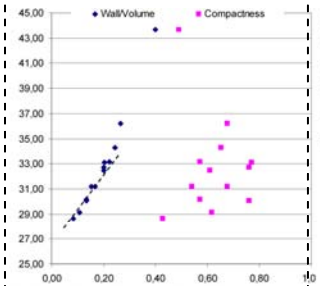
2,5 ach

1,5 ach

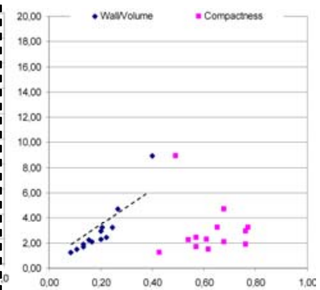
0,5 ach



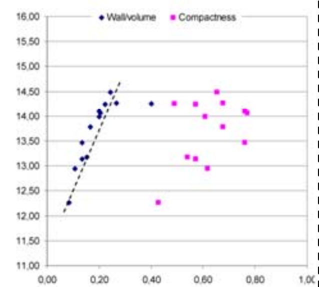
a) heating demand - 2,5 ach



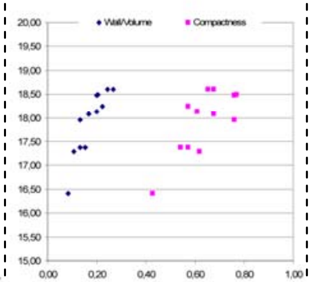
b) heating demand - 1,5 ach



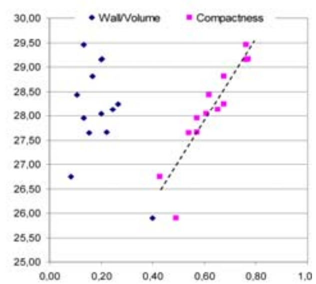
c) deating demand - 0,6 ach



a) cooling demand - 2.5 ach



b) cooling demand - 1.5 ach



c) cooling demand - 0,6 ach

Importance of using strategies for reducing the cooling demand or coping with it.

Completely different behaviour between heating and cooling demand in relation to the form in case of ach=0,5

THERMAL DEMAND

SPECIFIC CHARACTERISTICS

	Unit	Ref.	TEK07	LE
U-value external wall	$W/m^2/K$	1.2	0.15	0.15
U-value roof	$W/m^2/K$	0.60	0.13	0.13
U-value floor on ground	$W/m^2/K$	0.50	0.18	0.18
U-value windows, glazed walls and roofs	$W/m^2/K$	2.4	1.2	1.2
Air-tightness	ach	3.0	1.5	0.6
Heat recovery system efficiency	-	0.7	0.7	0.85
Occupancy	$Per./m^2$	0.1	0.1	0.1
Cooling set point temperature	$°C$	26	26	26
Heating set back temperature	$°C$	18	18	18
Lighting load	W/m^2	8	8	8
Equipment load	W/m^2	11	11	11