Thermal Comfort and market niches for apartment buildings:

Impact of the current Thermal Regulation in the private real estate market in Santiago de Chile

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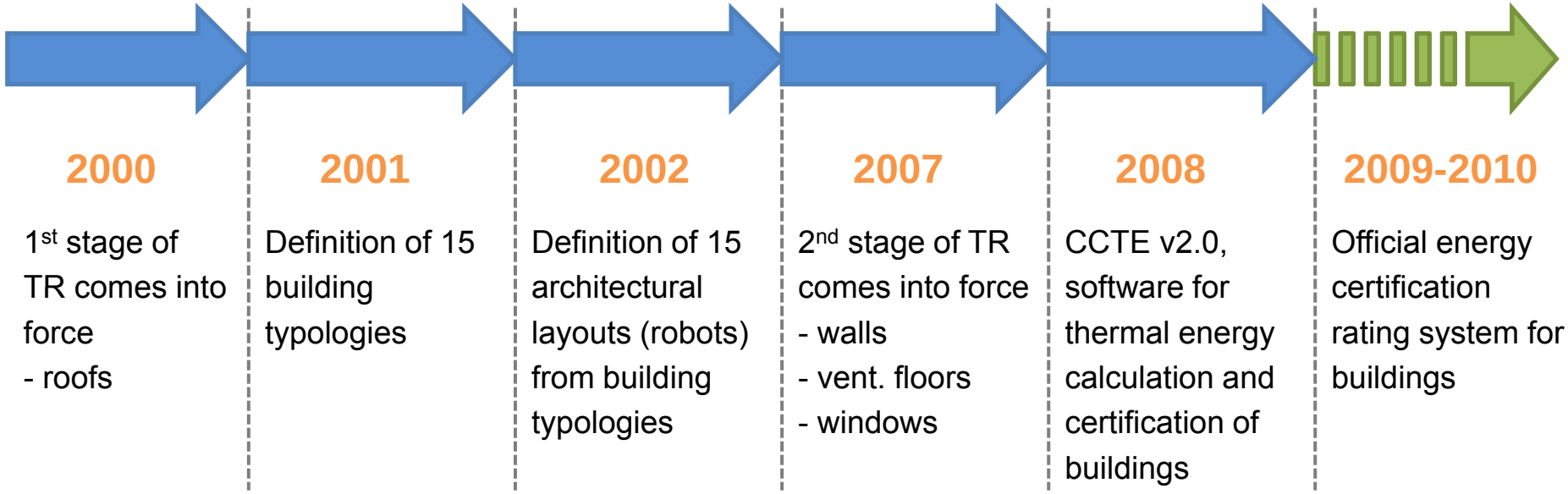
National Thermal Regulation [TR] and their stages



Typologies		Building permits, new dwellings, 1994-1998	
	number	number	%
Houses	10	389,540	79.9%
Apartments	5	98,070	**20.1%**
TOTAL*	15	487,610	100%

* Equivalent to 73,9% of total building permits

Source: Own elaboration based on IC (2001)

	Building permits, new dwellings, 2006					
	NATIONAL		SANTIAGO		REGIONS	
	number	%	number	%	number	%
Houses	106,054	65.0%	30,638	42.7%	75,416	82,5%
Apartments	57,182	**35.0%**	41,156	**57.3%**	16,026	**17,5%**
TOTAL	163,236	100%	71,794	100%	91,422	100%

Source: Own elaboration based on INE (2007)

2nd Stage of the National Thermal Regulation [TR]

THERMAL ZONES		BUILDING ENVELOPE					
		OPAQUE ELEMENTS			GLAZING SURFACES		
		Maximum allowable U-value			Maximum allowable glazing percentage regarding vertical building envelope		
N°	EXAMPLES OF CITIES	ROOFS	WALLS	VENTILATED FLOORS	SINGLE GLAZING	DOUBLE GLAZING	
		[W/m²K]	[W/m²K]	[W/m²K]		3.6 W/m²K ≥ U > 2.4 W/m²K	U ≤ 2.4 W/m²K
1	Iquique (20°32'S)	0.84	4.0	3.60	50%	60%	80%
2	Calama (22°28'S)	0.60	3.0	0.87	40%	60%	80%
3	Santiago (33°27'S)	0.47	1.9	0.70	25%	60%	80%
4	Concepción (36°47'S)	0.38	1.7	0.60	21%	60%	75%
5	Temuco (38°46'S)	0.33	1.6	0.50	18%	51%	70%
6	Puerto Montt (41°28'S)	0.28	1.1	0.39	14%	37%	55%
7	Punta Arenas (53°80'S)	0.25	0.6	0.32	12%	28%	37%

Source: Own elaboration based on Diario Oficial (4th January 2007)

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Source: Own elaboration based on Diario Oficial (4th January 2007)

How to give compliance to the regulation in Santiago?

Unifamiliar Houses

TRADE NAME	COMPONENTS				U-VALUE*
	MATERIAL	SIZE			
		LARGE	WIDTH	HIGH	
		[mm]	[mm]	[mm]	[W/m²K]
Extra Titán Reforzado Estructural	Brick	290	140	94	1.90

* Source: MINVU, IC (2006)

Apartment buildings

TRADE NAME	COMPONENTS				U-VALUE*
	MATERIAL	THICKNESS	DENSITY	THERMAL CONDUCTIVITY	
		[mm]	[kg/m³]	[W/mK]	[W/m²K]
Polyplak Knauf	Gypsum board	10	700	0.26	1.88
	Expanded polystyrene foam	10	10	0.043	
	Reinforced concrete	150	2400	1.63	

* Calculated by means of NCh 853 Of. 91

01. CONTEXT

Impact of the National Thermal Regulation in the private real estate market in Santiago

THREE FACTS:

a) The assumptions considered during the elaboration of the 2nd stage of the TR – related to the participation of apartment building in the real estate market – nowadays are not completely valid, especially when the focus is Santiago.

b) The application of the 2nd stage of the TR practically have not impact in the houses market, since the requirement could be satisfied using only bricks (without thermal insulation) in the building envelope. On the contrary, in apartment buildings, it is necessary to incorporate al least 10 mm of thermal insulation in external walls to give compliance to the regulation.

c) The National Thermal Regulation was designed exclusively based on winter comfort criteria (monthly heating degree-hours). Overheating phenomena for cooling season were not considered.

Impact of the National Thermal Regulation in the private real estate market in Santiago

THREE QUESTIONS:

a) Is it possible to generate more representative building typologies, regarding the private real estate market in Santiago?

"Energy Lord Cochrane" Building
30.35 m^2 useful surface
3.42 m^2 terrace surface
1,105 UF

"Estocolmo" Building
128.84 m^2 useful surface
46.84 m^2 terrace surface
7,500 UF

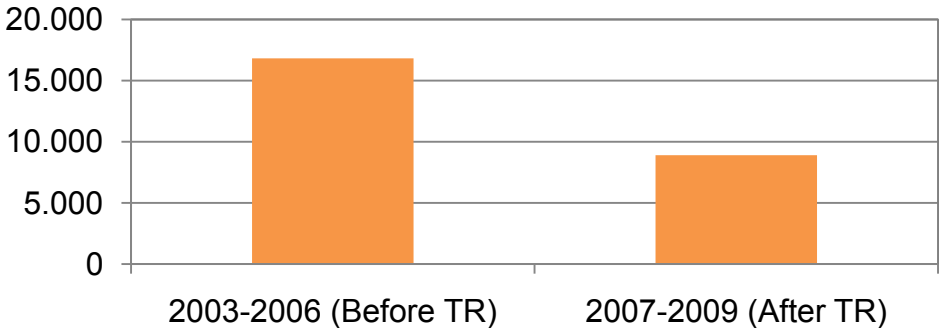
b) What has been the impact of the Thermal Regulation in the thermal behaviour of new apartment buildings in Santiago?

c) How the summer comfort of new apartment buildings in Santiago has been affected by the introduction of a Thermal Regulation, designed exclusively for the heating season?

Description of the database

Portal Inmobiliario.com *Database, corresponding to 25,711 apartments for sale in Santiago, during the period 2003-2008.*

Important: 2nd Stage of the TR comes into force on 4th January 2007



Description of the database

*Average values to apartments for sale in Santiago for the period **2003-2009***

CASES NUMBER	8,898			
	MIN	MAX	MEAN	STANDARD DEVIATION
Useful surface [m^2]	18.41	309.22	59.44	28.73
Terrace surface [m^2]	0	181.39	6.79	8.36
Total Surface [m^2]	18.41	354.16	66.23	35.21
Number of floors	1	26	9.03	6.09
Number of rooms	1	5	2.25	0.85
Number of bathrooms	1	5	1.73	0.70
Price [UF]*	567	22,500	2,464	1,773
Price [UF/m^2]*	15.23	90.93	39.79	9.95

* 1 UF = EUR 27.3 according to Central Bank of Chile (http://bcentral.cl), 15th June 2009

	MIN	MAX	MODE
Main central hall	1	4	2
Security	1	3	2
Loft or duplex	0	1	0
Green areas	0	1	1
Additional parking facilities	0	1	0
Quality finish for kitchen	1	4	2
Service rooms	0	4	0
Central heating	0	1	1
Loggia	0	1	0
Floating floor	0	1	1
Carpet floor	0	1	1
Quality finish	1	4	3
Parking and storage rooms	0	1	0

Comparison of both periods

Variance Analysis (ANOVA)

Variable	Groups	ANALYSIS BETWEEN GROUPS	
		F - test	Statistical Significance
Price [UF/m^2]	2003 – 2006 (before TR)	36.48	1.56 E-09
	2007 – 2007 (after TR)		

Levene Test for Equality of Variances

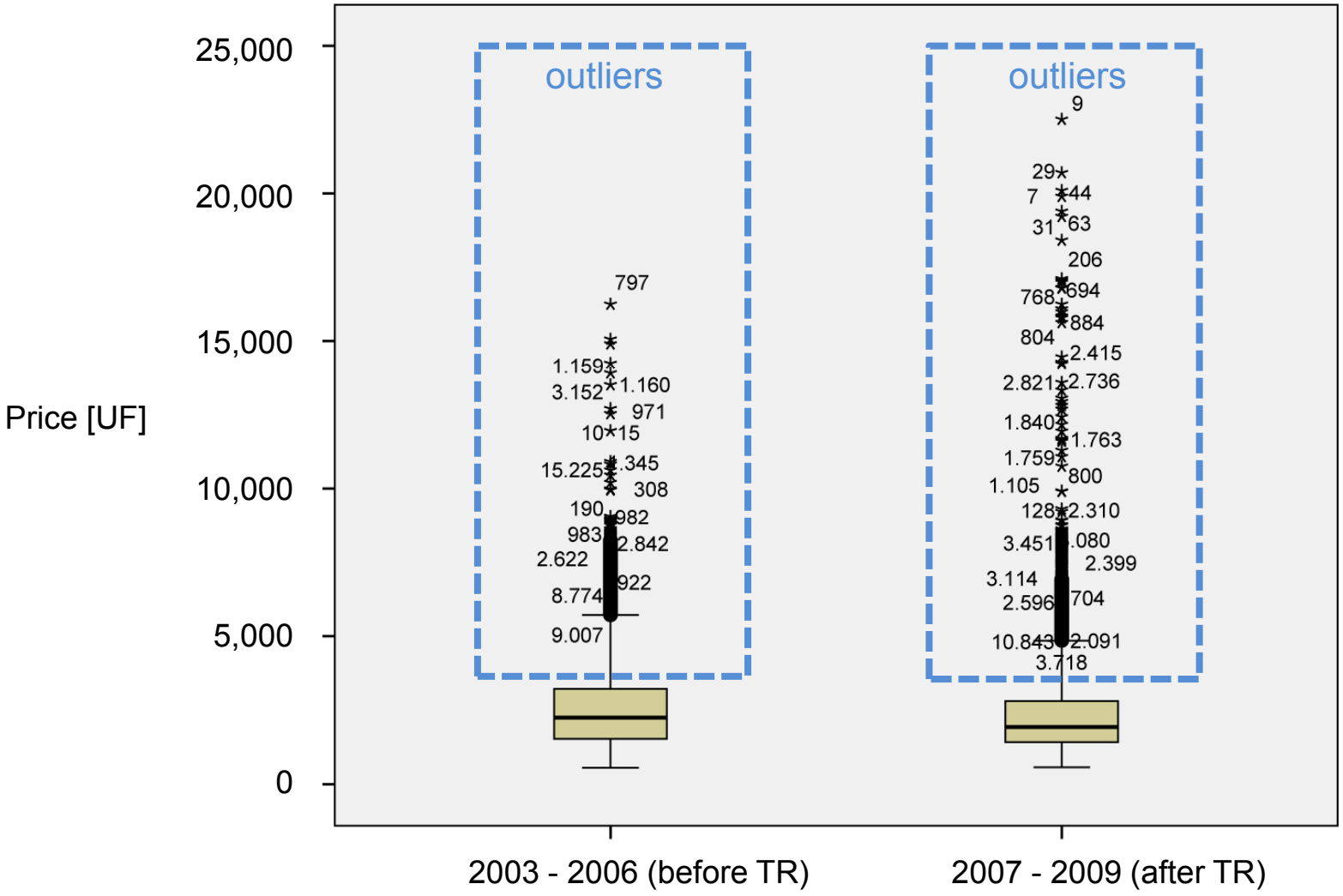
Variable	Groups	M-ESTIMATORS			
		Huber's M-Estimator	Tukey's Biweight	Hampel's M-Estimator	Andrews' Wave
Price [UF/m^2]	2003 – 2006 (before TR)	39.5393	39,2211	39.6484	39.2128
	2007 – 2007 (after TR)	39.4805	39.3062	39.5344	39.3004

a) There is not a significant change in the real estate values and products with the introduction of the Thermal Regulation.

b) Probably, the extra cost for incorporating Thermal Regulation improvements was absorbed in the profit margin of real estate developers.

Comparison of both periods

Box plots for both periods



Niches market definition for apartments in Santiago

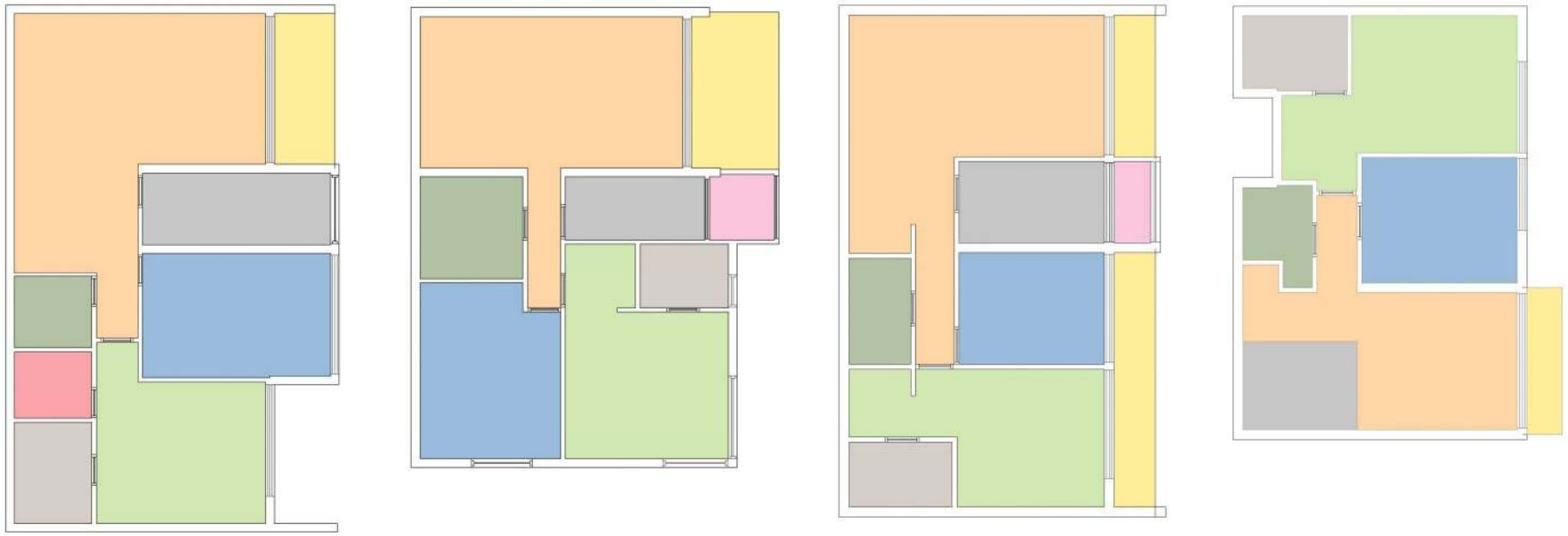
Number of apartments and percentage of the total for each cluster

CLUSTER	NUMBER OF APARTMENTS	PERCENTAGE OF TOTAL
I	4,975	19.3%
II	4,255	16.5%
III	7,563	29.4%
IV	8,918	34.7%
Total	**25,711**	**100.0%**

Centroids of clusters

CLUSTER	USEFUL SURFACE		TERRACE SURFACE		PRICE	
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	[m^2]	[m^2]	[m^2]	[m^2]	[UF]	[UF]
I	55.07	19.36	6.24	5.23	2,272.19	1,040.06
II	104.09	32.03	16.63	13.11	4,958.65	2,112.43
III	49.22	16.16	4.96	3.86	1,961.70	812.70
IV	56.01	18.23	5.68	4.77	2,045.63	896.10
Total	**61.78**	**28.23**	**7.39**	**7.94**	**2,546.86**	**1,607.96**

Description of the models used in the thermal simulations



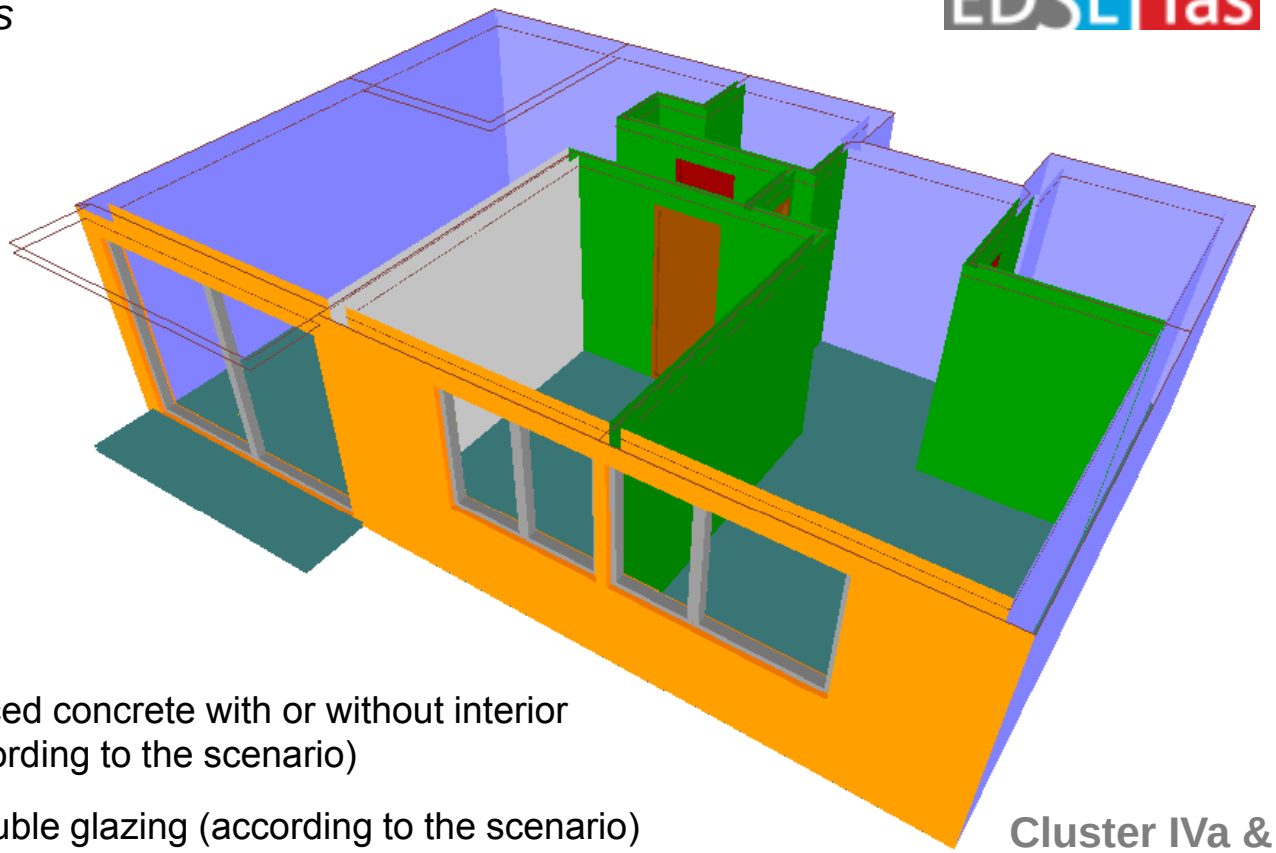
Description of the models used in the thermal simulations

Three scenarios regarding Thermal Regulation [TR]

SCENARIOS		BUILDING ELEMENTS						
		WINDOWS		EXTERNAL WALLS				
				COMPONENTS				
		MATERIAL	U-VALUE	MATERIAL	THICKNESS	DENSITY	THERMAL CONDUCTIVITY	U-VALUE
			[W/m²K]		[mm]	[kg/m³]	[W/mK]	[W/m²K]
S1	Before 2nd stage of TR	Single glazing	**5,8**	Reinforced concrete	200	2400	1,63	**3,41**
S2	After 2nd stage of TR	Single glazing	**5,8**	Gypsum board	10	700	0,26	**1,25**
				Expanded polystyrene foam	20	10	0,043	
				Reinforced concrete	200	2400	1,63	
S3	After 2nd stage of TR and double glazing	Double glazing	**2,8**	Gypsum board	10	700	0,26	**1,25**
				Expanded polystyrene foam	20	10	0,043	
				Reinforced concrete	200	2400	1,63	

Description of the models used in the thermal simulations

Different building elements



Cluster IVa & IVb

- **External wall**: Reinforced concrete with or without interior thermal insulation (according to the scenario)
- **Windows**: single or double glazing (according to the scenario)
- **Party wall (adiabatic)**: reinforced concrete
- **Internal wall 1**: gypsum board partition with thermal insulation
- **Internal wall 2**: reinforced concrete
- **Slab (adiabatic)**: concrete slab and floating floor

Results in terms of winter and summer thermal comfort

Impact of the Thermal Regulation (extra-insulation of the scenarios S2 & S3)

How can I reduce this overheating (as consequence of the insulation increase)?

CLUSTERS	SCENARIOS	HEATING DEGREE HOURS (WINTER COMFORT)		OVERHEATING DEGREE HOURS (SUMMER COMFORT)	
		Degree-hours below 20°C	% reduction compared to S1	Degree-hours over 26°C	% reduction compared to S1
I	S1	63,972	- - -	23,346	- - -
	S2	52,853	17%	31,694	- 36%
	S3	41,191	36%	47,474	- 103%
II	S1	73,008	- - -	17,948	- - -
	S2	63,677	13%	24,402	- 36%
	S3	48,925	33%	35,419	- 97%
III	S1	90,513	- - -	20,569	- - -
	S2	86,860	4%	22,744	- 11%
	S3	69,431	23%	37,171	- 81%
IVa	S1	80,430	- - -	30,459	- - -
	S2	73,769	8%	37,418	- 23%
	S3	58,809	27%	57,351	- 88%
IVb	S1	69,515	- - -	52,188	- - -
	S2	62,972	9%	61,233	- 17%
	S3	48,263	31%	87,009	- 67%

Different ventilation strategies used in the thermal simulations

DESCRIPTION		WINTER		SUMMER	
		ACH	OPERATION	ACH	OPERATION
V1	Steady ventilation	1	24 hours	1	24 hours
V2	Operable windows (managed by users)	1	*Windows are closed*	Free	*Windows are open*: when T° interior > T° exterior; T° interior ≥ 26°C and T° exterior ≥ 16°C
				1	*Windows are closed* (rest of the time)
V3	Night ventilation*	1	24 hours, from May to October	1	Daytime (between 07:00 and 24:00), from November to April
				4	Night (between 24:00 and 07:00), from November to April

* Ventilation regimen used by the CCTEv2.0 software, to give compliance to the procedures of the new official energy certification rating system for buildings

Results of the simulations considering ventilation strategies

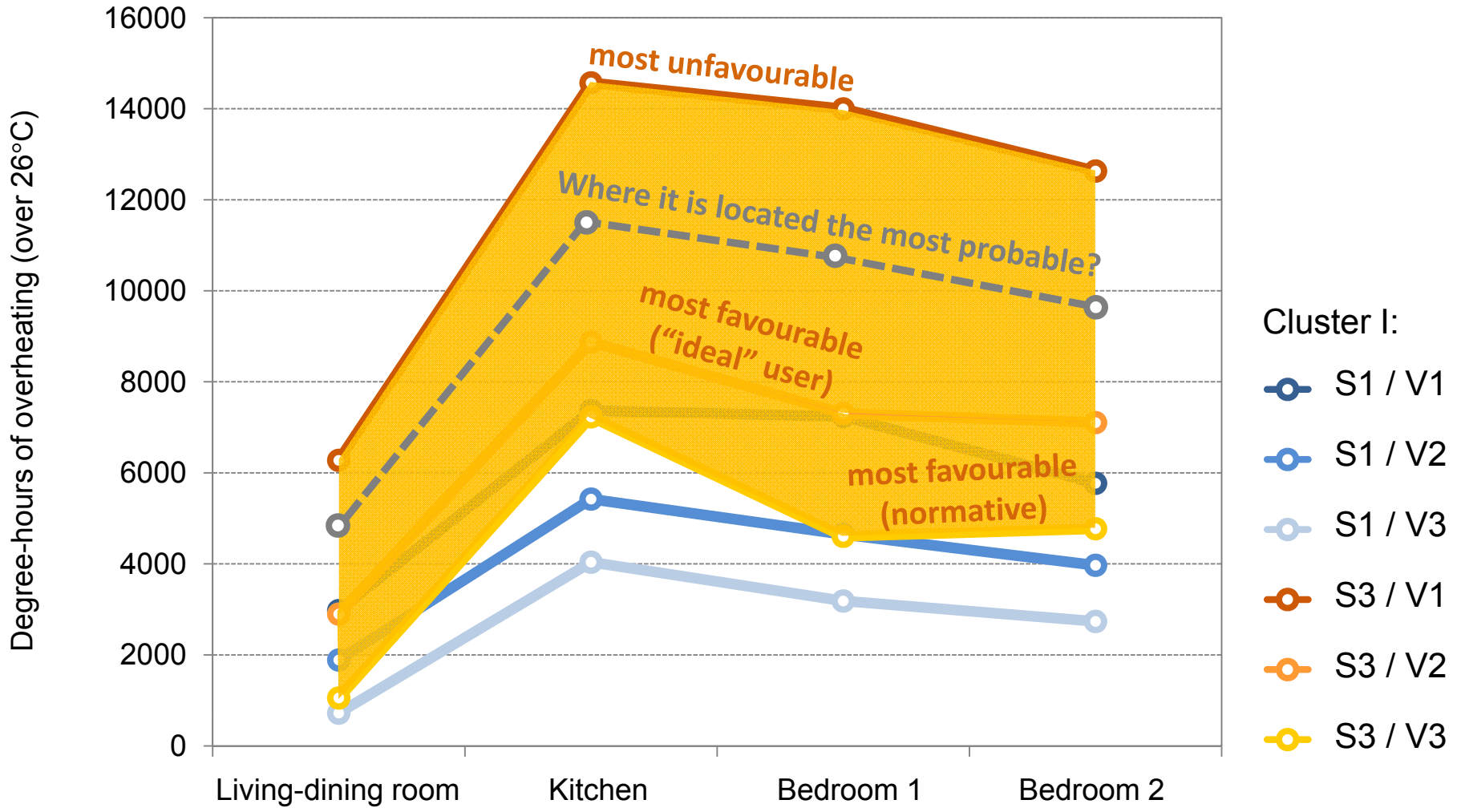
CLUSTER	SCENARIOS	VENTILATION STRATEGIES	OVERHEATING DEGREE HOURS (SUMMER COMFORT)	
			Degree-hours over 26°C	% reduction compared to V1
I	S1	V1	23,346	- - -
		V2	**15,922**	32%
		V3	**10,673**	54%
	S2	V1	31,694	- - -
		V2	**19,685**	37%
		V3	**13,307**	58%
	S3	V1	47,475	- - -
		V2	**26,179**	45%
		V3	**17,657**	63%

a) The percentage of reduction both V2 and V3 in comparison to V1 is more effective when the envelope is insulated, such as in the S2 and S3 scenarios.

b) With intensive night ventilation (V3), overheating due to application of Thermal Regulation and double glazing (S3) could be importantly reduced in comparison with the naturally ventilated initial scenario (S1-V2)

c) V3 is much more effective in absolute terms, but due to this corresponds typically to a normative approach, could be much less real than V2.

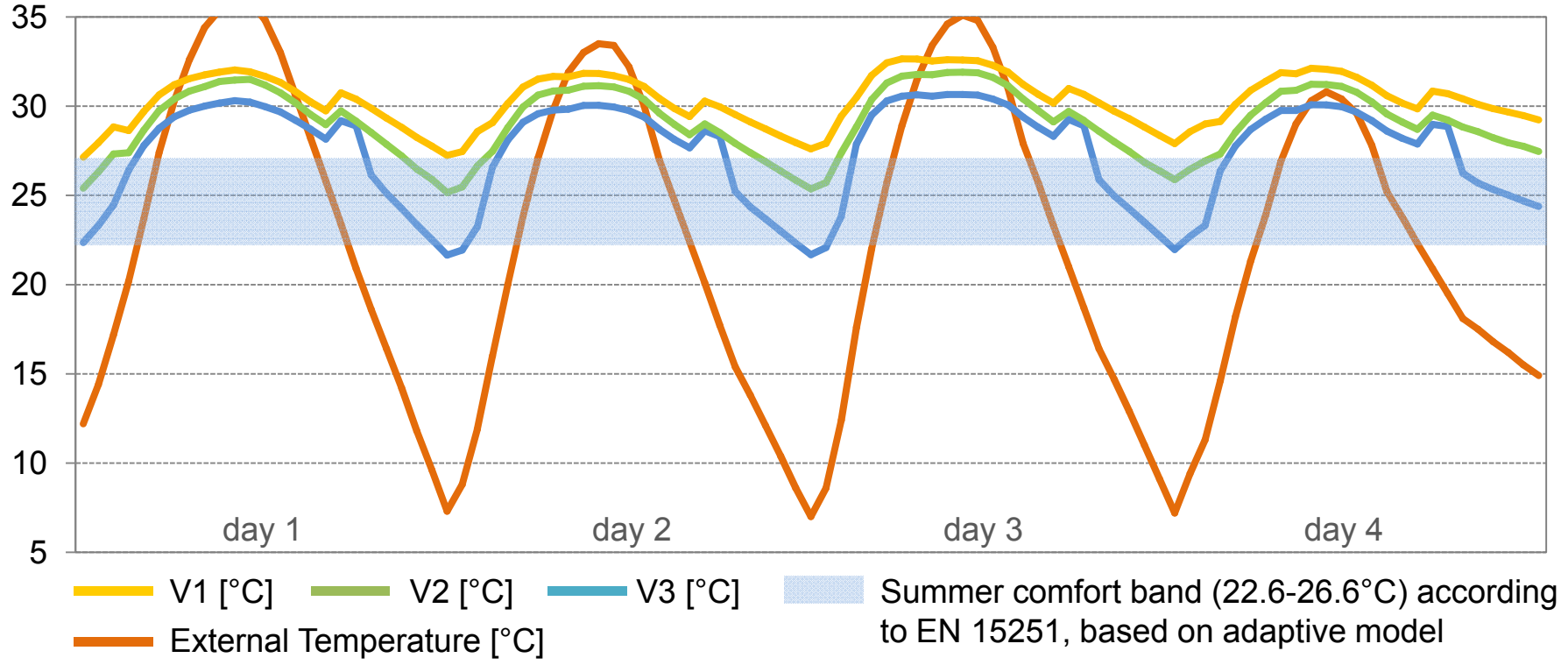
Results of the simulations considering ventilation strategies



c) V3 is much more effective in absolute terms, but due to this corresponds typically to a normative approach, could be much less real than V2.

Results of the simulations considering ventilation strategies

Temperature variation of Cluster I for different ventilation strategies and S3 in four summer days



d) Neither of the ventilation strategies is able to reduce completely overheating during daytime (reaching the summer comfort band).

e) Could be interesting to identify which clusters can reach summer comfort using just passive cooling techniques. For that, it is clear that it is necessary to integrate other measures in the study, such as solar protection and thermal inertia.

CONCLUSIONS

a) The decision of the current TR of incorporating thermal insulation in the external envelope of apartments in Santiago appears as appropriate to improve winter comfort conditions. However, overheating could be an important problem, if users are not aware of the role of natural ventilation in the thermal behaviour of apartments in summer.

b) Due to the achieved improvements related to the 2nd stage of TR are still limited, there is an important future challenge to introduce most restrictive requirements in the regulation and encouraging the use of double glazing.

FURTHER RESEARCH

c) The incorporation of other passive cooling techniques in the study, such as solar protection and thermal inertia (combined to the studied ventilation strategies), to define how it is possible reach summer comfort without the use of air conditioning.

d) A survey study of ventilation habits for apartments in Santiago is proposed as further research. The ventilation strategies used in this article just are boundary models (which define optimum and minimum performances related to ventilation), which should be compared to a most realistic behaviour.

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Thank you for your attention.

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