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The road to nearly zero energy buildings. Case of study: Spain. Comparison between CTE HE 2006 and 2013 in a simulated model.

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Abstract.

Achieving Nearly Zero-Energy Buildings (NZEBs) is a main goal for the European Union, in order to reduce energy consumption in the building sector. NZEB means a building that has a very high energy performance. Its energy requirements should be covered by renewable sources, produced on-site or nearby [1]. It could be possible if building were turned into a "small power generating station", or reducing consumption with passive building proposals. However, we think that it is worth looking for a balance between energy consumption and generation for every building, following this simple equation:

$$Consumption = demand - generation$$

The European regulations have already begun to indicate deadlines to implement NZEB requirements in buildings. Therefore, Spanish legislation related to energy efficiency and renewable energy generation in buildings has been recently updated, CTE HE [2].

This paper provides a comparative analysis for the new requirements (2013 CTE DB HE compared with previous 2006 regulation, revised in 2009).

This study was performed by using a computer building model, including its geometry, building materials, usage profiles and installations. Thus, we could compare the characteristics of the different regulations, and we could evaluate the progress toward the NZEB concept.

Key words

Power. Efficiency. Saving. Computer simulation. NZEB buildings.

1. Introduction

The study is based on the analysis of the energy saving regulation. We have worked with a computer model showing the differences between the requirements and verification methods included in the 2006 version (2009) and 2013 version of the "Documento de Ahorro de Energía del Código Técnico" (a public Spanish official document related with energy saving rules in building sector). We have also evaluated the progress towards the NZEB concept.

A Nearly Zero-Energy Building (NZEB) is the one that was conceive on the basis of energy efficiency systems, including severe regulatory requirements, and minimizing its energy supplies, which are covered to a very significant extent by energy from renewable sources (self-generating or imported from nearby areas).

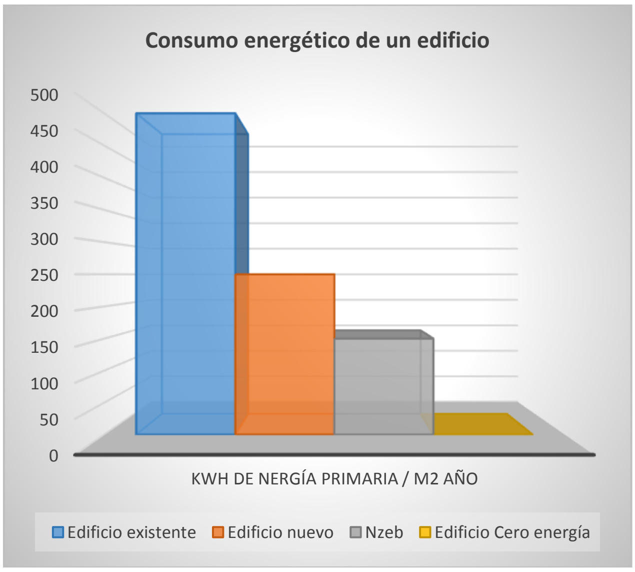


Fig. 1. Energy consumption at different kind of buildings.

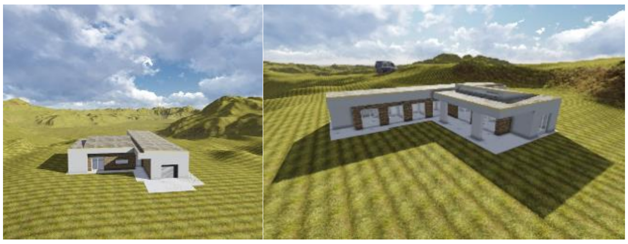


Fig. 2. Computer model used to perform the simulation.

In order to perform the comparison and to evaluate the differences, we have developed an example with a suposed new detached house, which observes the 2006 (2009) HE requirements. Then, the model simulates the 2013 HE requirements, including the corrections related with the building envelope and facilities to comply with directives.

2. Experimental

The building model consists of a single family house with four bedrooms, two bathrooms, kitchen, living room, sitting room, and garage, located at Badajoz (Spain).

A. The simulation procedure.

The procedure followed to make the comparative analysis of the CTE has been:

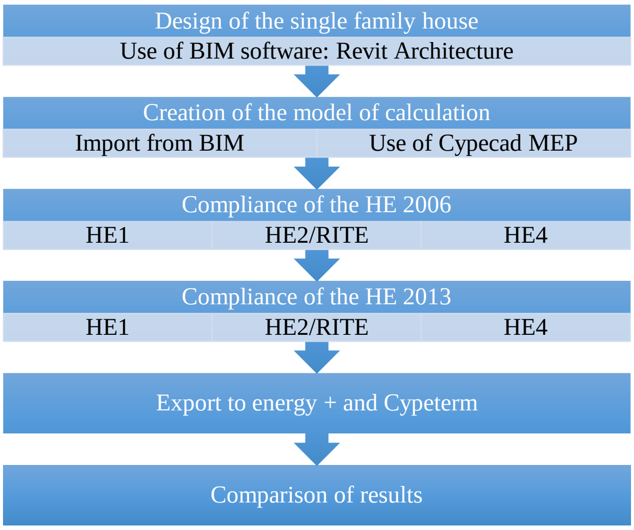


Fig. 3. The simulation procedure.

B. Normative analysis of the new CTE DB HE 2013.

The energy consumption in Spain. According to the explanatory documentation from the CTE HE 2013 [2]:

"The building sector has a relevant impact both on global energy consumption in the country (only the residential sector represents 17% of the total final consumption) as in effect gas emissions greenhouse (more than one ton per household)." All this is part of a current energy context that our country is characterized by a high dependency from the outside, close to 80% and well above the European average of 54%, resources which are limited and a future scenario of elevated energy prices".

In this context appear to European standards:

- Establish minimum requirements for energy efficiency in buildings.
- Requiring that new buildings built by 2020 (2018 in public buildings) are NZEB.

This roadmap begins to apply in Spain through the CTE 2013 HE. It will allow reducing the traditional Spanish energy dependence, reducing the greenhouse gases (GHG) emissions, and increasing the building sector competitiveness.
It tries to get buildings with increasing comfort degrees for the user, as well as try to reduce the energy consumption.

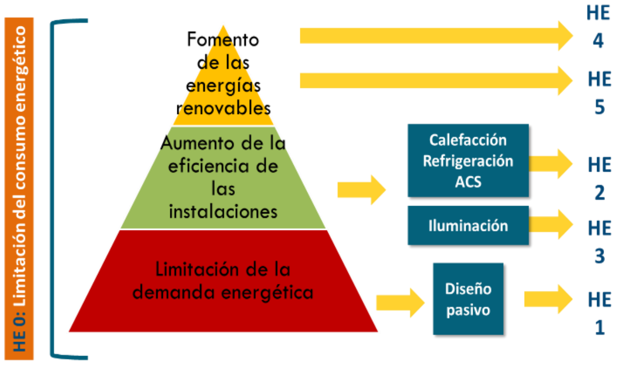


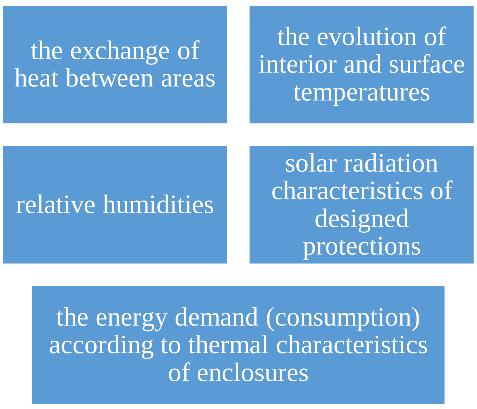
Fig. 4. 2013 HE description.

C. Computer energy simulations.

Using the fundamentals of the Energy Management Systems, and some architectural, structural recommendations, and from facilities, we have implemented:

The " integrated process design" (IPD). The IPD is defined by the International Energy Agency (IEA) as a procedure for building optimization, recognizing it as a comprehensive system across the life-cycle. It is based on interdisciplinary collaboration from the beginning until the end of the process.

If we model a building in a digital system and, then, we perform energy analysis, it is possible to determine:



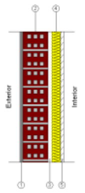
3. Results

Next, the model simulation results are analyzed. In order to compare between different standards, we have consider the demand for thermal energy (thermal envelope study. HE1), the air conditioning installation (HE 2. RITE), and the solar thermal installation (HE 4).

Thermal envelope study.

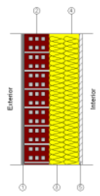
It is worth noting that that, for the 2013 legal requirements, the level of isolation in the building envelope must be increased considerably.

Fachada revestida con mortero monocapa, de hoja de fábrica, con trasdosado autoportante	Superficie total 119.06 m²



Listado de capas:	
1 - Mortero monocapa	1.5 cm
2 - Fábrica de ladrillo cerámico hueco	11.5 cm
3 - Separación	1.8 cm
4 - Lana de roca Confortpan 208 Roxul "ROCKWOOL"	4 cm
5 - Placa de yeso laminado	1.5 cm
6 - Pintura plástica	---
Espesor total:	20.3 cm

Limitación de demanda energética U_m: 0.58 W/(m²·K)

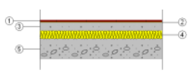


Listado de capas:	
1 - Mortero monocapa	1.5 cm
2 - Fábrica de ladrillo cerámico hueco	11.5 cm
3 - Lana de roca Confortpan 208 Roxul "ROCKWOOL"	6.8 cm
4 - Complejo multicapa	6.8 cm
5 - Placa de yeso laminado	1.5 cm
6 - Pintura plástica	---
Espesor total:	28.1 cm

Limitación de demanda energética U_m: 0.22 W/(m²·K)

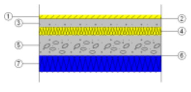
Fig. 5. Building wall.

Solera - Suelo flotante con lana mineral, de 40 mm de espesor. Solado de baldosas cerámicas colocadas con adhesivo	Superficie total 24.15 m²



Listado de capas:	
1 - Solado de baldosas cerámicas de gres esmaltado	1 cm
2 - Mortero autonivelante de cemento	0.2 cm
3 - Base de mortero autonivelante de cemento	4 cm
4 - Lana mineral	4 cm
5 - Solera de hormigón en masa	10 cm
Espesor total:	19.2 cm

Limitación de demanda energética U_s: 0.38 W/(m²·K)
(Para una solera con longitud característica B' = 4.4 m)
Solera con banda de aislamiento perimetral (ancho 1.2 m y resistencia térmica: 0.88 m²·K/W)



Listado de capas:	
1 - Entarimado de tablas de madera maciza	1.8 cm
2 - Mortero autonivelante de cemento	0.2 cm
3 - Base de mortero autonivelante de cemento	4 cm
4 - Lana mineral	4 cm
5 - Solera de hormigón en masa	10 cm
6 - Film de polietileno	0.02 cm
7 - Poliestireno extruido	8 cm
Espesor total:	28.02 cm

Limitación de demanda energética U_s: 0.19 W/(m²·K)
(Para una solera con longitud característica B' = 4.4 m)
Solera con banda de aislamiento perimetral (ancho 1.2 m y resistencia térmica: 2.35 m²·K/W)

Fig. 6. Building floor.

The decreasing in transmittance in the elements described in the tables above can be observed in the following graphs:

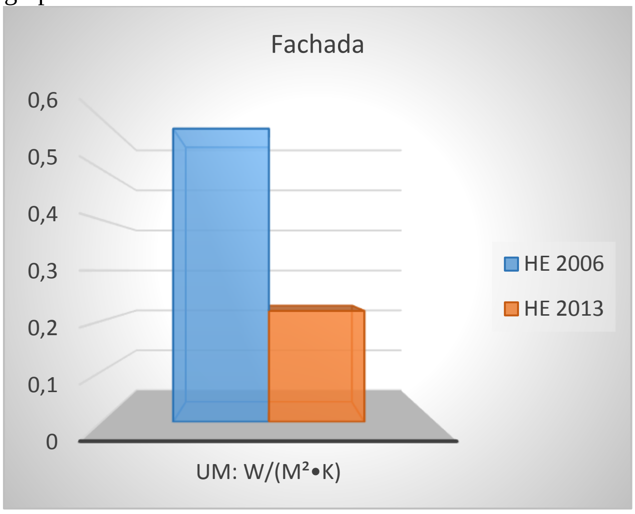


Fig. 7. Transmittance comparison (facade).

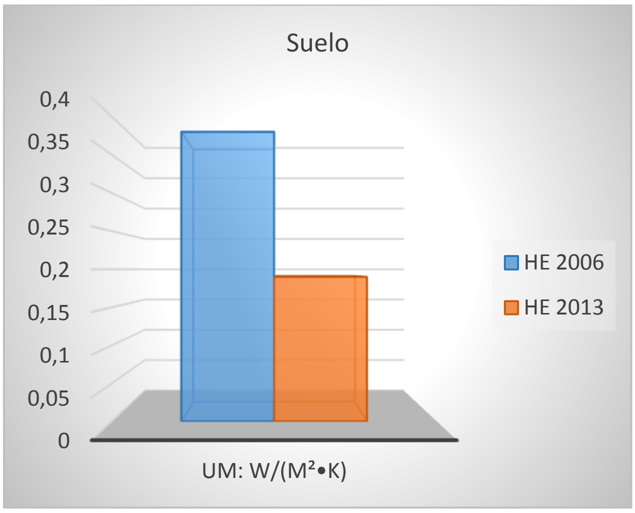


Fig. 8. Transmittance comparison (floor).

Building energy balance of the building (monthly).

Accounting for energy lost or gained by thermal transmission outside through heavy and light elements (Qtr, op and Qtr, w, respectively), the energy involved in the thermal link between areas (Qtr, ac), the energy exchanged by ventilation (Qve) gain net sensitive internal (Qint, s), the net solar gain (Qsol), the heat transferred or stored in the thermal mass of the building (Qedif), and the necessary contribution of (QH) heating and cooling (QC).

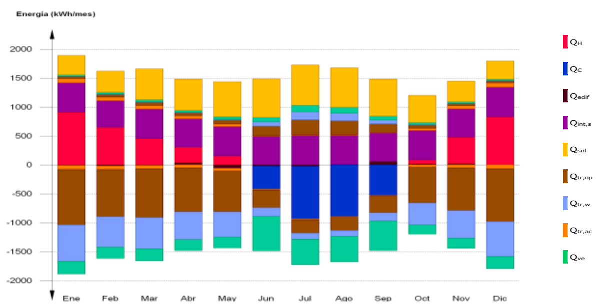


Fig. 9. Monthly energy balance.

HE1 requirements: heating.

HE 2006

$D_{cal,edificio} = 68.05\ kWh/m^2 \cdot año \leq D_{cal,lim} = D_{cal,base} + F_{cal,sup}/S = 26.6\ kWh/m^2 \cdot año$

HE 2013

$D_{cal,edificio} = 26.60\ kWh/m^2 \cdot año \leq D_{cal,lim} = D_{cal,base} + F_{cal,sup}/S = 27.0\ kWh/m^2 \cdot año$

$D_{cal,edificio}$:	Valor calculado de la demanda energética de calefacción. kWh/m²·año.
$D_{cal,lim}$:	Valor límite de la demanda energética de calefacción, considerada la superficie útil de los espacios habitables. kWh/m²·año.
$D_{cal,base}$:	Valor base de la demanda energética de calefacción, para la zona climática de invierno correspondiente al emplazamiento del edificio (tabla 2.1. CTE DB HE 1) 20 kWh/m²·año.
$F_{cal,sup}$:	Factor corrector por superficie de la demanda energética de calefacción. (tabla 2.1. CTE DB HE 1). 1000.
S:	Superficie útil de los espacios habitables del edificio. 151.60 m².

Fig. 10. HE1 requirements: heating.

HE1 requirements: cooling.

HE 2006

$D_{ref,edificio} = 27.53\ kWh/m^2 \cdot año \leq D_{ref,lim} = 20.0\ kWh/m^2 \cdot año$

HE 2013

$D_{ref,edificio} = 19.15\ kWh/m^2 \cdot año \leq D_{ref,lim} = 20.0\ kWh/m^2 \cdot año$

$D_{ref,edificio}$:	*Valor calculado de la demanda energética de refrigeración, kWh/m²·año.*
$D_{ref,lim}$:	*Valor límite de la demanda energética de refrigeración, kWh/m²·año.*

Fig. 11. HE1 requirements: cooling.

Energy demand for heating and cooling (monthly):

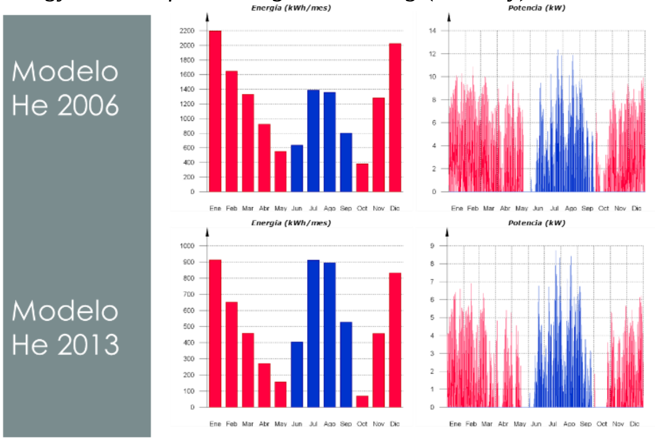


Fig. 12. Monthly energy demand.

Superimposed daily demand:

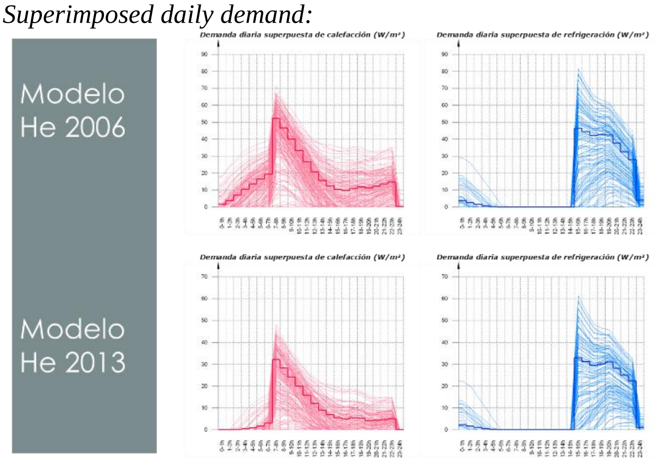


Fig. 13. Superimposed daily demand.

Typical demand by active day in model:

Modelo He 2006

	Nº activ.	Nº días activos (d)	Nº horas activas (h)	Nº horas por activ. (h)	Potencia típica (W/m²)	Demanda típica por día activo (kWh/m²)
Calefacción	264	223	3452	15	19.71	0.3051
Refrigeración	110	110	948	8	29.04	0.2503

Modelo He 2013

	Nº activ.	Nº días activos (d)	Nº horas activas (h)	Nº horas por activ. (h)	Potencia típica (W/m²)	Demanda típica por día activo (kWh/m²)
Calefacción	224	195	2226	11	11.95	0.1364
Refrigeración	110	108	873	8	21.93	0.1773

Fig. 14. Typical demand by active day.

Indoor temperature evolution in model areas.

Evolution of minimum, maximum and average temperatures each day, along with the daily mean outside temperature.

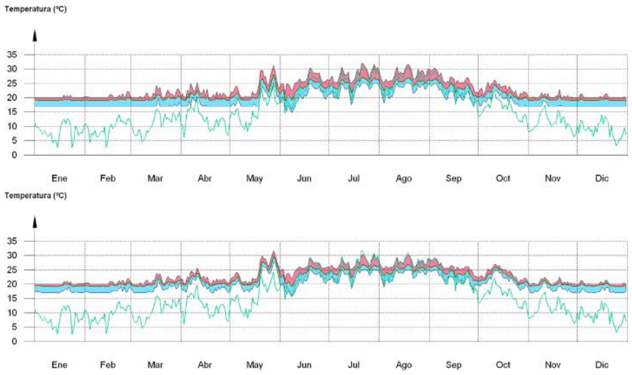


Fig. 15. Indoor temperature evolution.

Energy comparison (two cases).

The differences between demands of heating and cooling for the two studied cases can be observed in the following graphs:

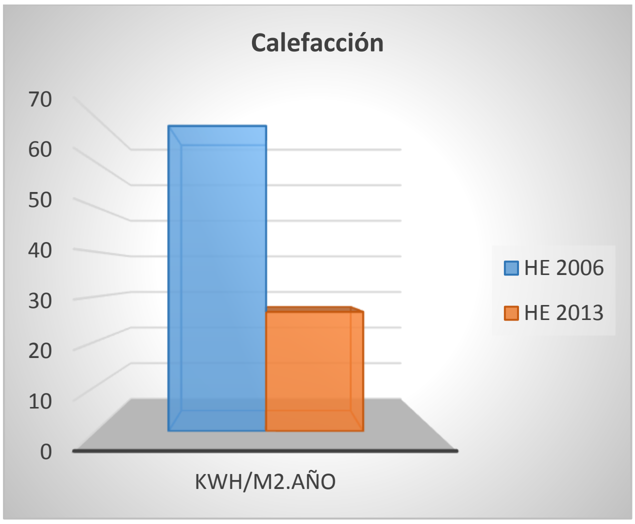


Fig. 16. Heating demand.

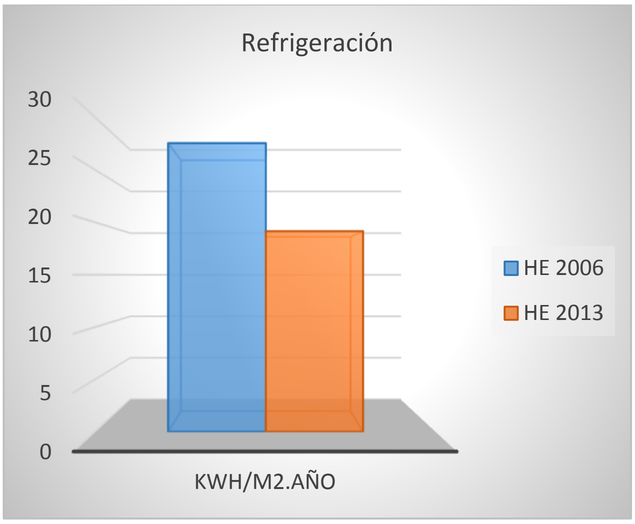


Fig. 17. Cooling demand.

Heating installation. CTE HE 2. RITE.

The decrease in thermal demand implies the possibility of reducing the power of the air conditioning installation, reducing the initial price of the equipment and its operation cost.

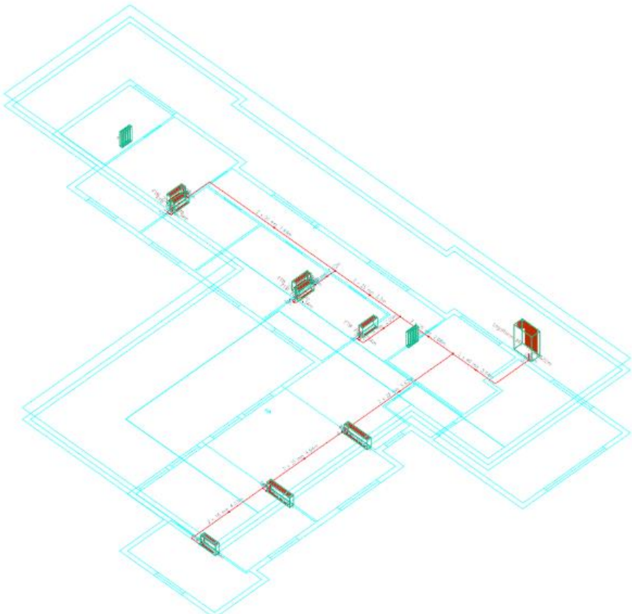


Fig. 18. Calculated air conditioning installation.

We can notice the savings if we analyze the next comparison between the needs of units not autonomous heating system (fan-coils) for the air conditioning of the housing:

Fancoils					
Modelo	P_{ref} (W)	P_{cal} (W)	Q_{ref} (l/s)	ΔP_{ref} (kPa)	PP_{ref} (kPa)
FTW 200 (A6-Planta baja)	1400.0	2300.0	0.07	1.200	7.955
FTW 200 (A7-Planta baja)	1400.0	2300.0	0.07	1.200	8.434
FTW 200 (A8-Planta baja)	1400.0	2300.0	0.07	1.200	5.347
FTW 200 (A9-Planta baja)	1400.0	2300.0	0.07	1.200	5.487
FTW 400 (A10-Planta baja)	3530.0	4470.0	0.17	9.600	4.598
FTW 400 (A11-Planta baja)	3530.0	4470.0	0.17	9.600	6.558
FTW 200 (A12-Planta baja)	1400.0	2300.0	0.07	1.200	9.175
FTW 200 (A13-Planta baja)	1400.0	2300.0	0.07	1.200	3.807

Fancoils					
Modelo	P_{ref} (W)	P_{cal} (W)	Q_{ref} (l/s)	ΔP_{ref} (kPa)	PP_{ref} (kPa)
RFR 1 MV (A6-Planta baja)	870.0	1060.0	0.04	10.800	11.928
RFR 1 MV (A7-Planta baja)	870.0	1060.0	0.04	10.800	12.189
RFR 1 MV (A8-Planta baja)	870.0	1060.0	0.04	10.800	6.817
RFR 1 MV (A9-Planta baja)	870.0	1060.0	0.04	10.800	6.893
RFR 4 MV (A10-Planta baja)	2800.0	3230.0	0.13	20.000	6.104
RFR 4 MV (A11-Planta baja)	2800.0	3230.0	0.13	20.000	7.292
RFR 2 MV (A12-Planta baja)	1300.0	1510.0	0.06	19.900	8.798
RFR 1 MV (A13-Planta baja)	870.0	1060.0	0.04	10.800	4.084

Abreviaturas utilizadas			
P_{ref}	*Potencia frigorífica total calculada*	ΔP_{ref}	*Pérdida de presión (Refrigeración)*
P_{cal}	*Potencia calorífica total calculada*	PP_{ref}	*Pérdida de presión acumulada (Refrigeración)*
Q_{ref}	*Caudal de agua (Refrigeración)*		

Fig. 19. Results for the emitting (by space).

Installation of thermal solar energy. CTE HE 4.

The 2013 HE 4 document has hardly changed, nevertheless the modification of the estimated consumption involves completely different calculation results. In our studied case the contribution of solar domestic hot water is reduced. We need two thermal solar panels of a specific model to comply with the rules of 2006 and only one in the 2013.

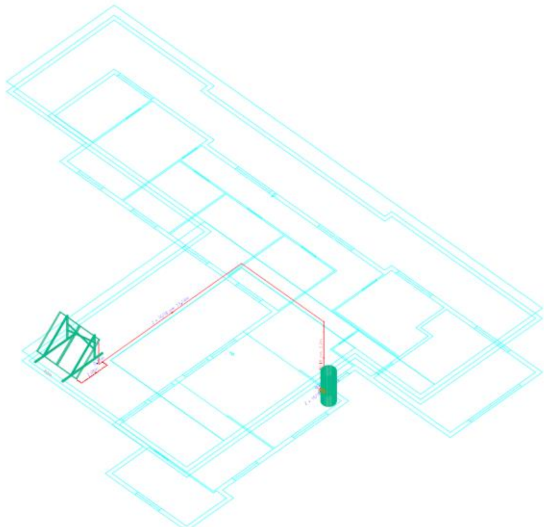


Fig. 20. Solar domestic hot water installation.

Modelo He 2006

Mes	Ocupación (%)	Consumo (m³)	Temperatura de red (°C)	Salto térmico (°C)	Demanda (MJ)	Radiación global (MJ/m²)	Temperatura ambiente diaria (°C)	Demanda (MJ)	Energía auxiliar (MJ)	Fracción solar (%)
Enero	100	7.9	9	36	1179.80	8.75	9	1179.80	472.63	60
Febrero	100	7.2	10	35	1044.73	12.02	10	1044.73	253.29	76
Marzo	100	8.0	11	34	1133.53	17.28	12	1133.53	66.71	94
Abril	100	7.9	13	32	1052.19	21.02	14	1052.19	0.00	101
Mayo	100	8.4	15	30	1041.00	24.48	18	1041.00	0.00	107
Junio	100	8.4	18	27	940.26	28.22	22	940.26	0.00	115
Julio	100	8.9	20	25	925.33	29.02	25	925.33	0.00	120
Agosto	100	8.9	20	25	925.33	25.63	25	925.33	0.00	118
Septiembre	100	8.4	18	27	940.26	20.20	22	940.26	0.00	112
Octubre	100	8.4	15	30	1041.00	13.64	17	1041.00	66.84	94
Noviembre	100	7.9	12	33	1074.58	9.47	12	1074.58	305.88	72
Diciembre	100	7.9	9	36	1179.80	7.13	9	1179.80	566.17	52

Modelo He 2013

Mes	Ocupación (%)	Consumo (m³)	Temperatura de red (°C)	Salto térmico (°C)	Demanda (MJ)	Radiación global (MJ/m²)	Temperatura ambiente diaria (°C)	Demanda (MJ)	Energía auxiliar (MJ)	Fracción solar (%)
Enero	100	6.1	9	36	917.62	8.75	9	917.62	520.06	43
Febrero	100	5.6	10	35	812.57	12.02	10	812.57	356.23	56
Marzo	100	6.3	11	34	881.64	17.28	12	881.64	242.80	72
Abril	100	6.2	13	32	818.37	21.02	14	818.37	166.42	80
Mayo	100	6.5	15	30	809.67	24.48	18	809.67	113.09	86
Junio	100	6.5	18	27	731.31	28.22	22	731.31	23.81	97
Julio	100	6.9	20	25	719.70	29.02	25	719.70	0.00	103
Agosto	100	6.9	20	25	719.70	25.63	25	719.70	0.00	101
Septiembre	100	6.5	18	27	731.31	20.20	22	731.31	54.99	92
Octubre	100	6.5	15	30	809.67	13.64	17	809.67	222.05	73
Noviembre	100	6.1	12	33	835.78	9.47	12	835.78	393.73	53
Diciembre	100	6.1	9	36	917.62	7.13	9	917.62	576.09	37

Fig. 21. Calculation results.

4. CONCLUSIONS

The study includes a final summary with lessons related to new 2013 CTE HE requirements:

The HE revision implies a greater demand reduction and zero increasing in generation through renewable. In the case we have studied, the minimum contribution of solar heating was reduced and the contribution of electricity using photovoltaic solar did not apply.

It may be necessary to reduce thermal transmittance values by 84%. That is, depending on the materials, the wall thickness can be increased to more than three times what it was.

The installation of mechanical ventilation is a determining factor in the final results.

A heat recovery system just increases the demands on the walls with respect to the previous legislation.

A facility without recovery would increase the necessary insulation values at a higher level than indicated on the first point.

The thicknesses of enclosures listed in HE appendices are only indicative and should not be used in the justification of the standars.

The default values included by calculation programs for thermal bridges are inadequate to the new requirements.

We have obtained different simulation results in different programs with the same geometry.

Reducing the demand implies the need for smaller air conditioning installations.

In our model, solar domestic hot water demand decreases.

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[2] Código técnico de la edificación. Documento básico de ahorro de energía. CTE DB HE.

[3] Diego Carmona Fernández, Awf Al Kassir Abdulla, Miguel Ángel Jaramillo Morán, Luis Alberto Horrillo Horrillo. Zero energy buildings rehabilitated for low energy demand by using solar and biomass energy. Current Opinion in Biotechnology ISSN: 0958-1669. Volume 24, Supplement 1, July 2013, Pages S45. 2013. Elsevier Ltd.