Temperature and CO2 in Madrid social housing through one year monitored data

Carmen Alonso Ruiz-Rivas
Arch, PhD
c.alonso@ietcc.csic.es

Instituto de Ciencias de la Construcción Eduardo Torroja
Consejo Superior de Investigaciones Científicas
IETCC-CSIC

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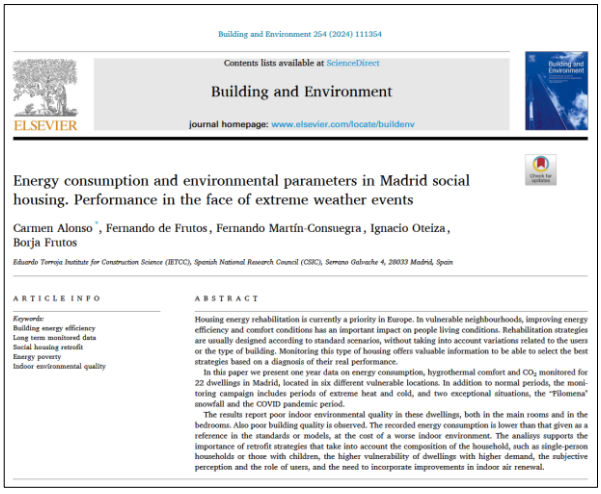

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ELSEVIER

Energy consumption and environmental parameters in Madrid social housing. Performance in the face of extreme weather events

Carmen Alonso *, Fernando de Frutos, Fernando Martín-Consuegra, Ignacio Oteiza, Borja Frutos

Eduardo Torroja Institute for Construction Science (IETCC), Spanish National Research Council (CSIC), Serrano Galvache 4, 28033 Madrid, Spain

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ABSTRACT

Housing energy rehabilitation is currently a priority in Europe. In vulnerable neighbourhoods, improving energy efficiency and comfort conditions has an important impact on people living conditions. Rehabilitation strategies are usually designed according to standard scenarios, without taking into account variations related to the users or the type of building. Monitoring this type of housing offers valuable information to be able to select the best strategies based on a diagnosis of their real performance.

In this paper we present one year data on energy consumption, hygrothermal comfort and CO_2 monitored for 22 dwellings in Madrid, located in six different vulnerable locations. In addition to normal periods, the monitoring campaign includes periods of extreme heat and cold, and two exceptional situations, the "Filomena" snowfall and the COVID pandemic period.

The results report poor indoor environmental quality in these dwellings, both in the main rooms and in the bedrooms. Also poor building quality is observed. The recorded energy consumption is lower than that given as a reference in the standards or models, at the cost of a worse indoor environment. The analisys supports the importance of retrofit strategies that take into account the composition of the household, such as single-person households or those with children, the higher vulnerability of dwellings with higher demand, the subjective perception and the role of users, and the need to incorporate improvements in indoor air renewal.

https://doi.org/10.1016/j.buildenv.2024.111354

New integrative tool for assessing vulnerable urban areas. Refurbishment model for energy self-sufficient and bio-healthy neighbourhoods. Madrid, Spain. HABITA-RES

https://doi.org/10.3389/fbuil.2023.1120674

Cross- reference information -Upscaling data

Tools for environmental information for building stock

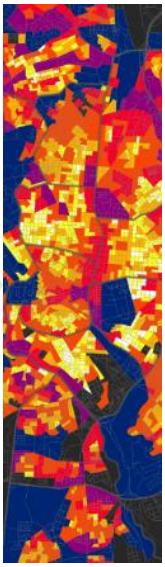
monitoring

- Housing census
- Urban Audit: Income
- M.Fomento-UPM: Vulnerable neighbourhoods
- CNMC: Energy bill
- Simulations: Archetypes
- Cadaster: Buildings and dwellings
- Spacial data GIS
- Outdoor monitoring
- Indoor environment monitoring
- Energy consumption
- Construction: In situ measurements

CITY

DWELLING

CONSTRUCTION

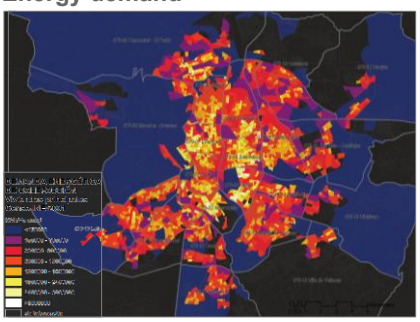


22 dwellings in the outskirts of Madrid

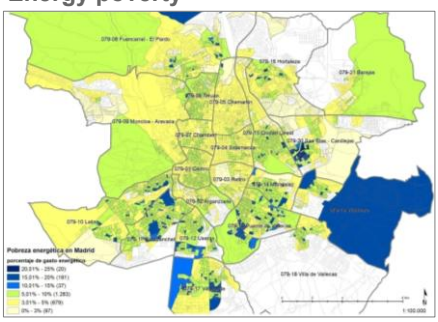
Visit and face to face surveys: use pattetrns, comfort perception, facilities, construction quality.

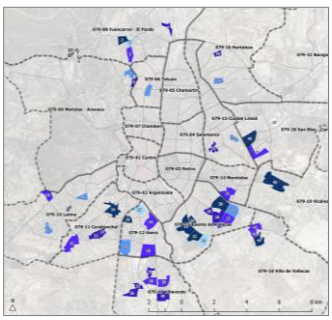
- Size: 70 m2 to 117 m2
- With Shutters for solar protection
- With heating systems-radiators
- Heat cold pump or fans for cooling
- Natural ventilation

Energy demand

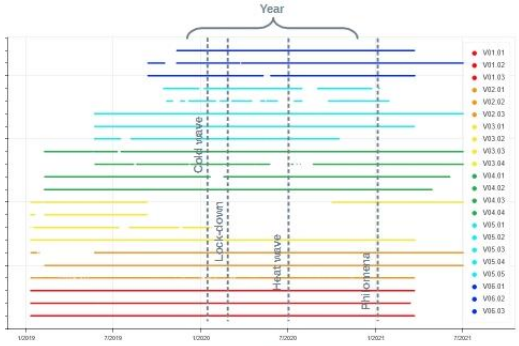


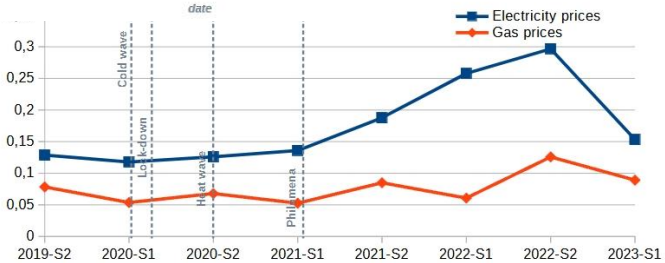
Energy poverty





Monitoring data: outdoor T, RH, dwelling energy consumption, indoor T, RH, CO_2





Dwelling performance under stress conditions:

- Cold and heat waves
- Philomena
- COVID and Lockdown

Improving energy efficiency and indoor comfort conditions has a significant impact on residents' quality of life and well-being, while reducing the risk of energy poverty

- Warm/extremely warm period
- Stable energy prices

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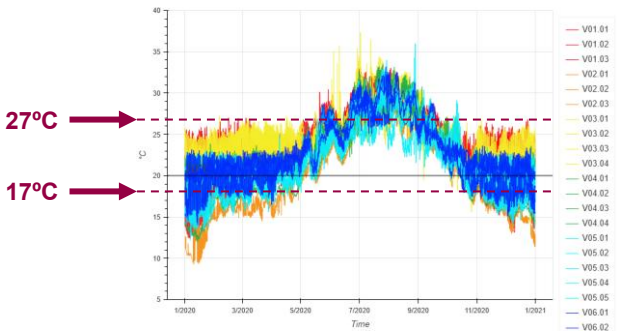
Indoor temperature

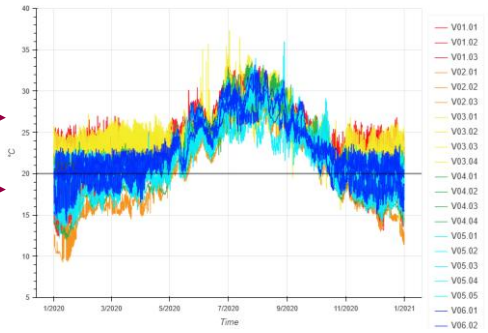


6

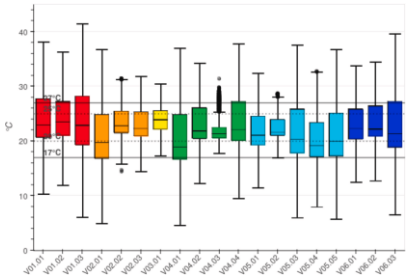
Indoor temperature

27ºC

17ºC



Anual data

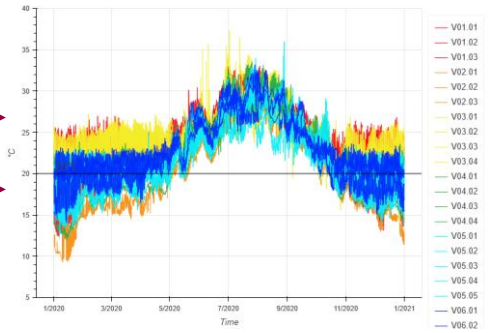


7

Indoor temperature

27ºC

17ºC



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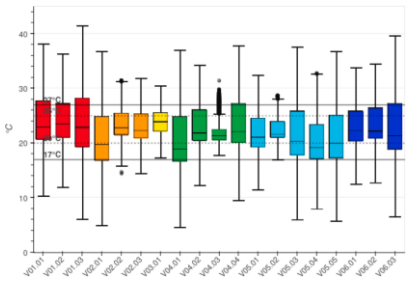
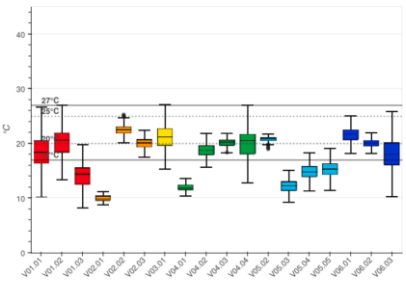
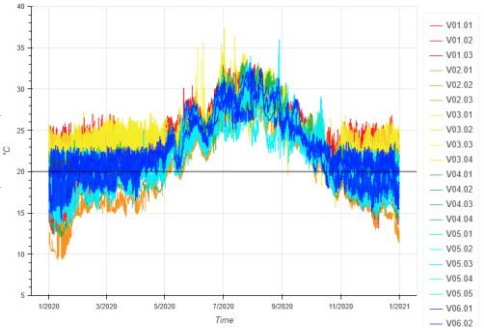


Philomena



8

Indoor temperature



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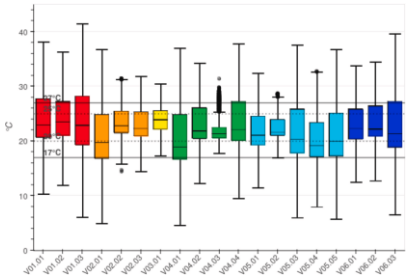
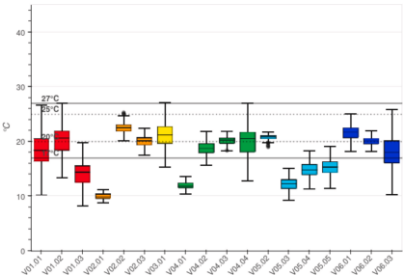
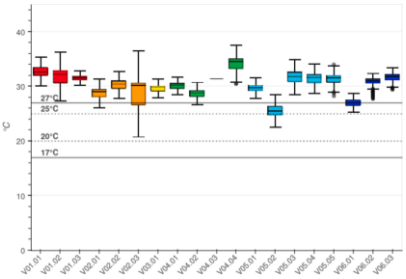


Philomena



Heat wave



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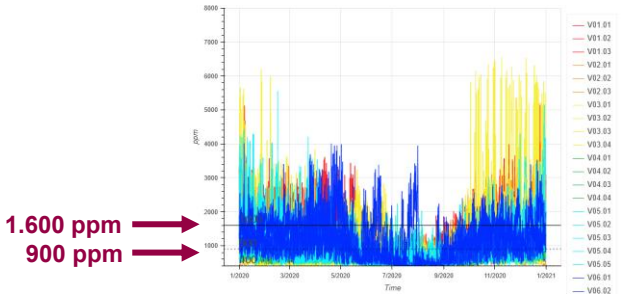
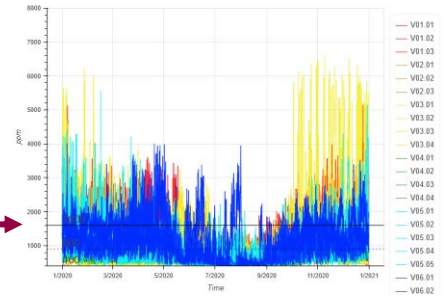
Indoor CO_2



10

Indoor CO_2

1.600 ppm →



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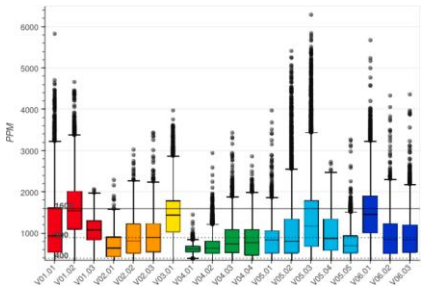

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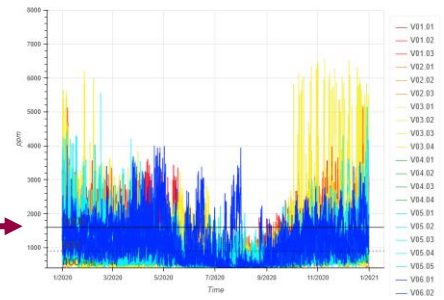
Indoor CO_2

1.600 ppm →



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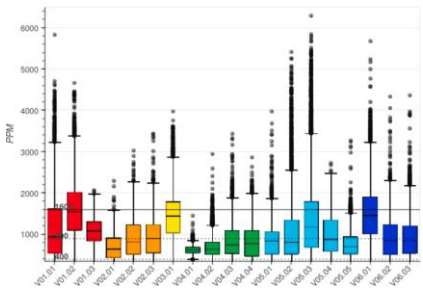
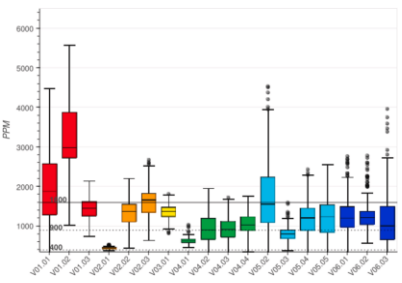


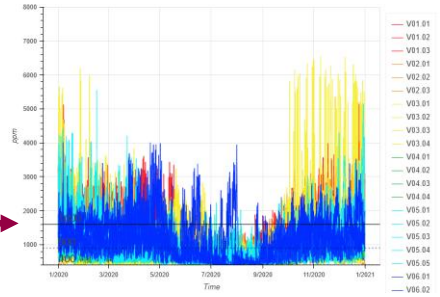
Philomena



12

Indoor CO_2

1.600 ppm →



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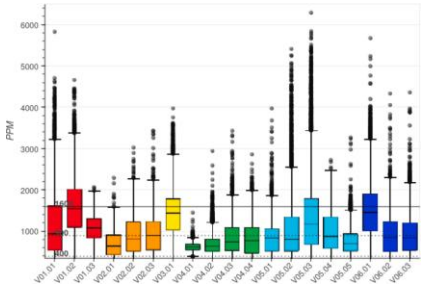
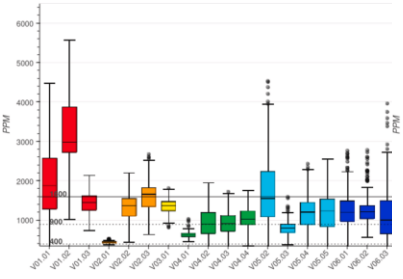
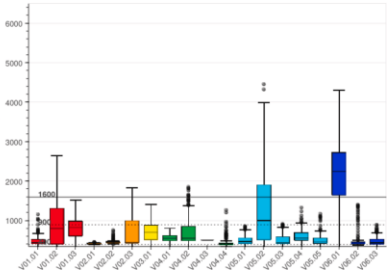


Philomena



Heat wave



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Zone differences

Livingroom

Table 7
Percentage of hours per year by rank. LIVINGROOM ([1] percentage of hours per rank, [2]sum of CO_2 concentration exceeding 1600 ppm and [3]mean CO_2 concentration value, SD = no valid data).

ID	T (°C)		CO_2 (ppm)				RH (%)		% null
	<17°C [1]	>27°C [1]	900ppm-1600ppm[1]	>1600ppm[1]	Acumulated hours[2]>1600ppm	Mean[3] (ppm)	<30 %[1]	>70 %[1]	
V01.01	3,32	27,03	25,82	25,43	4.983.243	925	6,27	0	0,05
V01.02	0,32	21,24	38,38	46,53	9.019.684	1.541	1,50	0,68	0,28
V01.03	8,96	29,76	66,11	2,72	403.761	1.070	17,55	0,02	0,28
V02.01	SD	SD	SD	SD	SD	SD	SD	SD	SD
V02.02	0,02	12,81	39,69	4,97	781.763	812	0,40	0	0,16
V02.03	0	13,71	44,67	4,87	769.502	896	1,23	0	0,32
V03.01	0	14,8	44,98	36,95	6.596.602	1.428	0	30,38	0,28
V03.02	SD	SD	SD	SD	SD	SD	SD	SD	SD
V03.03	SD	SD	SD	SD	SD	SD	SD	SD	SD
V03.04	SD	SD	SD	SD	SD	SD	SD	SD	SD
V04.01	29,45	16,48	0,3	0	0	618	1,18	0	0,28
V04.02	0	16,62	14,52	0,48	76.682	638	5,17	0	8,05
V04.03	SD	SD	SD	SD	SD	SD	SD	SD	SD
V04.04	0,16	25,38	36,81	3,37	532.974	769	17,74	0	0,58
V05.01	0,32	12,11	40,82	1,22	224.989	837	4,09	0	4,75
V05.02	0	1,55	25,57	17,78	3.534.128	800	0,87	0,14	0,38
V05.03	12,63	18,82	31,42	31,3	6.923.771	1.170	5,33	45,48	0,75
V05.04	SD	SD	SD	SD	SD	SD	SD	SD	SD
V05.05	SD	SD	SD	SD	SD	SD	SD	SD	SD
V06.01	0	11,96	37,57	38,82	7.397.437	1.446	0	22,01	4,23
V06.02	1,9	20,47	38,91	5,25	850.304	843	1,00	0	3,89
V06.03	6,49	24,74	37,58	6,64	1.111.576	841	7,24	5,32	3,15

Bedroom

Table 8
Percentage of hours per year by rank. BEDROOM ([1] percentage of hours per rank, [2]sum of CO_2 concentration exceeding 1600 ppm and [3]mean CO_2 concentration value, SD = no valid data).

ID	T (°C)		CO_2 (ppm)				RH (%)		% null
	<17°C [1]	>27°C [1]	900ppm-1600ppm[1]	>1600ppm[1]	Acumulated hours >1600ppm[2]	Mean (ppm)[3]	<30 %[1]	>70 %[1]	
V01.01	4,45	22,42	22,04	31,33	7.500.003	972	2,87	7,01	0,28
V01.02	2,17	30,48	23,74	66,88	17.947.771	2.003	2,94	30,12	0,05
V01.03	24,59	27,87	66,89	2,39	354.081	1.071	16,55	4,83	0,28
V02.01	SD	SD	SD	SD	SD	SD	SD	SD	SD
V02.02	0,08	11	31,52	18,24	3.685.707	901	0,52	0	0,57
V02.03	1,96	15,3	42,85	9,76	1.614.552	942	1,43	0,56	0,08
V03.01	0	19,77	56,48	28,62	5.200.794	1.336	0	16,94	0,28
V03.02	SD	SD	SD	SD	SD	SD	SD	SD	SD
V03.03	SD	SD	SD	SD	SD	SD	SD	SD	SD
V03.04	SD	SD	SD	SD	SD	SD	SD	SD	SD
V04.01	41,79	15,59	4,31	0	0	686	0,08	1,29	0,28
V04.02	0,33	12,02	27,91	0,26	40.688	688	2,25	0	7,95
V04.03	SD	SD	SD	SD	SD	SD	SD	SD	SD
V04.04	20,48	17,83	31,52	17,98	2.949.333	956	7,96	37,44	6,79
V05.01	0,63	9,56	40,95	1,49	270.596	830	5,03	0	4,82
V05.02	0	2,37	31,77	19,47	3.391.929	927	1,15	0,63	0,8
V05.03	1,12	21,55	34,51	20,28	4.414.697	998	6,4	15,31	1,18
V05.04	SD	SD	SD	SD	SD	SD	SD	SD	SD
V05.05	SD	SD	SD	SD	SD	SD	SD	SD	SD
V06.01	0,11	15,22	24,43	50,83	11.541.368	1.689	0	55,09	4,47
V06.02	2,48	18,34	40,18	2,21	382.355	805	0,14	0	1,23
V06.03	12,2	7,62	23,03	16,52	2.932.731	1.038	2,05	14,58	32,5

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Considerations

- the air renewal in the monitored dwellings (occasional ventilation for up to 2 h and infiltration) is not sufficient to guarantee good indoor air quality
- **thermal comfort standards are not being achieved**
- poor indoor environmental quality: **both in living spaces and bedrooms**, alongside evidence of deficient building envelope
- **energy consumption is consistently lower** than reference values established by standards or predictive models, achieved at the expense of **indoor temperatures outside comfort ranges**
- Minimum temperatures during cold periods are lower, and maximum temperatures during warm periods are higher in **single-person households and in dwellings located under the roof**
- Higher CO_2 concentrations are associated with higher relative humidity, a greater number of occupants, and longer periods of stay in the dwellings.
- Significant **differences between the living room and the bedroom**: temperatures are generally lower, while CO_2 concentration and relative humidity are typically higher, with marked seasonal variations
- no clear **relationship between reported and monitored data**
- Higher CO2 concentration is associated with higher RH, a higher number of occupants and longer periods of stay in the dwellings
- dwellings without gas have recorded higher average CO2 levels, perhaps due to the air infiltration through the safety grilles

need to incorporate **adequate retrofitting strategies for buildings in these vulnerable areas**, addressing energy efficiency improvements, along with the improvement of the indoor environment, which should focus on **improving their resilience**

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Monitoring buildings that are being refurbished with public subsidies

HABITAMADRID PLATFORM

https://habitamadrid.ietcc.csic.es/

Data:
- Surveys
- Energy consyumption
- T, RH, CO2
- Radon, VOCs, Formaldehyde, PM
- Building facilities and construction

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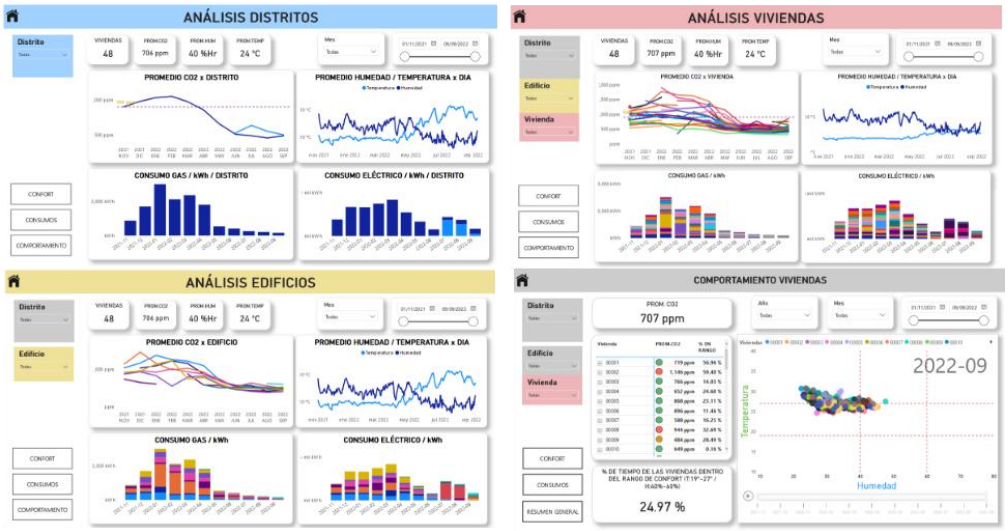
HABITAMADRID PLATFORM



https://habitamadrid.ietcc.csic.es/

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Monitoring households with energy poverty in Spain

IDAE

Assessment of energy poverty in Spain: Key findings from a household panel
https://www.idae.es/en/node/36111

National Strategy against Energy Poverty 2019–2024 (ENPE)

Universidad Carlos III de Madrid
ACA Asociación de Ciencias Ambientales
Instituto de Ciencias de la Construcción EDUARDO TORROJA

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Instituto de Ciencias de la Construcción Ed
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THANK YOU!!

21-22 April 2026, Workshop, Madrid, "Climate Change, Ventilation and Resilience"