SUREFIT

SUstainable solutions for affordable REtroFIT of domestic buildings

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The impact of retrofitting in southern European residential buildings with intermittent or continuous heating

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Study objective

- Compare the impact of retrofit technologies on building energy consumption and indoor climate in southern European countries

- Analyze the impact of intermittent or continuous heating schedules on the energy conservation potential of renovation technologies

Demo buildings in south Europe

Small apartment building in Athens, Greece

The annual heating degree hours at indoor temperature 15.5 °C are 612.3 °Ch, 467.5 °Ch, and 1577.8 °Ch in Athens, Lisbon and Valladolid.

Social house in Lisbon, Portugal

Terraced house in Valladolid, Spain

Properties of demo buildings before renovation

Demo building	Greek apartment building	Portuguese social house	Spanish terraced house
U-values of envelope (W/m^2K)			
External wall	0.7	2.4	1.7
Roof	3.9	3.8	1.6
External floor	3.6	1.0	2.9
External door	1.1	3.6/3.7/3.9	2.2
Windows	5.9/3.0	5.1	5.8/2.8
Infiltration			
Air leakage rate, n_{50} (ACH)	6.7	6.7	6.7

Building envelope properties before renovation

Demo building	Greek apartment building	Portuguese social house	Spanish terraced house
Ventilation system	Natural ventilation	Natural ventilation	Natural ventilation
Space heating system	Oil boiler and water radiators	Portable electric heaters	Gas boiler and water radiators
Cooling system	Split cooling units	No	No
DHW heating system	Solar collector and boiler	Gas boiler	Gas boiler

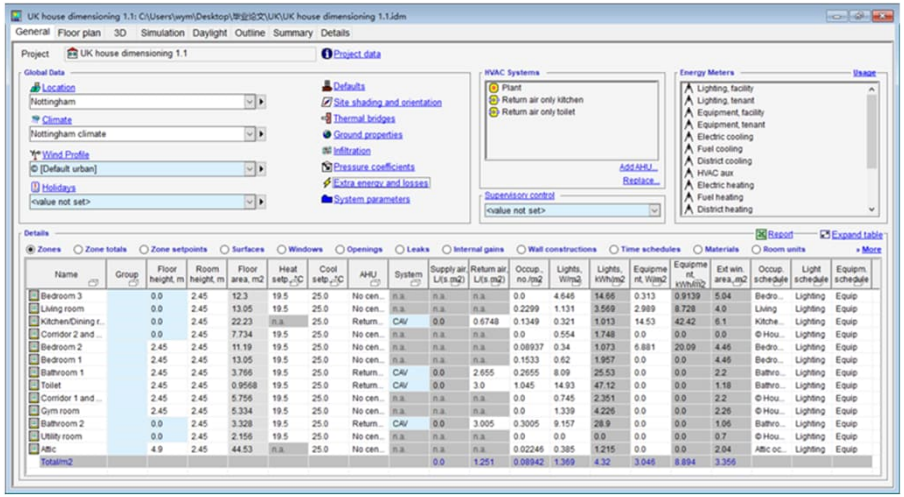
HVAC systems before renovation

Intermittent heating VS. Continuous heating

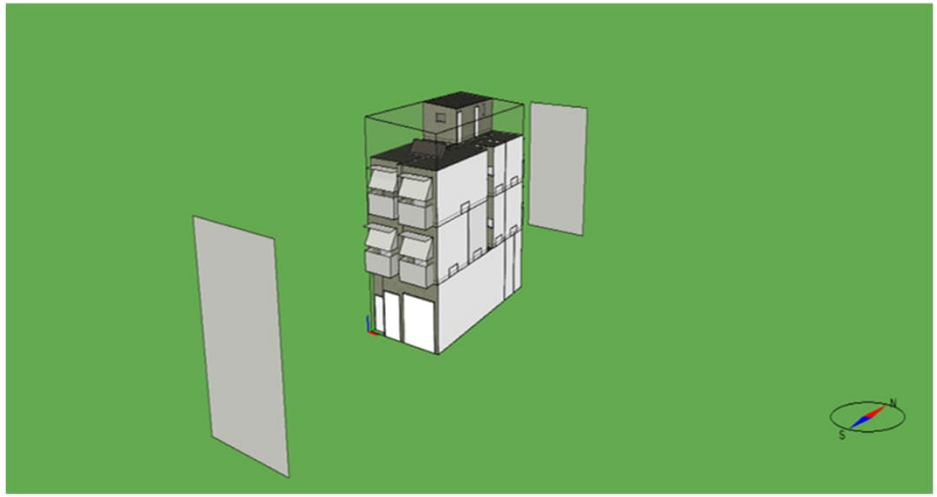
Demo site	Heated space	Intermittent heating schedule	Continuous heating schedule
Greek apartment building	The whole apartment area	From 1 Nov to 31 Mar, 20 °C [7-9, 19-22]	From 1 Sep to 31 May, 20 °C
Portuguese social house	All living spaces	From 1 Dec to 28 Feb, Weekdays: 20 °C [7-8, 15-23], Weekends & Holidays: 20 °C [8-23]	
Spanish terraced house	Ground floor	All year round, 20 °C [14-23], 17 °C otherwise	
	Top floor	All year round, 18 °C [14-23], 17 °C otherwise	
	Attic	From 1 Oct to 30 Apr, 20 °C [14-23]	

Simulation tool

- IDA ICE allows dynamic multi-zone simulations and modelling of building characteristics including geometry, structures and technical systems.
- Output files: building energy consumption, indoor air quality, and thermal comfort



IDA-ICE interface



Building model example in IDA ICE

Purchased energy of demo buildings before renovation

Demo site	Greek apartment building	Portuguese social house	Spanish terraced house
Fuel heating total	36.8	18.3	115.0
Fuel boiler	36.8	18.3	115.0
Electricity total	14.8	97.1	19.4
Equip, Light & HVAC aux	10.3	13.2	19.4
Electric heater	-	83.9	-
Split cooling unit	4.5	-	-
Total purchased energy	51.6	115.4	134.4

Purchased energy (kWh/m^2) of the demo buildings before renovation when they were intermittently heated

Demo site	Greek apartment building	Portuguese social house	Spanish terraced house
Fuel heating total	109.3	18.3	145.5
Fuel boiler	109.3	18.3	145.5
Electricity total	18.2	210.8	19.4
Equip, Light & HVAC aux	11.0	13.2	19.4
Electric heater	-	197.6	-
Split cooling unit	7.2	-	-
Total purchased energy	127.5	229.1	164.9

Purchased energy (kWh/m^2) of the demo buildings before renovation when they were continuously heated

Indoor climate of demo buildings before renovation

Demo site	Greek apartment building	Portuguese social house	Spanish terraced house
Thermal comfort			
Proportion of time indoor temperature is lower than the heating setpoint* [%]	44.2	49.0	5.1
Proportion of time indoor temperature is higher than 25 °C [%]	20.7	7.1	11.9
Maximum air temperature [°C]	28.7	27.9	30.5
Indoor air quality			
Proportion of time CO_2 concentration is lower than 1200 ppm [%]	20.3	34.2	41.3
Proportion of time CO_2 concentration is lower than 1800 ppm [%]	79.6	72.5	98.1

Indoor climate of the demo buildings before renovation when they were intermittently heated

Demo site	Greek apartment building	Portuguese social house	Spanish terraced house
Thermal comfort			
Proportion of time indoor temperature is lower than the heating setpoint* [%]	0.6	0.0	0.1
Proportion of time indoor temperature is higher than 25 °C [%]	0.0	7.1	9.9
Maximum air temperature [°C]	25.0	27.9	30.5
Indoor air quality			
Proportion of time CO_2 concentration is lower than 1200 ppm [%]	21.7	35.5	43.8
Proportion of time CO_2 concentration is lower than 1800 ppm [%]	79.7	73.3	98.2

Indoor climate of the demo buildings before renovation when they were continuously heated

Retrofit technologies simulation

U-value: External wall: 1.0 → 0.4, Roof: 3.9 → 0.6

U-value of windows: 3.0/5.9 → 0.6, Efficiency: 3.5%

Thickness: 3.2 cm, Melting temperature: 18-36 °C

Reference building models before renovation

Passive package

Bio-aerogel thermal insulation (Ins)

Bio-aerogel thermal insulation + PV vacuum window (Win)

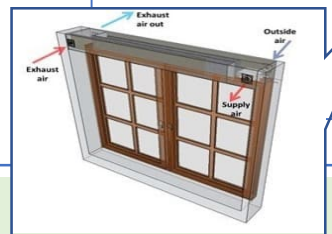
Bio-aerogel thermal insulation + PV vacuum window + Phase change material (PCM)

Ventilation package

Insulating breath membrane (Mem) 50% airtightness improvement

Insulating breath membrane (Mem) 100% airtightness improvement

Insulating breath membrane + Room specific air handling unit with heating recovery (RAHU)



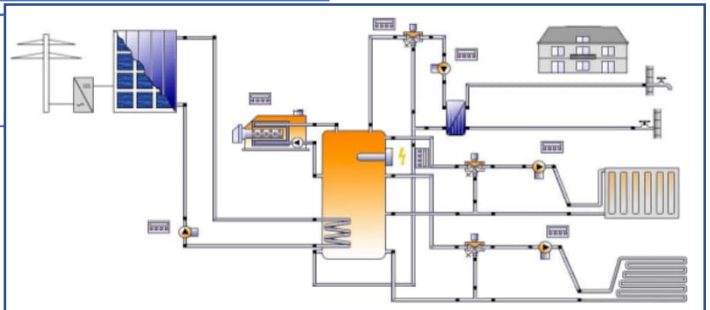
Heat recovery efficiency: 0.76

U-value: External wall: 1.0 → 0.5, Roof: 3.9 → 0.9, Infiltration (ACH, n_{50}): 6.7 → 3.4

Infiltration (ACH, n_{50}): 6.7 → 0.07

Generation package

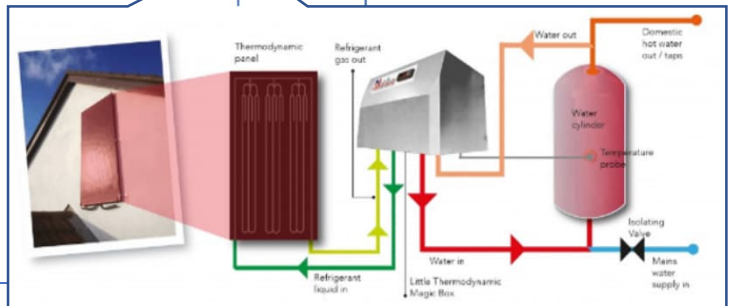
Photovoltaic/Thermal (PV/T) system



Conversion factor of solar thermal: 0.486, Electricity generation efficiency: 0.13

Generation package

Solar assisted heat pump (SAHP)



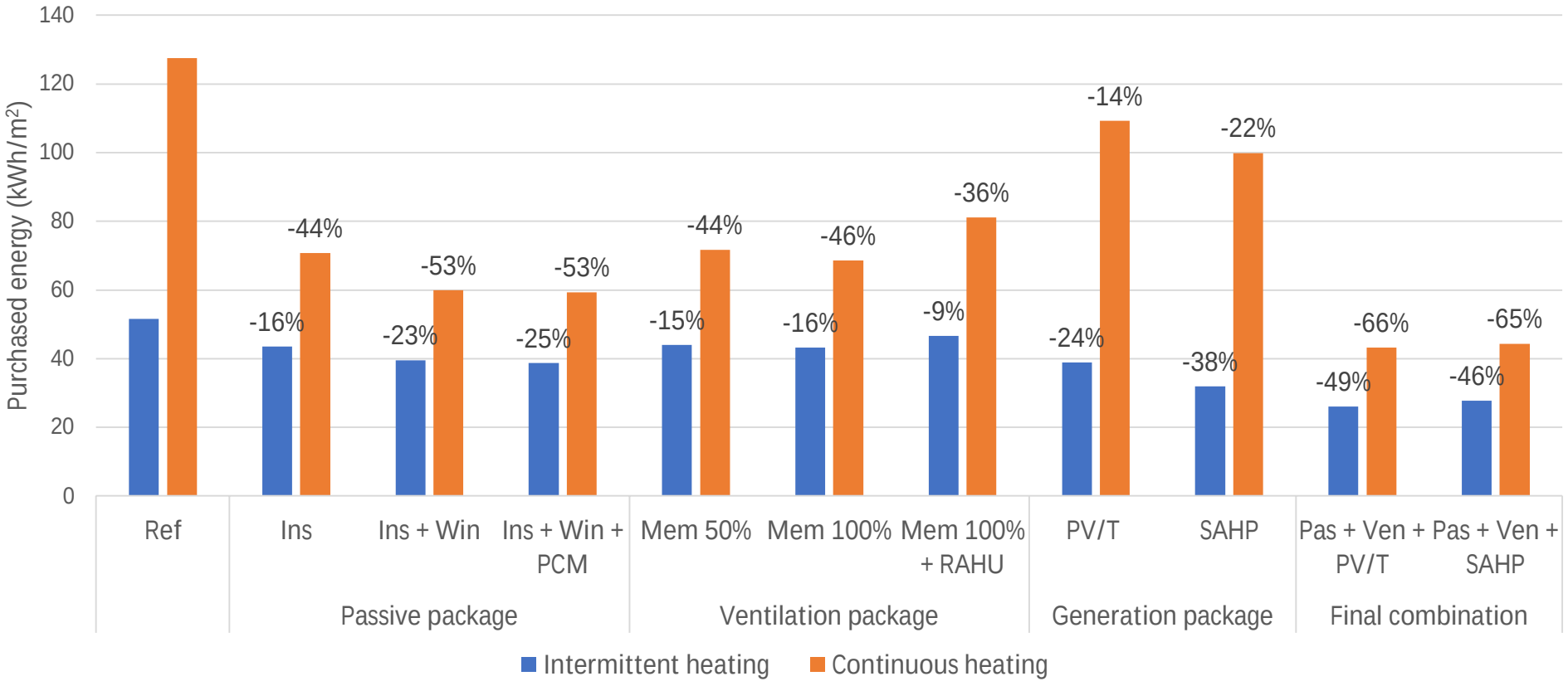
Heating capacity: 11 kW, COP: 4

Final Combinations

Scenario 1: Passive + Ventilation + Generation (PV/T)

Scenario 2: Passive + Ventilation + Generation (SAHP)

Greek demo building: intermittent VS. continuous



Greek demo building: intermittent VS. continuous

		Passive package			Ventilation package		
	Ref	Ins	Ins + Win	Ins + Win + PCM	Mem 50%	Mem 100%	Mem 100% + RAHU
T < 20 °C [%]	44.2	40.2	34.3	34.3	40.0	39.2	42.5
T > 25 °C [%]	20.7	19.8	24.4	24.6	19.9	22.0	19.5
T_max [°C]	28.7	27.8	28.6	28.6	27.8	27.8	28.2
CO_2 < 1200 ppm [%]	20.3	20.6	20.8	20.7	12.8	8.4	100.0
CO_2 < 1800 ppm [%]	79.6	79.9	80.8	80.6	66.4	46.2	100.0

Indoor climate of the Greek demo building with intermittent heating

Thermal insulating measures led to indoor temperature increase if the demo was intermittently heated.

Insulating breath membrane has a negative impact on IAQ, then installing RAHU guaranteed CO_2 concentration always lower than 1200 ppm.

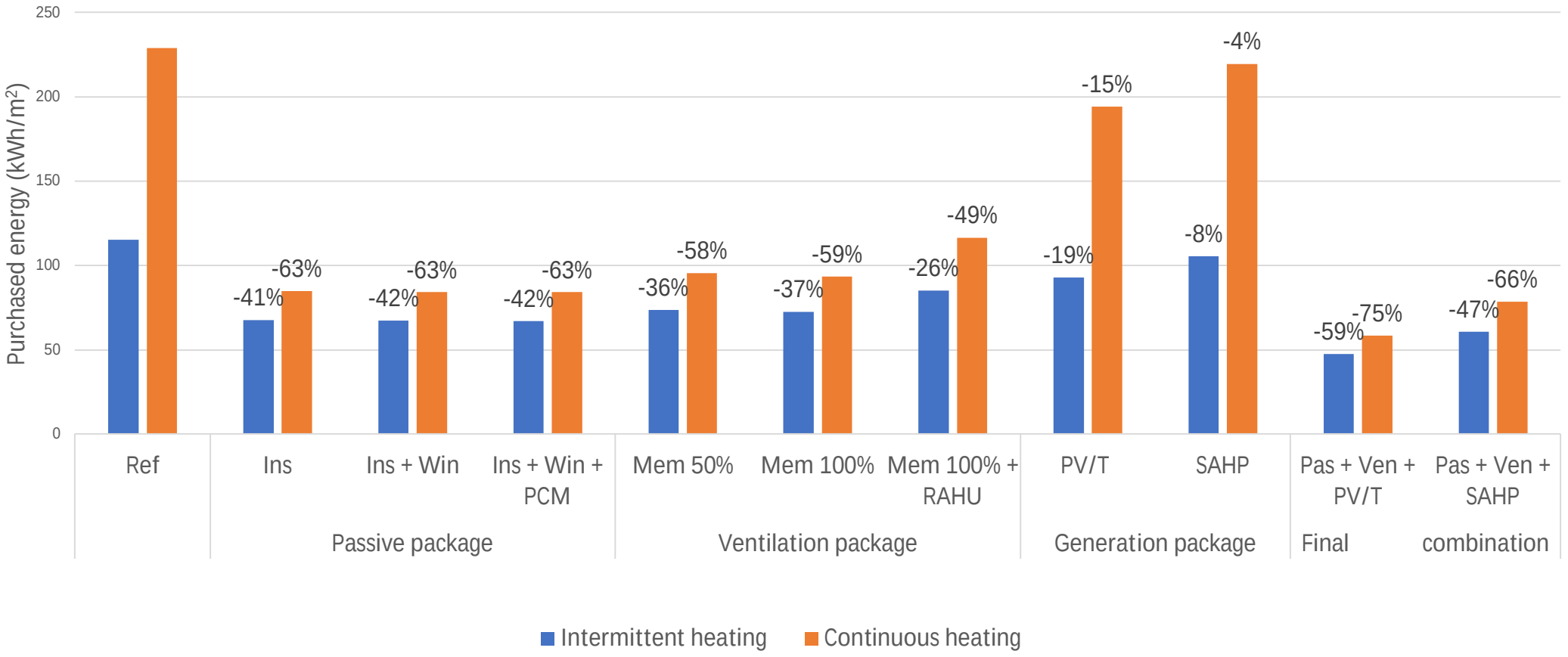
		Passive package			Ventilation package		
	Ref	Ins	Ins + Win	Ins + Win + PCM	Mem 50%	Mem 100%	Mem 100% + RAHU
T < 20 °C [%]	0.6	0.9	0.1	0.0	0.6	0.5	0.5
T > 25 °C [%]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_max [°C]	25.0	25.0	25.0	25.0	25.0	25.0	25.0
CO_2 < 1200 ppm [%]	21.7	21.4	23.9	23.6	13.3	10.4	100.0
CO_2 < 1800 ppm [%]	79.7	80.2	81.9	81.7	67.2	48.6	100.0

Indoor climate of the Greek demo building with continuous heating

Indoor temperature was kept at a similar level before and after renovation if the demo was continuously heated.

T < 20 °C/T > 25 °C: Proportion of time indoor temperature is lower than 20 °C or higher than 25 °C; T_max: Maximum air temperature; CO_2 < 1200/1800 ppm: Proportion of time CO_2 concentration is lower than 1200 or 1800 ppm.

Portuguese demo building: intermittent VS. continuous



Portuguese demo building: intermittent VS. continuous

		Passive package			Ventilation package		
	Ref	Ins	Ins + Win	Ins + Win + PCM	Mem 50%	Mem 100%	Mem 100% + RAHU
T < 20 °C [%]	49.0	33.5	33.6	33.9	36.7	36.9	42.9
T > 25 °C [%]	7.1	2.7	2.2	0.0	3.8	3.9	2.0
T_max [°C]	27.9	26.3	26.2	25.7	26.5	26.5	26.8
CO_2 < 1200 ppm [%]	34.2	38.5	39.0	42.2	23.6	16.3	100.0
CO_2 < 1800 ppm [%]	72.5	75.5	75.7	76.2	61.6	33.6	100.0

Thermal insulating measures led to indoor temperature increase if the demo was intermittently heated.

Insulating breath membrane has a negative impact on IAQ, then installing RAHU guaranteed CO_2 concentration always lower than 1200 ppm.

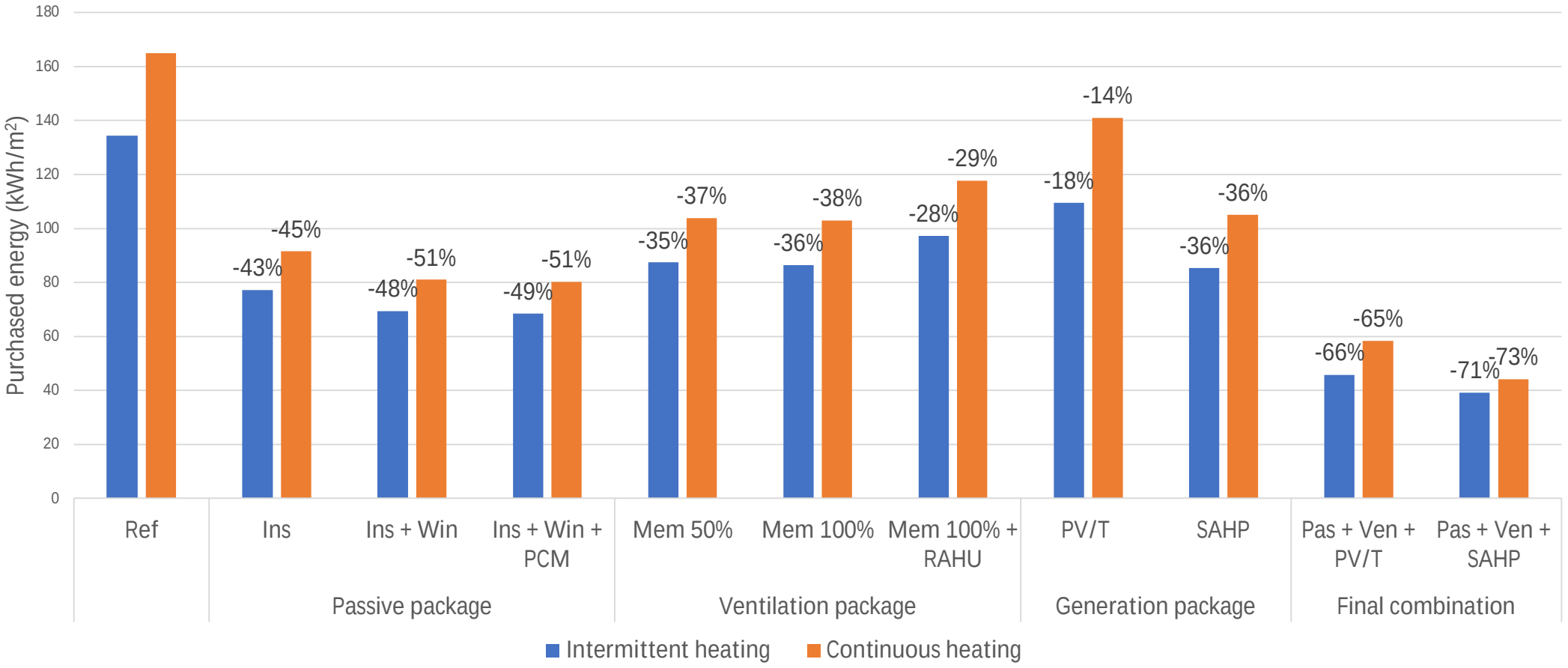
Indoor climate of the Portuguese demo building with intermittent heating

		Passive package			Ventilation package		
	Ref	Ins	Ins + Win	Ins + Win + PCM	Mem 50%	Mem 100%	Mem 100% + RAHU
T < 20 °C [%]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T > 25 °C [%]	7.1	2.7	2.2	0.0	3.8	3.9	2.0
T_max [°C]	27.9	26.3	26.2	25.7	26.5	26.5	26.8
CO_2 < 1200 ppm [%]	35.5	39.5	40.0	43.2	24.3	16.3	100.0
CO_2 < 1800 ppm [%]	73.3	75.8	76.2	76.9	61.8	32.6	100.0

Indoor temperature was kept at a similar level before and after renovation if the demo was continuously heated.

Indoor climate of the Portuguese demo building with continuous heating

Spanish demo building: intermittent VS. continuous



Spanish demo building: intermittent VS. continuous

		Passive package			Ventilation package		
	Ref	Ins	Ins + Win	Ins + Win + PCM	Mem 50%	Mem 100%	Mem 100% + RAHU
T < 18 °C [%]	5.1	0.0	0.0	0.0	4.6	0.0	0.2
T > 25 °C [%]	11.9	11.4	10.1	10.5	12.4	12.0	9.9
T_max [°C]	30.5	29.6	29.1	28.5	29.9	30.2	30.2
CO_2 < 1200 ppm [%]	41.3	43.9	44.6	45.4	35.8	24.2	99.5
CO_2 < 1800 ppm [%]	98.1	98.6	98.8	98.9	97.9	95.7	100.0

Thermal insulating measures led to an indoor temperature increase if the demo was intermittently heated.

Insulating breath membrane has a negative impact on IAQ, then installing RAHU guaranteed CO_2 concentration always lower than 1200 ppm.

Indoor climate of the Spanish demo building with intermittent heating

		Passive package			Ventilation package		
	Ref	Ins	Ins + Win	Ins + Win + PCM	Mem 50%	Mem 100%	Mem 100% + RAHU
T < 20 °C [%]	0.1	0.0	0.0	0.0	0.0	0.0	0.0
T > 25 °C [%]	9.9	9.3	8.2	8.4	9.8	9.9	8.2
T_max [°C]	30.5	29.6	29.1	28.5	30.2	30.2	30.2
CO_2 < 1200 ppm [%]	43.8	47.0	48.3	49.4	36.7	24.5	98.4
CO_2 < 1800 ppm [%]	98.2	98.8	98.9	99.0	97.9	96.5	100.0

Indoor temperature was kept at a similar level before and after renovation if the demo was continuously heated.

Indoor climate of the Spanish demo building with continuous heating

Conclusion

- When continuous heating switched to intermittent heating, the energy conservation potential of thermal insulating measures was enlarged, while that of generation measures became lower.

- Thermal insulating measures resulted in indoor temperature increase if the demo was intermittently heated.

- Insulating breath membrane has a negative impact on IAQ. Then, installing RAHU is necessary for an improved IAQ .

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Thank you!

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