



Sustainable solutions for affordable
REtroFIT of domestic buildings

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CO₂ emissions reduction potential of sustainable residential renovations in England

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Study objective



- What is the CO₂ emissions reduction potential of different renovation technologies?
- Whether building CO₂ emissions can be reduced by over 60%? How?
- Besides, how the renovation technologies improve indoor climate?

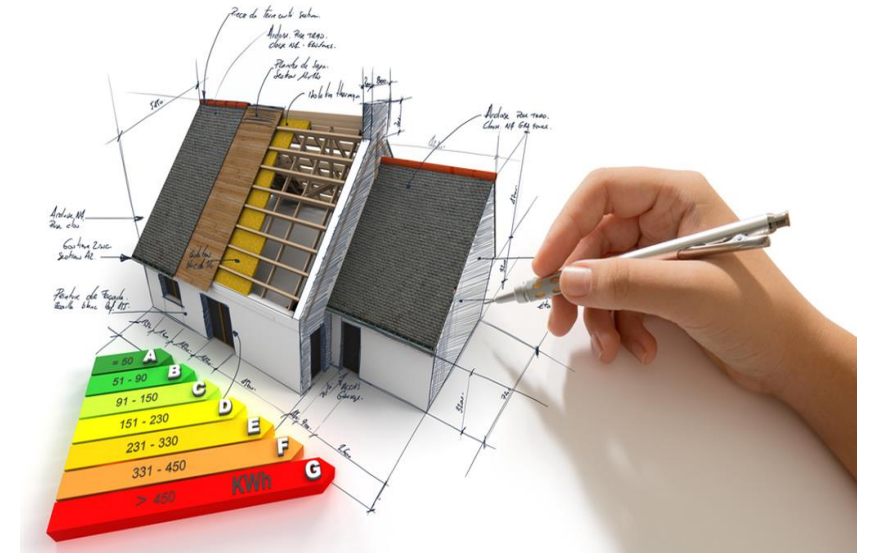
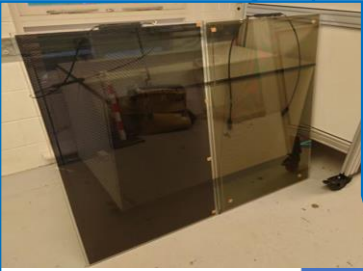


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Renovation technologies simulations



Whole panel thermal conductivity: 0.024 W/mK



U-value: 0.6 W/m²K, Power generation efficiency: 3.5%



PCM product S21, Melting temperature: 18-36 °C

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)

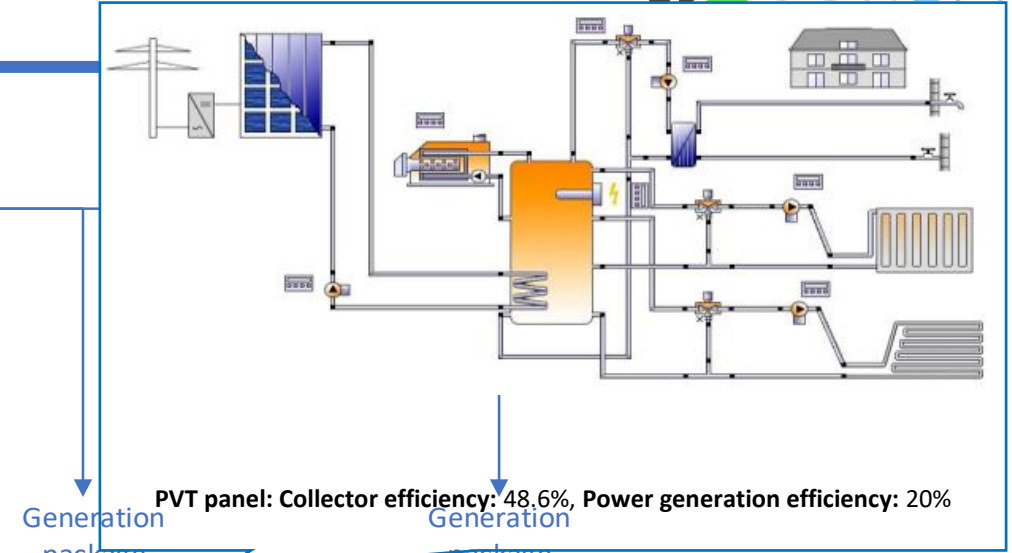


Heat recovery by heat pipe: 76%

Reference building models before renovation



Thermal conductivity: 0.029 W/mK, Airtightness, q₅₀: 0.17 m³/hm²



Generation package

PVT panel: Collector efficiency: 48.6%, Power generation efficiency: 20%

Generation package

Photovoltaic/Thermal (PV/T) system

Solar assisted heat pump (SAHP)

Final Combinations

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

Scenario 2: Passive + Ventilation + Generation (SAHP)



Maximum heat capacity: 11 kW, Annual COP: 4

Demo house description



South façade, English semi-detached house



Northeast façade, Spanish terraced house

Semi-detached house in Nottingham, UK

Building properties before renovation		HVAC systems before renovation	
U-values of envelope (W/m²K)		Ventilation system	Mechanical exhaust ventilation for kitchen, bathroom and toilet; Natural ventilation for other spaces
External wall	2.1		
Roof	0.22		
External floor	0.85	Space heating system	Natural gas boiler and water radiators, electric radiators
Windows	2.4/2.5		
Air leakage rate, n₅₀ (ACH)	16.1	DHW heating system	Electric water heater

Poorly thermal insulated and highly air infiltrated

Living space	Heating setpoint & schedules
Most of the living spaces except kitchen and attic	All year round, 19.5 °C, all day
Kitchen	Weekdays: 19.5 °C [7:00-8:00, 17:00-18:00], Weekends & Holidays: 19.5 °C [9:00-10:00, 12:00-13:00, 17:00-18:00]
Attic	From 1 Apr to 30 Sep, Weekends: 19.5 °C [18:00-23:00]

*The annual heating degree hours at indoor temperature 15.5 °C are 1671 °Ch in Nottingham.

Simulation tool IDA ICE 4.8



- A simulation program allows dynamic multi-zone simulations and modelling of building characteristics including geometry, structures and technical systems.
- It is suitable for simulating energy consumption and indoor climate.

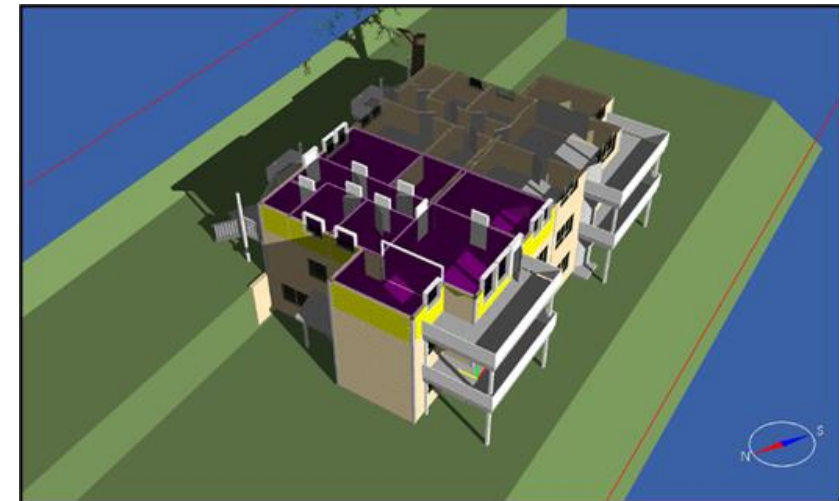
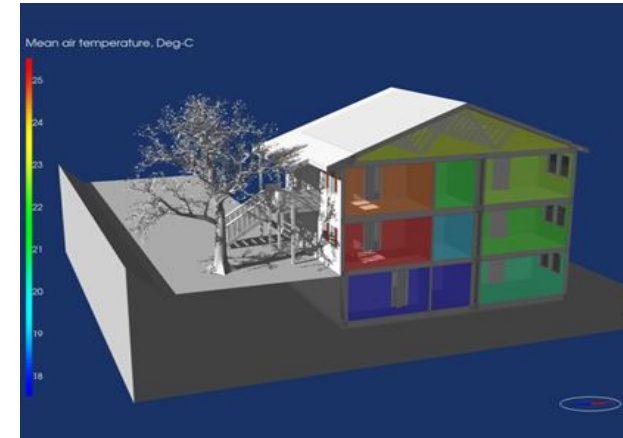
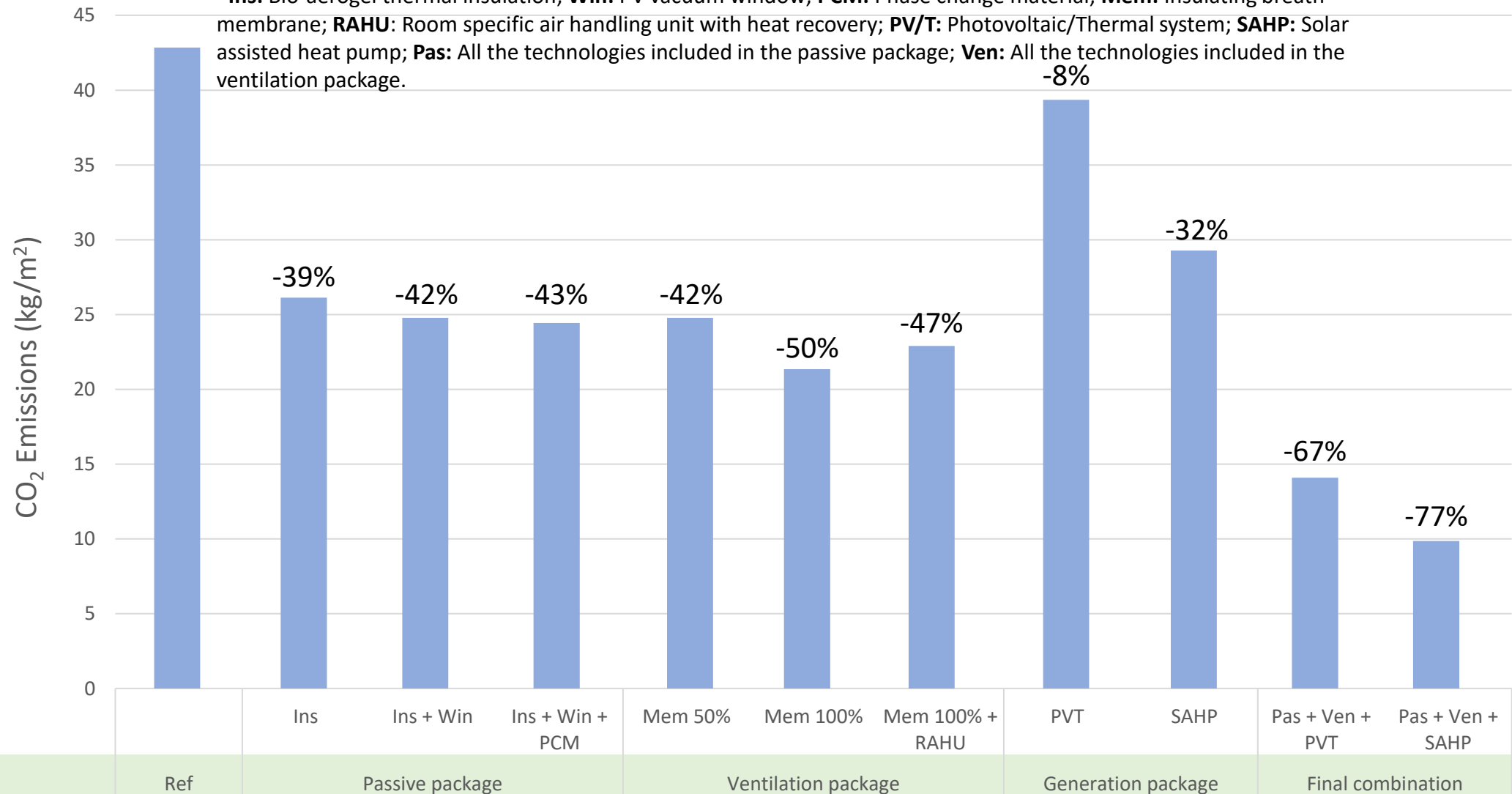


Image retrieved from: <http://www.equa.se/>

Building CO₂ emissions before and after renovation



***Ins:** Bio-aerogel thermal insulation; **Win:** PV vacuum window; **PCM:** Phase change material; **Mem:** Insulating breath membrane; **RAHU:** Room specific air handling unit with heat recovery; **PV/T:** Photovoltaic/Thermal system; **SAHP:** Solar assisted heat pump; **Pas:** All the technologies included in the passive package; **Ven:** All the technologies included in the ventilation package.



Indoor climate in a bedroom before and after renovation



	Ref	Passive package			Ventilation package			Generation package		Final combination	
		Ins	Ins + Win	Ins + Win + PCM	Mem 50%	Mem 100%	Mem 100% + RAHU	PVT	SAHP	Pas + Ven + PVT	Pas + Ven + SAHP
T < 19.5 °C [%]	0	0	0	0	0	0	0	0	0	0	0
T > 25.0 °C [%]	0.4	0.5	0.1	0.1	0.7	0.9	0.8	0.4	0.4	0.2	0.2
T_max [°C]	29.1	29	26.8	26.4	29.3	29.4	29.4	29.1	29.1	27.2	27.2
CO ₂ < 1200 [%]	100	100	100	100	96.8	3.3	100	100	100	100	100
CO ₂ < 1800 [%]	100	100	100	100	100	6.8	100	100	100	100	100

Insulating breath membrane has a negative impact on IAQ, RAHU is required together with insulating breath membrane

PV vacuum windows and PCM slightly lower down maximum summer indoor temperature

*T < 19.5 °C/T > 25 °C : Proportion of time indoor temperature is lower than 19.5 °C or higher than 25 °C; T_max: Maximum air temperature; CO₂ < 1200/1800 ppm: Proportion of time CO₂ concentration is lower than 1200 or 1800 ppm.

Conclusions



- Thermal insulating technologies (e.g., bio-aerogel, insulating breath membrane) are the most effective solutions for CO₂ emissions reduction.
- The building airtightness improvement led by insulating breath membrane worsens IAQ. Thus, if membrane is selected, it is also necessary to equip the demo house with RAHU for a better IAQ.
- SAHP is a more suitable option than PVT system in the English climate conditions.
- A over 60% CO₂ emissions reduction can be achieved by either final combination of renovation technologies in the English semi-detached house.



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Thank you!

Questions & Comments



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