CIB W040 · Heat and Moisture Transfer in Buildings

Passive Energy Conservation Measures Under a Changing Climate in Urban Settings

A summary of the systematic review (CIB Publication 432, 2026)

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Authors: 30 Researchers from 11 Countries; full list of authors, https://cibworld.org/w040-roadmap/

Reviewers: 15 members of international advisory board

WHY THIS REPORT

Buildings must be decarbonized in a changing climate

1.1 °C

global warming already reached (2011–2020 vs pre-industrial)

31%

of global CO_2 emissions come from buildings

2050

net-zero target under the Paris Agreement (1.5 °C)

Where cities have stopped growing
Europe, North America, Oceania: deep energy retrofit of existing buildings is the main lever.

Where cities are still expanding
East and South Asia, Africa, Latin America: retrofits plus low-carbon urban planning.

Passive measures: lower maintenance, better durability and resilience, lower life-cycle cost — but their effect depends on climate, and each can carry side effects.

THE REPORT AT A GLANCE

One question: how to properly apply passive measures?

Chapter 1

Introduction

Climate, emissions and the case for passive measures

Chapter 2

Add-on insulation & moisture loads

Mainly heating-dominated regions

Chapter 3

Passive cooling & urban heat island

Mainly cooling-dominated regions

Chapter 4

HAM tools & probabilistic assessment

How performance is predicted

Chapter 5

Future climate data

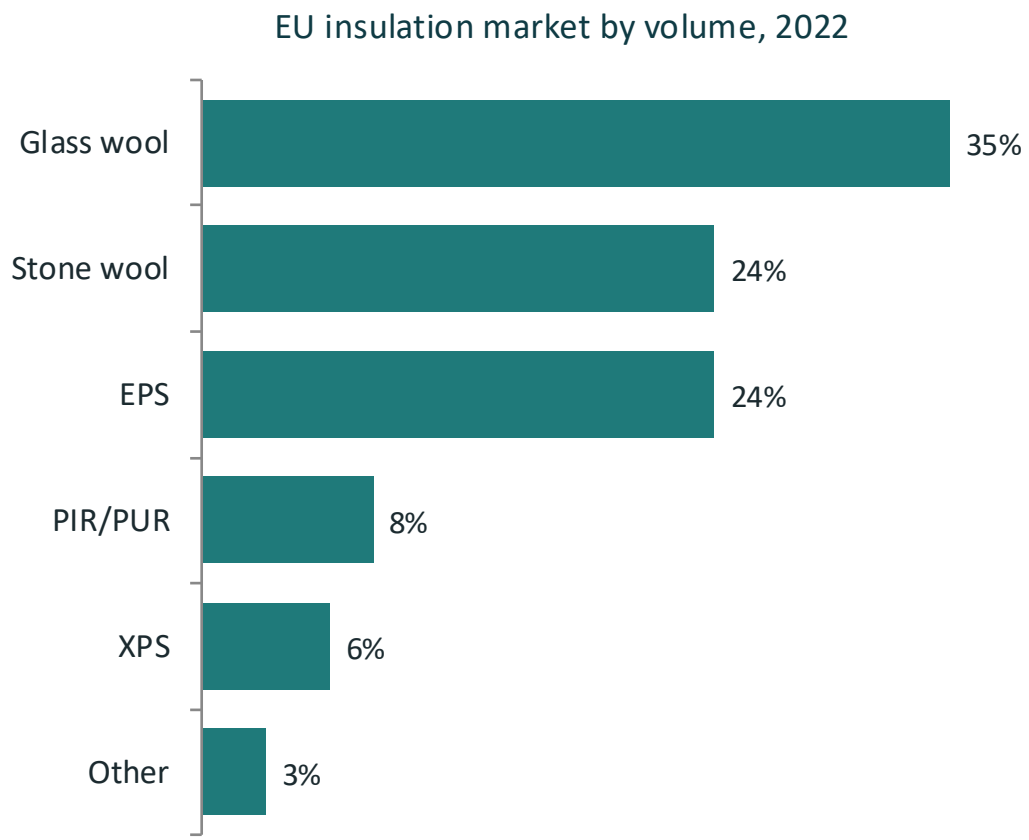
What climate we design for

Each measure is reviewed for

Benefits | **Side effects** | **Risk factors** | **Climate suitability** | **Urban-scale applicability**

220 pages · ~30 authors from 11 countries · peer-reviewed by a 15-member international advisory board

Add on thermal insulations



Bio-based materials are ~2/3 of "Other"; aerogels and vacuum panels ≈ 0.1%

What the 21 journal papers of 2025 studied

80% insulate walls (40% interior, 25% exterior)

10 / 21 model heat and energy only — moisture ignored

1 / 21 accounts for future climate

1 / 21 uses a probabilistic (Monte Carlo) analysis

Section 2.1. Posani, M. et al. Overview of add on insulations in building façade system

Insulating a wall changes how it gets wet and how it dries

Interior insulation — higher risk

- Colder masonry → more freeze–thaw damage
- Rot of embedded wooden beam ends
- Interstitial condensation behind the insulation
- Mould growth on cold interfaces

Exterior insulation (ETICS) — lower risk

- Reduces thermal bridges and rain exposure of the old wall
- But can cut drying potential if vapour-tight
- Night-time overcooling of the render → algae and mould on the facade

Up to 40%

more heat loss when wind-driven rain wets internally insulated walls (Porto) vs 8% (Krakow)

Overheating

insulation can raise summer discomfort — worst for interior insulation on heavy walls

Frost models

no consensus — use them to compare options, not to predict damage

Section 2.1. Posani, M. et al. Overview of add on insulations in building façade system

Three moisture loads that influence wall performance

Rainwater infiltration

0.05% → 70%

- Ranges from vinyl siding to open-joint blocks
- The ASHRAE 160 default of 1% is often wrong
- New 7-category cladding classification for design
- Lab data are worst case (saturated walls)

Section 2.3 Van Den Bossche, N. and Van Linden, S. Rain infiltration rates in façade system: review and modelling approach

Wind-driven rain

+100%

- Wetting can double as wind rises 2 → 10 m/s
- Taller upwind building shields; lower one amplifies
- ~70% of studies model isolated buildings only

Section 2.5 Gholamalipour, P. The impact of key parameters on WDR in urban area

Rain

Air leakage

~100×

- Air through a 4 cm² hole carries ~100× more moisture than diffusion
- Worst path: in at a low outlet, out at the top of the wall
- No assembly stays airtight — limit indoor RH

Section 2.4 Junginger, M. The impact of air leakage on hygrothermal performance of building façade system

Air

Uncertainties of hygrothermal properties of building materials

1 Measurement

- Lab methods disagree across moisture ranges
- Batch heterogeneity and inter-lab reproducibility dominate
- Bio-based materials vary most

2 Transformation

- Curve fitting and extrapolation to model inputs
- Sparse data near saturation
- Hysteresis often omitted

3 Implementation

- Same data, different tools → different answers
- Users swap in “similar” library materials
- Inconsistent definitions (e.g. “saturation”)

Systematic errors create false confidence: a narrow probability distribution around a biased mean. Remedy: curated material databases and machine-learning estimates of missing properties.

Section 2.2 Dang, Hygrothermal Material Properties in Probabilistic Assessments of Passive Energy Conservation Measures

Cooling surfaces works — where the climate is right

Green roofs and walls

15–25 °C lower peak roof surface temperature

40–90% rainfall runoff retained

up to 2 °C neighbourhood air cooling (models)

Risks: structural weight, clogged drainage (a roof collapse in Illinois, 2011), failed irrigation, and fire from dry plants (Ealing, London, 2018).

Section 3.1 Convertino, F. Vegetated building envelope systems

Daytime radiative cooling

–44% cooling electricity, warehouse roof film

12–49% HVAC savings in warm climates

< 1% savings in cold climates

Cautions: winter heating penalty; humidity and clouds weaken it; benefits will be compromised in well-insulated buildings.

Section 3.2 An, J. and Yan, D. Radiative cooling technologies

Control solar gain outside the glass; natural ventilation

Technology readiness for retrofit

Strong	Double/triple low-E glazing · PVC & composite frames · · overhangs, fins, external blinds
Medium	Secondary glazing (heritage) · liquid-crystal and SPD glass
Emerging	Thermochromic and photochromic glazing

External shading beats internal: it stops solar heat before it passes through the glass.

Section 3.3 Bottino-Leone, D. High performance window and shading device

Natural ventilation

- Cross ventilation outperforms single-sided
- Window-to-wall ratio of 20–40% balances airflow and energy
- Future Mediterranean summers: ~40% fewer comfortable hours
- Add humidity control in humid climates; polluted cities may need to limit it
- Urban layout and wind corridors matter as much as the building

Section 3.4 Zhang, L. and Zhang X., Natural ventilation of buildings and spatial uncertainties of microclimate conditions due to different urban planning and landscaping

At city scale, urban form and landscape shape performance, moisture transfer matters

Hot climates: compact clusters shade each other

Cold climates: dispersed forms keep winter sun

Retrofit strategy	Cooling effect	Watch out for
Green roofs & walls	3–37% lower cooling loads	Irrigation and maintenance
Well-placed trees	20–50% lower cooling loads	Utility interference, root intrusion
Cool roofs & pavements	Less heat storage, lower air temperature	Glare and pedestrian discomfort
Water bodies	Evaporative “cooling islands”	Place along prevailing winds

Section 3.5. Ortner, F.P., Aydin, E.E., Govindarajan, P. Impact of urban planning and landscaping on energy and thermal comfort performance of buildings.

The humidity catch

Evaporative cooling adds humidity, and humidity worsens heat stress. In humid districts the heat index ran 5.4 °C above air temperature.

0.1 °C lower daily max ≈ 3% fewer heat deaths

Section 3.6. Teng, X., Fan, Y. Urban moisture distribution and its impact on thermal comfort.

From pass/fail checks to the probabilistic assessment



Tools

- WUFI and Delphin dominate envelope analysis
- Only some allow scripted stochastic runs (Delphin, EnergyPlus, ESP-r, COMSOL)
- Few couple indoor and outdoor microclimate

Evidence-based design

- Calibrate models with lab and field data
- Bayesian updating (MCMC) with monitoring
- ML surrogates make 100,000+ runs feasible

Urban scale

- No urban-scale HAM model exists yet
- Chicago study: mould in 13 of 17 older homes
- 85% of those residents didn't know

Chapter 4. Shams, S.A. et al. HAM tools and probabilistic approach for building performance assessment.

The climate file is a major source of uncertainty

1

Emission scenario

RCPs (CMIP5) → SSPs (CMIP6). Cooling demand rises 5–90% depending on scenario.

2

Climate model choice

GCM choice alone can shift results by up to 10 °C; RCM by up to 5 °C. Use ensembles.

3

Bias correction

Quantile mapping etc. align models with local data — but assume the bias stays constant. Report methods.

4

Reference years

Typical (TMY), extreme (DSY, warm/cold years) and moisture reference years — no consensus on selection.

Chapter 5. Zou, J., et al. Future climate and reference year selection for building performance simulations.

KEY TAKEAWAYS

Robust design for uncertainties, not only for the average case

Every measure has a trade-off

Insulation can raise moisture risk and overheating; cooling can raise humidity or winter heating.

Moisture is the hidden variable

Half of recent insulation studies ignore it, though it drives both energy and durability.

Probabilistic, not deterministic

Only 1 of 21 recent studies quantified uncertainty; tools and data must catch up.

Future and local climate as inputs

Use climate model ensembles and urban microclimate, not historical weather files.

Ongoing and planned tasks

- International round-robin test of material properties, hygrothermal modelling guidelines
- Screen the wall designs, configurations and materials in different countries, cities and climate zones
- Field and lab measurements of buildings and microclimates performance
- Probabilistic assessment of passive energy conservation measures (AI – Assisted)
- Coupled microclimate–building simulation · BIM-integrated workflows · life-cycle carbon cost analysis

CIB W040 work program 2025–2028

Thank you

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