Climate Change, Ventilation and Resilience
AIVC International Workshop / Madrid, Spain / 21-22 April 2026

Multi-Criteria Evaluation of Eight Ventilation Systems in Renovated Houses: Energy, Air Quality and Comfort Performance

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on behalf of the JUSTAIR Team

Madrid, April 21st 2026

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Context

- **Renovation of single-family homes**
  - Airtightness level often improved
  - Ventilation often overlooked
  - → Risk for the indoor air quality (IAQ)
- Need of a **multi-criteria evaluation** of ventilation strategies
  - IAQ
  - Energy use
  - Comfort (thermal, acoustic, olfactive)
  - Cost

Credit: www.izi-by-edf-renov.fr

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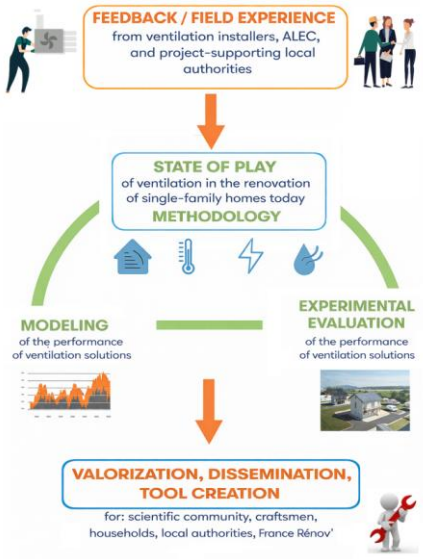
JUSTAIR Project (2022 – 2026)

- **Field experience** from ventilation installers, inhabitants, local authorities (37 interviews, including 17 installers)
- **Identification of 8 ventilation systems**
- **Identification of performance indicators**
- **Creation of a numerical model CONTAM-TRNSYS**
  - airflow
  - Pollutant transport (CO_2, H_20, $PM_{2.5}$, NO_2, formaldehyde, radon)
  - Comfort (thermal, olfactive)
- **Experimental tests on 3 systems (INCA test house)**
- **Calibration of the model**
- **Parametric study**
- **Tools creation**



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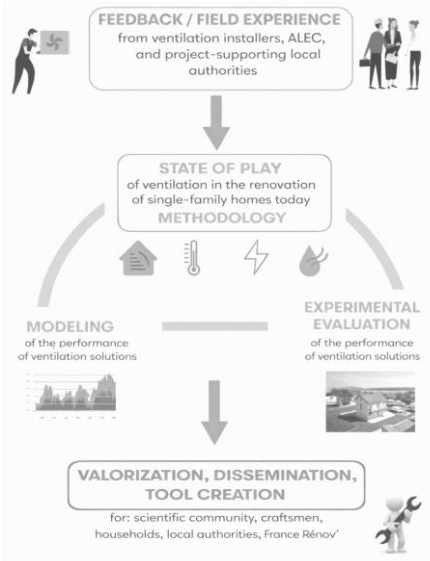

8 ventilation systems

System		Total flowrates			Air change (vol/h)		Sources
		Min	Max	Boost	Min	Max	
EV-rh a	Single **exhaust humidity** based **– hygro A**	30	160	240	0,11	0,61	Avis technique (Regulatory tech. document)
EV-rh b	Single **exhaust humidity** based **– hygro B**	30	160	240	0,11	0,61	Avis technique (Regulatory tech. document)
BV	**Balanced** with heat recovery **- low flowrate**	105			0,40		Arrêté du 24 mars 1982 Regulation
	Balanced with heat recovery **- high flowrate**	180			0,68		
BV-thermo	**Balanced** with heat recovery **- thermodynamic**	180			0,68		
BV-nsd	**Balanced** with heat recovery **– without supply duct**	135	210		0,51	0,80	Manufacturer
SV	**Supply** ventilation	110	220		0,41	0,83	Manufacturer
DBV	**Decentralized** mechanical **balanced** ventilation in 1 Bedroom + EV-rh b	15	40		0,42	1,11	Manufacturer
DEV	**Distributed exhaust** mechanical ventilation **(activated only when RH>60%)**	16	280		0,06	1,06	Manufacturer

Experimental tests

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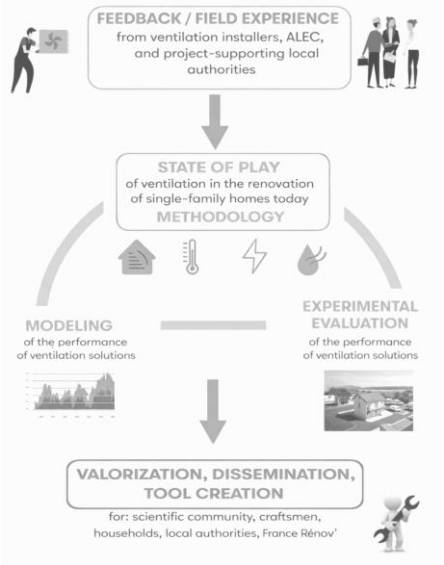

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Performance indicators

Indoor air quality	Comfort	Energy	Air transfer	Costs
• **CO_2**: $I_{ICONE,r}$, E_{CO2} (ppm), $P95_{CO2}$ (ppm) • **Humidity**: E_{RH} (%), E_{RH_70}% (%) • **Pollutants**: E_{p_0} ($\mu g.m^{-3}.h$), E_{pacute_0} ($\mu g.m^{-3}.h$) for **$PM_{2.5}$, NO_2, formaldehyde, radon**	• **Olfactive** (95 percentile of a fictive pollutant concentration emitted in the toilets) • **Acoustic** • **Thermal** : %time, nb of hours	• **Fan** energy use • **Heating** load due to air change	• **Air change** per hour (h-1) • **Mean age** of the air • % of air entering through **leaks** • % of air exiting through **leaks** • Wrong direction of the airflow – indoor doors (%)	• **Installation** costs • **Maintenance** annual costs

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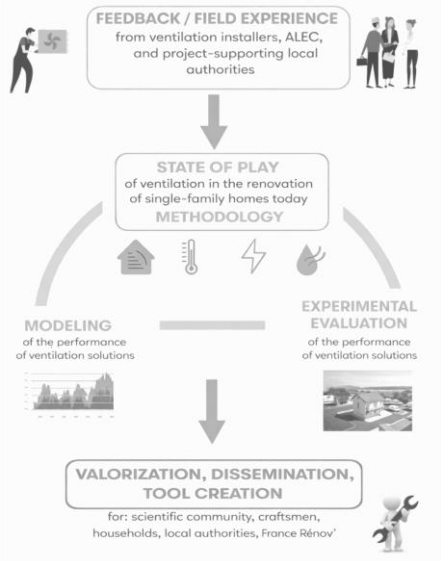


Parametric study - Methodology

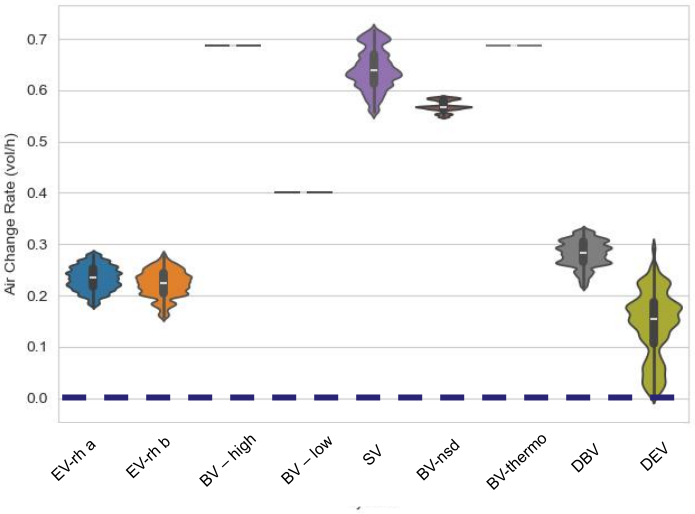
Categories	Values			
Weather zone (Fr)	H1b (continental)	H2b (oceanic)	H3 (mediterranean)	3
Outdoor pollution (NO_2 & $PM_{2.5}$)	Average		High	2
Envelope	Low insulation + Low airtightness	Good insulation + Good airtightness	Good insulation + High airtightness	3
Occupation	4 occupants + moderate occupation	4 occupants + high occupation	6 occupants + high occupation	3
Internal emissions	Low	Moderate	High	3
Opening of windows	Rare		Often	2
Moisture buffer	Moderate		High	2
			Number of simulations per system	**648**

Parametric study – Results – air change rate

Boxplot (descriptive statistics) and violon plot (probability distribution) of the 648 simulations

Air change rate due to mechanical ventilation

Heating period



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EV-rh b	Single **exhaust humidity** based **– hygro B**
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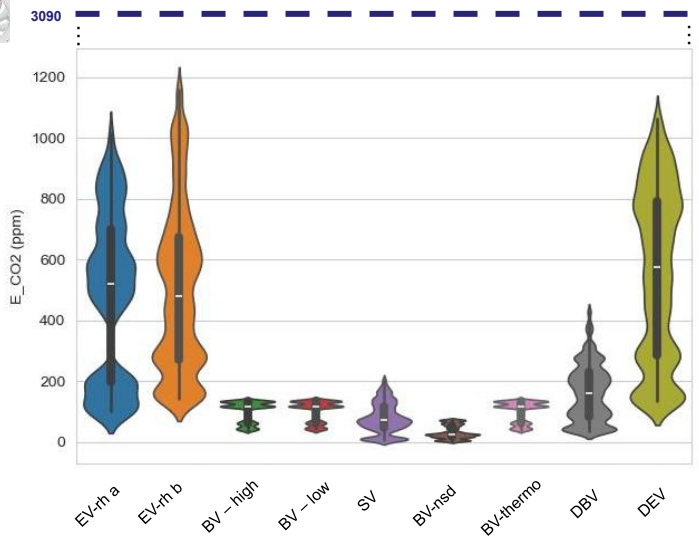
BV-thermo	**Balanced** with heat recovery **- thermodynamic**
BV-nsd	**Balanced** with heat recovery **– without supply duct**
SV	**Supply** ventilation
DBV	**Decentralized** mechanical **balanced** ventilation in 1 Bedroom + EV-rh b
DEV	**Distributed exhaust** mechanical ventilation **(activated only when RH>60%)**

← 0 vol/h
no mechanical ventilation

Parametric study – Results – CO_2



Cumulated CO_2 exposition above 1000 ppm (worst room)

Heating period

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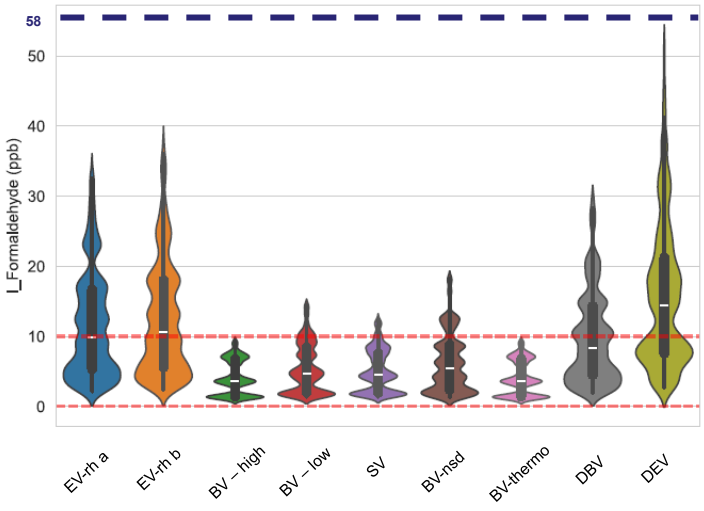
Parametric study – Results – Formaldehyde



Average exposition of formaldehyde (worst occupant)

Heating period

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10µg/m³ (~8ppb)
(Anses 2018)

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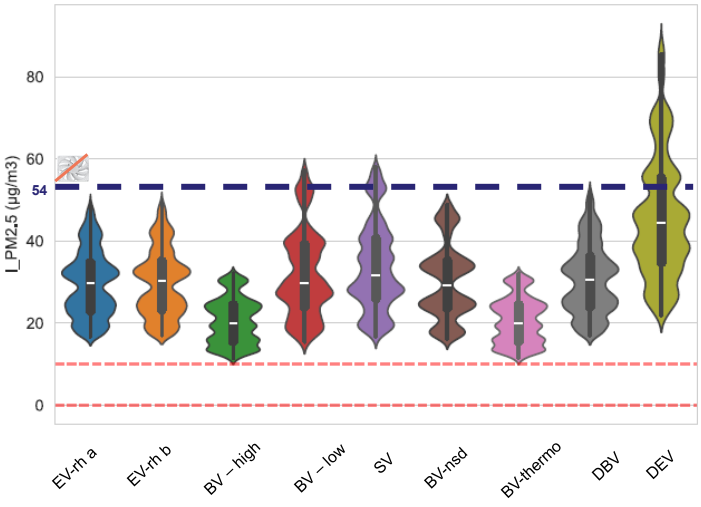
Parametric study – Results – $PM_{2.5}$

Average exposition of $PM_{2.5}$ (worst occupant)

Heating period



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10µg/m³
(OMS 2005)

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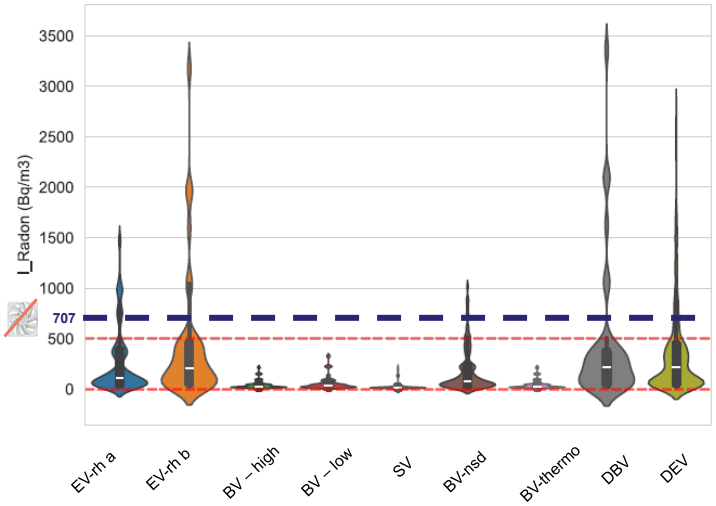
Parametric study – Results – Radon

Average exposition of radon (worst occupant)

Heating period



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300 Bq/m³
CSTB

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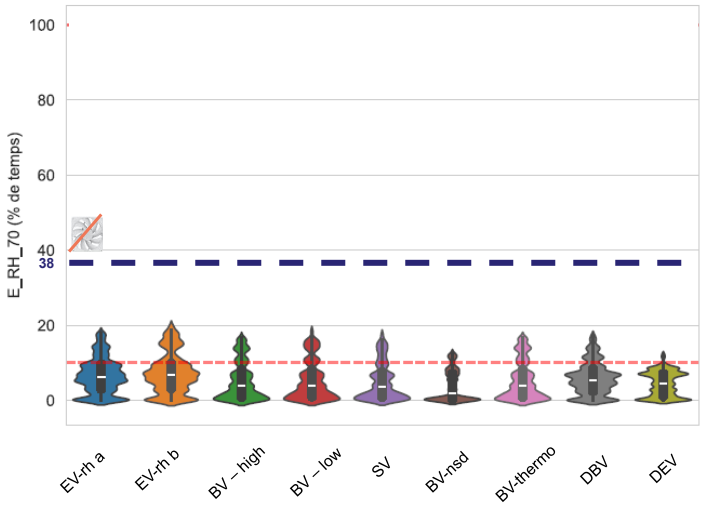
Parametric study – Results – Humidity

Percentage of time with RH > 70% (worst room)

Heating period



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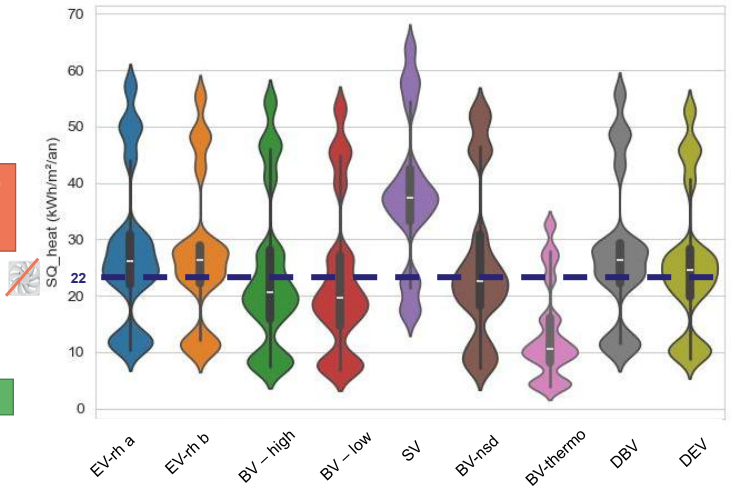
Parametric study – Results – Heating loads

Heating load due to the total air change rate

Heating period



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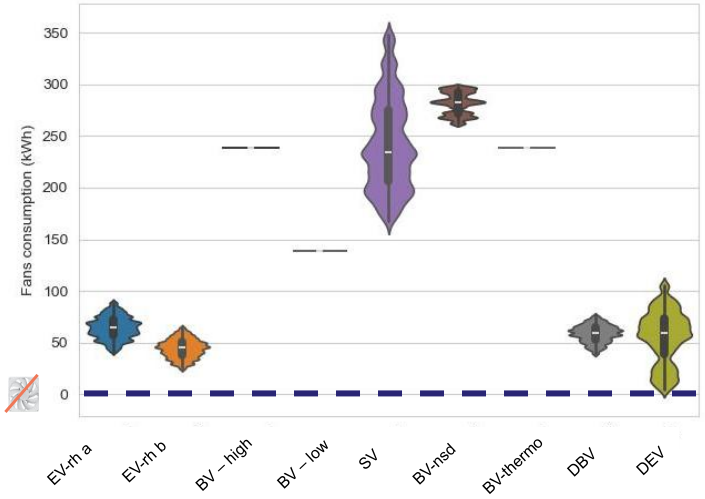
Parametric study – Results – Fan energy use



Heating period

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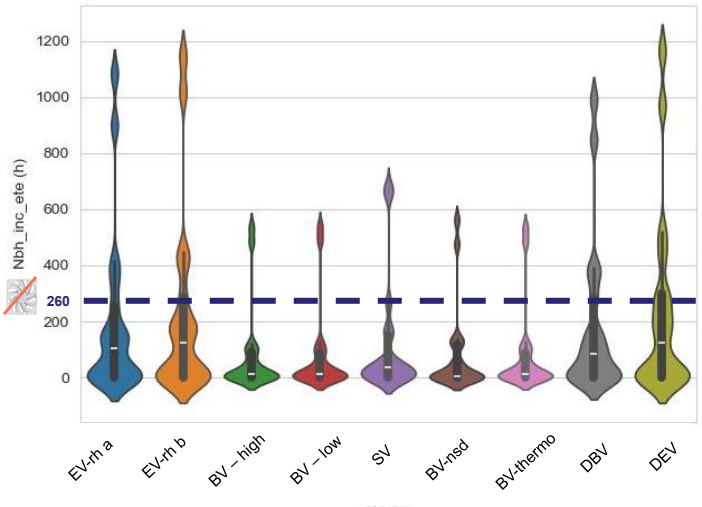
Parametric study – Results – Thermal confort



Number of hours of discomfort (T>28°C, worst room)

Hot period

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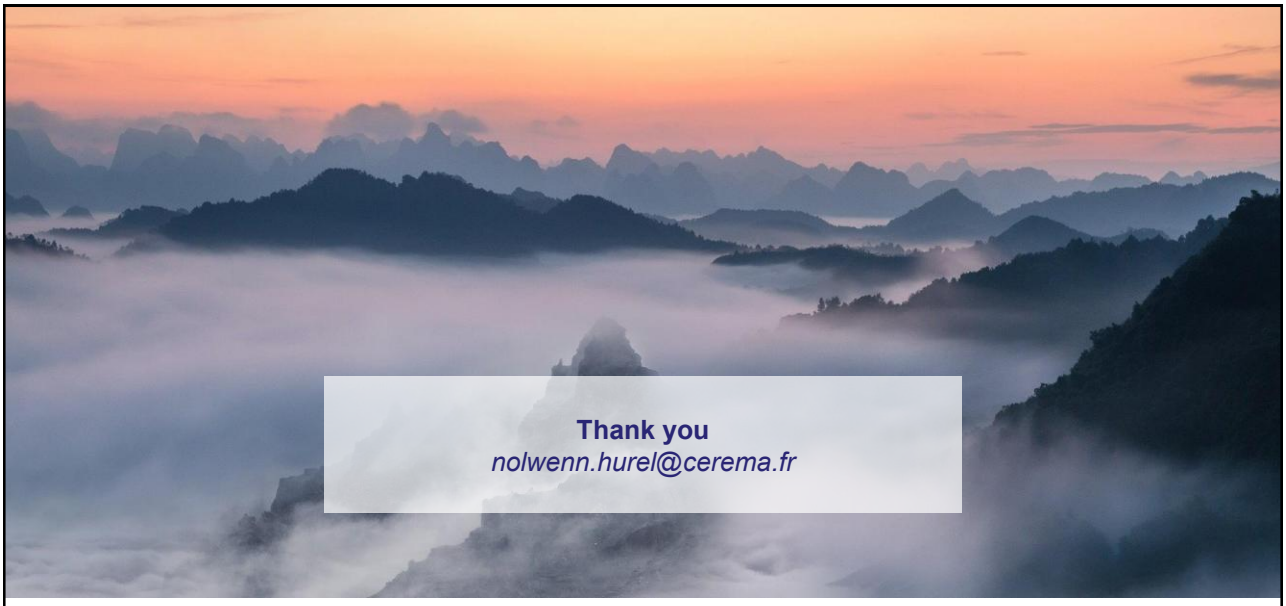
Conclusions (1/2)

- Indoor air quality
  - **High airflow rates (on average)** → significant reduction in CO_2 and formaldehyde concentrations
  - **Humidity-controlled** modulated airflow → Good control of H_2O and $PM_{2.5}$ due to peak extraction during cooking
  - **Particle exposition** → high for all systems (and mostly coming from indoor emissions)
  - **Outdoor pollution (NO_2)** → no significant difference between systems
  - **Over-pressurization**: improved radon level (no ventilation worse than depressurization)
  - **No ventilation** → Issues: IAQ, RH (during peaks), odor comfort … with high risks
- Air transfer
  - **Good building airtightness** → Reduces the risk of air short-circuiting
  - **Opening of windows** → Risk of air short-circuiting and very poor IAQ for non-balanced systems

Conclusions (2/2)

- Comfort
  - **Thermal:** High airflow rates → Lower number of discomfort hours
  - **Acoustic**: 3 systems tested → good acoustic performance for all (meeting the requirements)
  - **Olfactive:** Worst for supply systems than exhaust & balanced; worst case: non-permanent ventilation
- Energy use
  - **Fan energy use**: lower for systems with reduced flowrates (outside RH peaks)
  - **Heating load**: lower for systems with heat recovery and/or heat pumps; and for systems with airflow modulation (with low minimum airflow rates)



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