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VIP46 : BUILDING AIRTIGHTNESS IMPACT ON ENERGY PERFORMANCE (EP) CALCULATIONS

AIVC Webinar - Nolwenn Hurel

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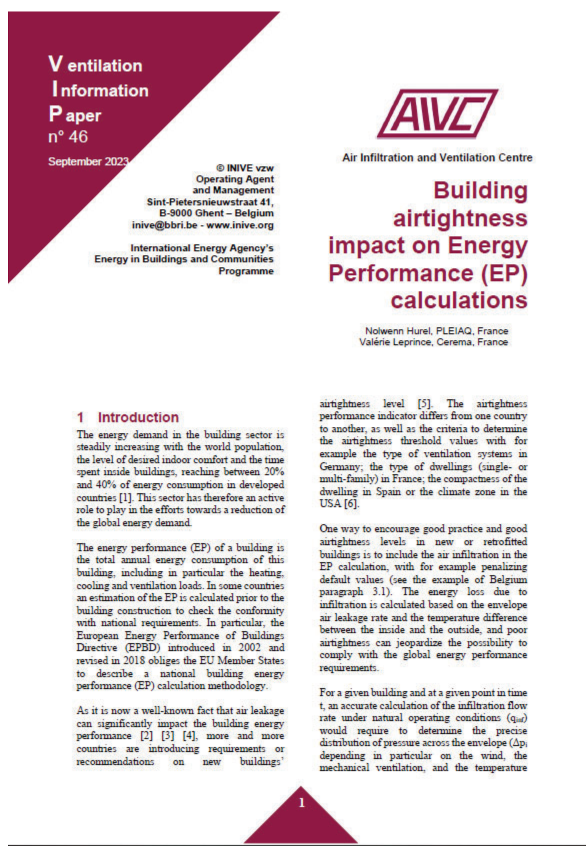

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International Energy Agency's
Energy in Buildings and Communities
Programme

AIVC
Air Infiltration and Ventilation Centre

Building airtightness impact on Energy Performance (EP) calculations

Nolwenn Hurel, PLEIAQ, France
Valérie Leprince, Cerema, France

1 Introduction

The energy demand in the building sector is steadily increasing with the world population, the level of desired indoor comfort and the time spent inside buildings, reaching between 20% and 40% of energy consumption in developed countries [1]. This sector has therefore an active role to play in the efforts towards a reduction of the global energy demand.

The energy performance (EP) of a building is the total annual energy consumption of this building, including in particular the heating, cooling and ventilation loads. In some countries an estimation of the EP is calculated prior to the building construction to check the conformity with national requirements. In particular, the European Energy Performance of Buildings Directive (EPBD) introduced in 2002 and revised in 2018 obliges the EU Member States to describe a national building energy performance (EP) calculation methodology.

As it is now a well-known fact that air leakage can significantly impact the building energy performance [2] [3] [4], more and more countries are introducing requirements or recommendations on new buildings' airtightness level [5]. The airtightness performance indicator differs from one country to another, as well as the criteria to determine the airtightness threshold values with for example the type of ventilation systems in Germany; the type of dwellings (single- or multi-family) in France; the compactness of the dwelling in Spain or the climate zone in the USA [6].

One way to encourage good practice and good airtightness levels in new or retrofitted buildings is to include the air infiltration in the EP calculation, with for example penalizing default values (see the example of Belgium paragraph 3.1). The energy loss due to infiltration is calculated based on the envelope air leakage rate and the temperature difference between the inside and the outside, and poor airtightness can jeopardize the possibility to comply with the global energy performance requirements.

For a given building and at a given point in time t, an accurate calculation of the infiltration flow rate under natural operating conditions (q_{inf}) would require to determine the precise distribution of pressure across the envelope (Δp_i depending in particular on the wind, the mechanical ventilation, and the temperature

1

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  - **Total annual energy consumption** of the building, incl. heating, cooling and ventilation
  - **Some countries:** calculated prior to the construction to check conformity with requirements
  - **European Energy Performance of Buildings Directive (EPBD)**
    - introduced in 2002 and revised in 2018 and 2024
    - obliges the EU Member States to describe a national building EP calculation methodology

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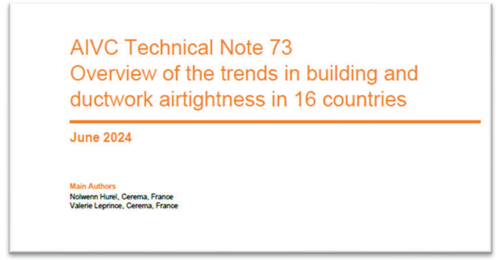
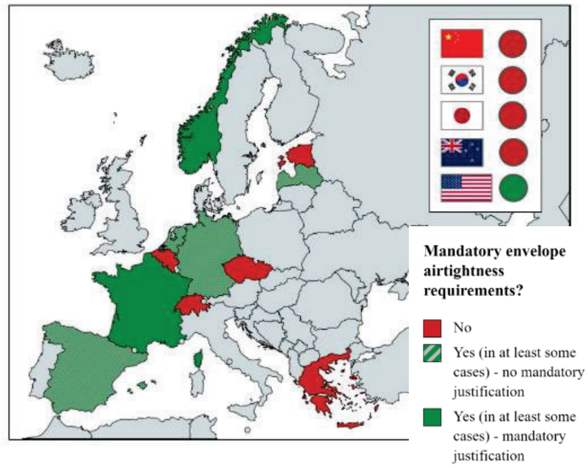
Introduction


AIVC Technical Note 73
Overview of the trends in building and ductwork airtightness in 16 countries

June 2024

Main Authors
Nolwenn Hurel, Cerema, France
Valerie Leprince, Cerema, France

- Building airtightness regulation
  - More and more countries with **mandatory envelope airtightness requirements**
    - **With or without mandatory justification**
    - **Various indicators:** vol./surf., 4/20/50 Pa
    - **Various criteria to determine the threshold values :** Type of ventilation systems (Germany); type of dwellings (France); compactness (Spain); climate zone (USA), etc
    - **Other countries with recommendations**



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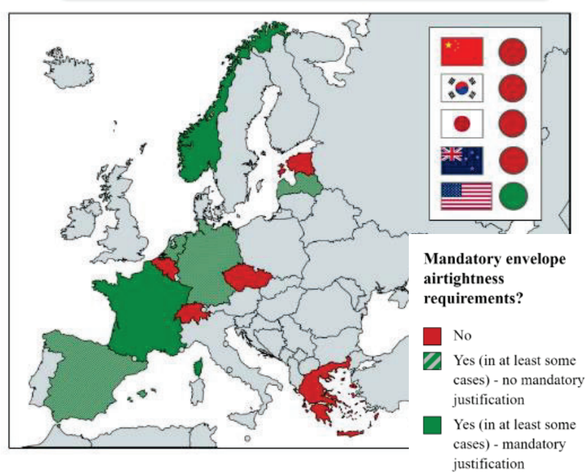
    - **Other countries with recommendations**

  - Other/complementary option encouraging good airtightness: **include air infiltration in EP calc.**
    - energy loss due to infiltration calculated based on the **envelope air leakage rate**
    - poor airtightness can jeopardize the possibility to comply with the global energy performance requirements



Introduction

- Envelope air leakage rate calculation (q_{inf})
  - For a **precise calculation** at a time t, we need:
    - the precise **pressure distribution** across the envelope (Δp_i) depending in particular on :
      - the wind
      - the mechanical ventilation
      - the temperature difference
    - precise **leakage distribution** and characterization of each leak i :
      - flow coefficient C_i
      - flow exponent n_i

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Introduction

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      - the temperature difference
    - precise leakage distribution and characterization of each leak i :
      - flow coefficient C_i
      - flow exponent n_i
  - But **in practice**:
    - precise distribution of pressure **unknown**
    - leakage distribution & characterization of each leakage path usually **unknown** → airtightness estimated/measured for the whole building envelope;
    - airtightness usually estimated/measured at 50 Pa VS operational dP rather between -10 and +10 Pa;

$$q_{inf} = \sum_i C_i \times \Delta p_{i,t}^{n_i}$$

→ **Need of simplified models**

Simplified models

Not included in the EP calculations

- In some countries the envelope airtightness is not an input for the EP calculation
  - **Switzerland**
  - **Sweden**
    - requirements on envelope airtightness for new buildings BUT
    - Energy Performance Certificates based on measured energy performance
  - **New Zealand**
    - No specific target for building airtightness
    - Three methods to comply with the performance requirements, only one include airtightness (as a constant) in a detailed hourly calculation; but not the preferred choice (most complex one)

Leakage – Infiltration Ratio (LIR)

$$n_{inf} = \frac{n_{50}}{N}$$

- Linear relationship between infiltration rate (n_{inf}) and leakage rate at 50 Pa (n_{50})
  - Used to estimate the **building steady-state infiltration heat loss**, usually applied in semi-steady state calculation methods
  - **Quick estimation** but with **significant limitations**

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  - **Belgium**
    - No requirement on minimum airtightness level, but **very disadvantageous default value in EPC** if no test
    - In Flanders: requirement on the global performance → all building tested
    - N = 25

$$q_{inf} = \frac{q_{E50,av,ext} \times A_T}{25}$$

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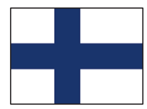
  - **Finland**
    - N is a floor coefficient: 35 (1 floor); 24 (2 floors); 20 (3-4 floors); 15 (>5 floors)

$$q_{inf} = \frac{q_{E50,av,ext} \times A_T}{25}$$



$$q_{inf} = \frac{q_{E50}}{x} A$$

Simple Infiltration Models (SIM)

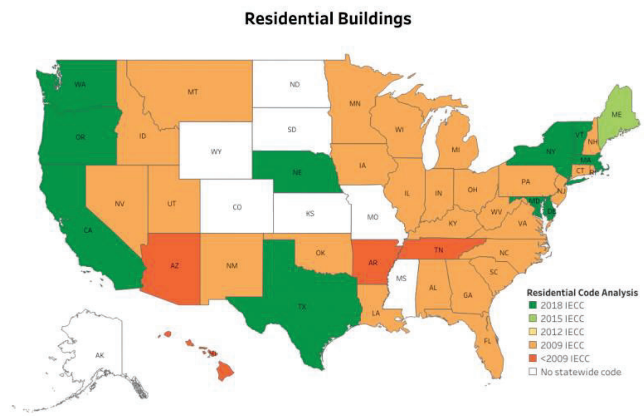
$$n_{inf} = \frac{n_{50}}{N}$$

- Take into account time-dependent parameters
  - More complex but more precise than LIR
  - **UK**
    - N = 20 but with monthly correction factors to account for wind fluctuations
    - Presentation by Xiaofeng

Simple Infiltration Models (SIM)

$$n_{inf} = \frac{n_{50}}{N}$$

- Take into account time-dependent parameters
  - More complex but more precise than LIR
  - UK
  - **USA**
    - Regulation depends on the states, most states adopted the International Energy Conservation Code (IECC) with limit for leakage and three compliance methods, incl. Energy Rating Index: the hourly air exchange rate for the year is calculated and **includes stack and wind coefficient**



US DOE BECP: Status of State Energy Code Adoption - https://www.energycodes.gov/status/residential
Updated as of 10/01/21

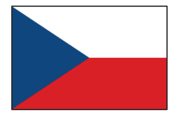
Simple Infiltration Models (SIM)

$$n_{inf} = \frac{n_{50}}{N}$$

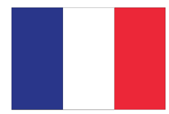
- Take into account time-dependent parameters
  - More complex but more precise than LIR
  - UK
  - USA
  - **Spain**
    - Requirements on airtightness since 2019 for residential buildings > 120 m²
    - Dynamic hourly model for EPC **BUT** infiltration calculated with a simplified model, with parameters:
      - 2 values of **wind speed** of 0 and 4 m/s
      - **pressure coefficients**: +0.25 windward ; -0.50 downwind; -0.60 for roofs
      - **exposure to wind**: by default, 50% windward surface; 50% downwind surface
      - **flow coefficient** (n) : 0.5 for big openings; 0.67 for small openings like cracks.
      - **ventilation design rate**
      - etc

Equilibrium Pressure Model (EPM)

- Pressure calculated by a mass balance equation
  - More complex but more precise than LIR and SIM
  - Calculation performed at a time step (often hourly)
  - Requires an estimation of pressure and leakage distribution
  - Presented by Valérie right after



  - **The Czech Republic**
    - Presented by Jiri



  - **France**
    - Very similar to CZ

Comparison SIM - EPM

- Happle et al. : test on 24 Swiss buildings

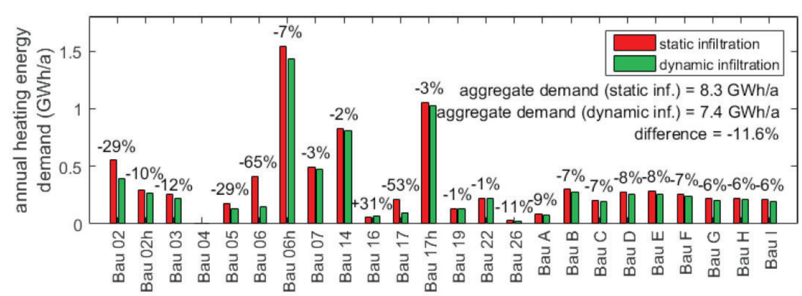
[18] G. Happle, J. A. Fonseca, and A. Schlueter, "Effects of air infiltration modeling approaches in urban building energy demand forecasts," Energy Procedia, vol. 122, pp. 283–288, Sep. 2017, doi: 10.1016/j.egypro.2017.07.323.

- A SIM calculation: static infiltration rate with fixed air change rate (from DIN 1946-6:2009 [19]):

$$q_{inf} = f_{system} \times V_{int} \times n_{50} \times \left(f_{location} \times \frac{\Delta p_{dim}}{50}\right)^{n}$$

where $f_{system} = 0.5$, $f_{location} = 1$, $n = 0.66$; a design differential pressure $\Delta p_{dim} = 5$ Pa is suggested for a multi-storey building shielded from wind (DIN 1946-6).

- An EPM calculation: dynamic calculation based on wind pressure and air temperatures, with the infiltration rate calculated according to an iterative procedure described in EN 16798-7.



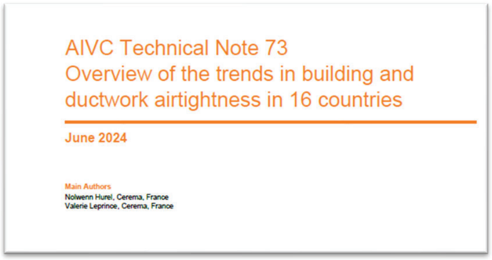
→The **model choice can drastically affect the energy demand** in the individual building level
→ the annual heating demand was reduced with the EPM for all buildings but one, with an **average reduction of 11.6%** and **a maximum reduction of 65%.**

Conclusion

Summary

Country	Airtightness in EP calc.?	Method	Comments
Sweden	No	-	Energy Performance Certificates are based on measured energy performance
New-Zealand	It depends	- / const.	Airtightness not included for 2 methods of compliance; included for the 3rd one through a constant air exchange lumped parameter (mechanical ventilation & infiltration)
Belgium	Yes	LIR	Based on pressurization test measurement
Finland	Yes	LIR	Based on pressurization test measurement Fixed infiltration rate (annual) with a leakage-infiltration ratio depending on the number of floors
USA	It depends	- / SIM	Most jurisdictions use a prescriptive approach and do not model energy use IECC: SIM; dynamic infiltration rate California: SIM; fixed infiltration rate
Spain	Yes	SIM	Based on pressurization test measurement or estimated according to the building's parameters and default values - Fixed infiltration rate (annual)
UK	Yes	SIM	Based on pressurization/pulse technique test measurement or estimated according to the building's parameters Monthly infiltration rates (according to the wind)
France	Yes	EPM	Based on method 1 of EN 16798-7:2017 Dynamic infiltration rates (hourly)
Czech Republic	Yes	EPM	Based on method 1 of EN 16798-7:2017 Dynamic infiltration rates (hourly)

Additional info.



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Level of accuracy and complexity

Type of model	Country	Details	Default values		
			Used?	Values	Comments
Constant value	CH	Not a variable: fixed additional outside air volume flow of 0.15 m³/(h.m²) (net floor area reference) regardless of the quality of the envelope (not possible to use test values)			
Constant value	NZ	Airtightness not included for 2 methods of compliance; included for the 3rd one through a constant air exchange lumped parameter (mechanical ventilation & infiltration)			
Tabulated values	GR	Fixed tabulated air infiltration rates (m³/h) given for different types of windows and doors; for chimneys and ventilation boxes (not possible to use test values)			
Leakage-infiltration ratio	BE	$v_{inf} = 0.04 * v_{50} * A_T$	YES	**VERY penalising** v_{50}: 12 m³/(h·m²) for heating; 0 for cooling	Test not officially mandatory but almost necessary for the EP calculation (better v_{50})
	DE	With ventilation system: $n_{inf} = n_{50}.e_{wind}$ (with **e_{wind}** typically = 0,07) Without: $n_{inf} = n_{50} \cdot e_{wind} \left(1 + f_{V,mech} \frac{t_{V,mech}}{24\,h}\right)$	YES	Penalising n_{50} (h^{-1}): 4; 6 or 10 depending on the building (typically 4)	If a test will be performed: maximum mandatory requirements are the default values
	EE	$q_{inf} = q_{50}.A/X$ A: area of the building envelope (m²) X: factor depending on the **number of stories** (ranging from 15 to 35)	YES	Penalising q_{50} (m³/(h.m²)): – detached house: 4 (6 for minor renovation) – - other buildings: 2,5 (4)	Other possibilites: – Use 1.5 m³/(h·m²) to be justified by test later – Use of a calculated "declared air leakage rate"
	ES	Fixed infiltration rate estimated from n_{50} with hypotheses (wind speed: 2,8 m/s, Cp values; n=0,67; etc.)	YES	Calculation of n_{50} by a formula: $n_{50} = 0.629 \frac{C_o.A_o + C_h.A_h}{V_{int}}$	-
	KR	According to ISO 13789: $n_{inf} = \frac{n_{50} \times e}{1+\frac{f}{e}\left(\frac{V_1-V_2}{V \times n_{50}}\right)^2}$ f, e: **shielding factors**; V_1, V_2: sup. and exh. **airflows**	YES	Penalising for residential: 6 ACH50 non-residential: 1,5 ACH50	Mandatory test for residential building: the measured value is used in the final certification
	NO	Common case: $n_{inf} = n_{50}.0{,}07$ but depends **on number of facades exposed** and **degree of exposure to wind**	NO	-	Requirements can be used prior to the test
Equilibrum pressure model	CZ	Method 1 of the standard EN 16798-7, with an hourly time step (pressure calculated by a **mass balance equation**)	NO	-	Common practice: use recommended n_{50} values at level I according to ČSN 73 0540-2
	FR		YES	Non-residential: $Q_{4PaSurf}$: 1.7 or 3 m³/(h·m²) depending on the building use	No default values for residential buildings: minimum requirements to be justified

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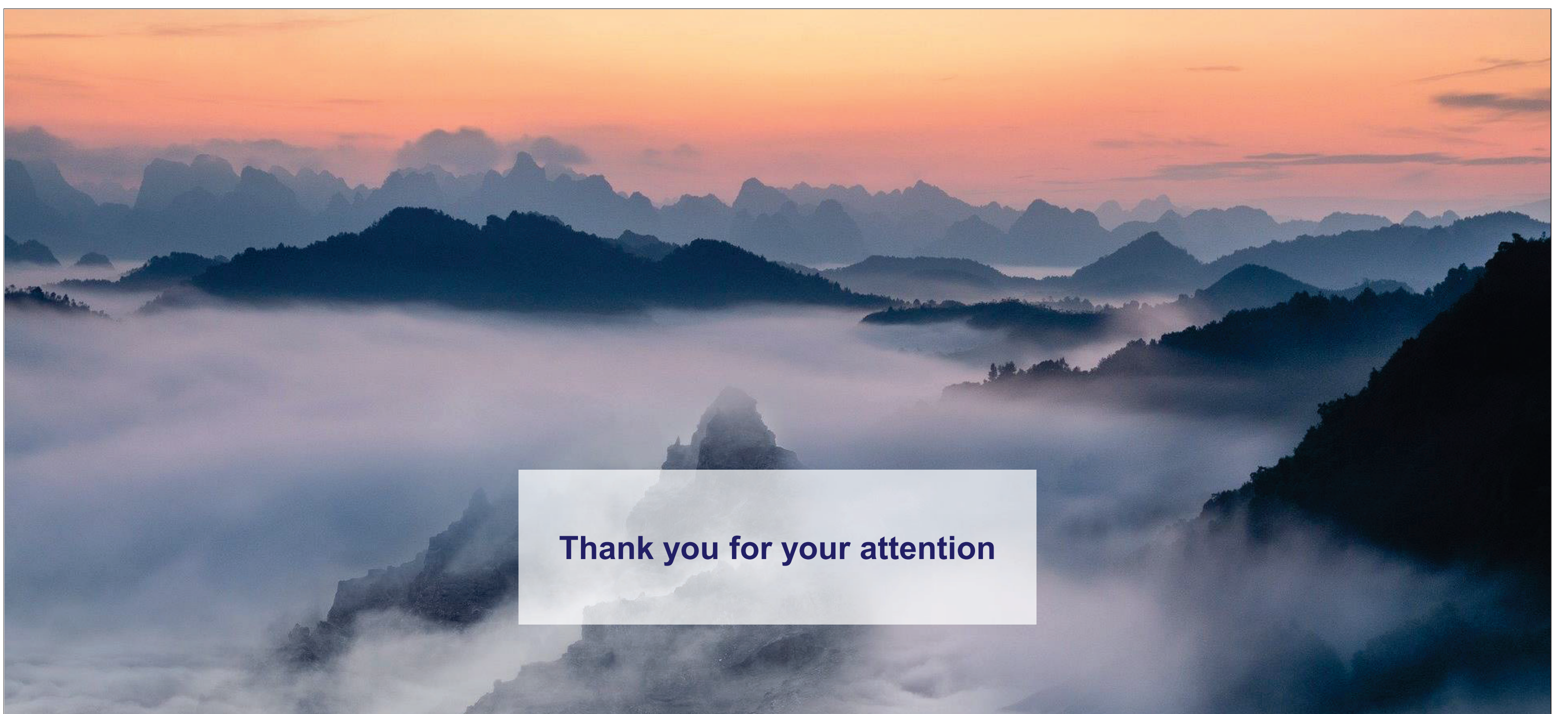

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