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

AIVC Webinar - Nolwenn Hurel

December 9, 2024

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  Nolwenn Hurel & Valérie Leprince, Cerema
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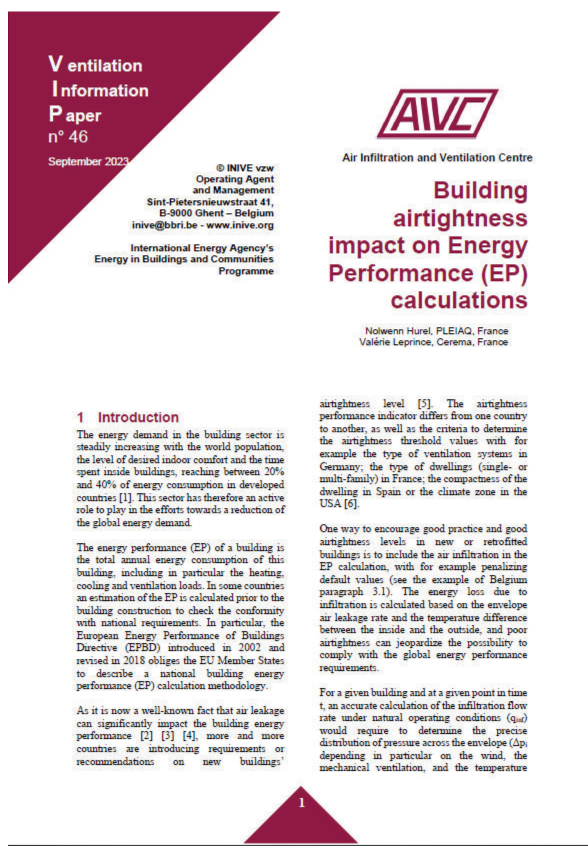

Ventilation **I**nformation **P**aper n° 46

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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

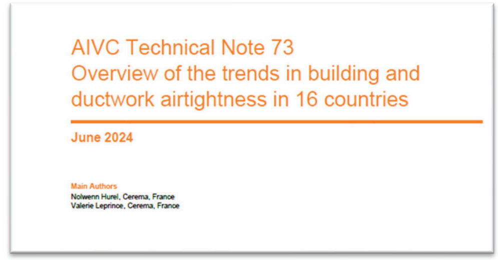
1

Introduction

Introduction

- Energy performance (EP) of a building
  - **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

Introduction

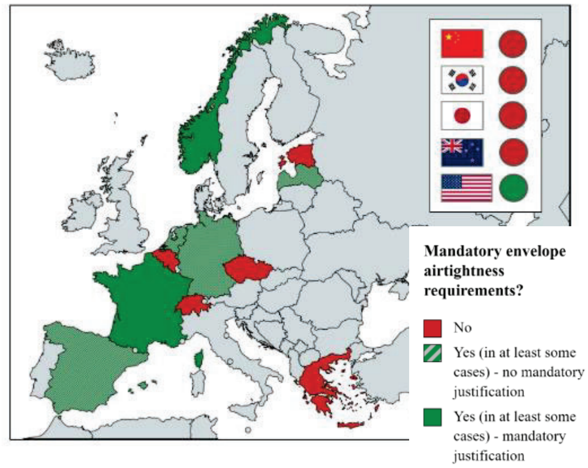


AIVC Technical Note 73
Overview of the trends in building and ductwork airtightness in 16 countries

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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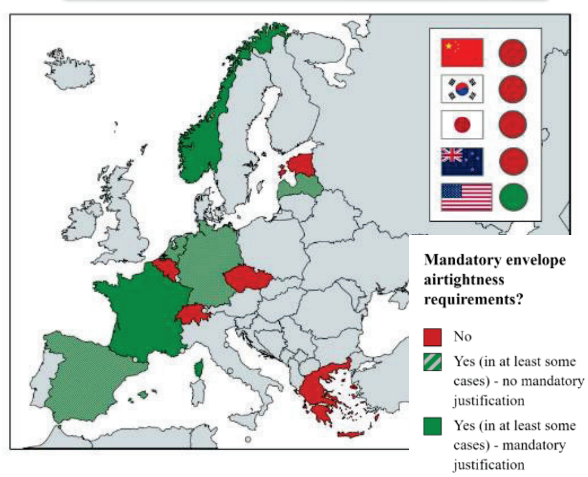
    - **Various criteria to determine the threshold values :** Type of ventilation systems (Germany); type of dwellings (France); compactness (Spain); climate zone (USA), etc
    - **Other countries with recommendations**
  - Other/complementary option encouraging good airtightness: **include air infiltration 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

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

Introduction

- Envelope air leakage rate calculation (q_{inf})
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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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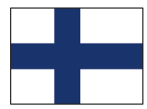
  - **Finland**
    - N is a floor coefficient: 35 (1 floor); 24 (2 floors); 20 (3-4 floors); 15 (>5 floors)

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



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

Simple Infiltration Models (SIM)

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

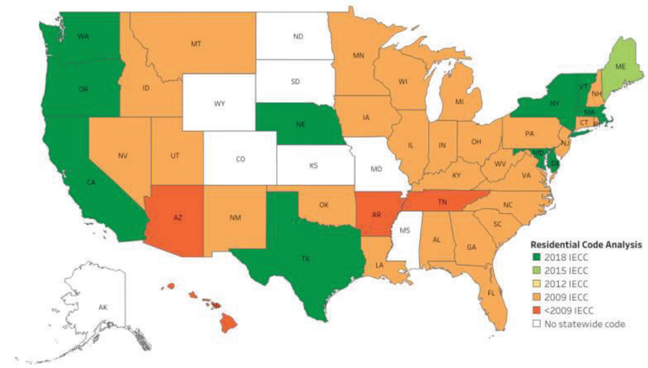
- Take into account time-dependent parameters
  - More complex but more precise than LIR
  - **UK**
    - N = 20 but with monthly correction factors to account for wind fluctuations
    - Presentation by Xiaofeng

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**

Residential Buildings



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

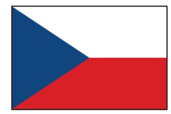
Simple Infiltration Models (SIM)

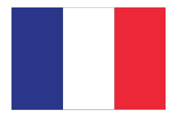
$$n_{inf} = \frac{n_{50}}{N}$$

- 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





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Comparison SIM - EPM

- Happle et al. : test on 24 Swiss buildings

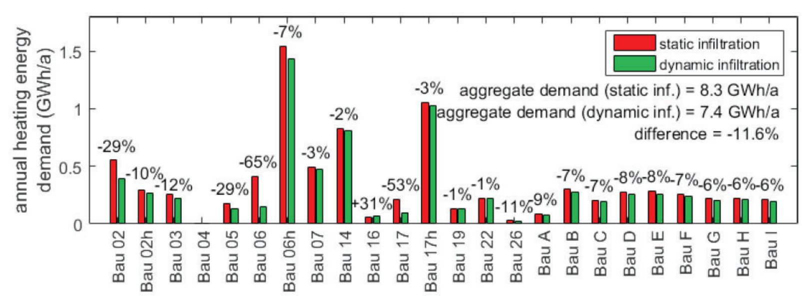
[18] G. Happle, J. A. Fonseca, and A. Schlueter, "Effects of air infiltration modeling approaches in urban building energy demand forecasts," Energy Procedia, vol. 122, pp. 283–288, Sep. 2017, doi: 10.1016/j.egypro.2017.07.323.

- 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%.**

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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)			
	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: $n_{inf} = n_{50}\, e_{wind} \left(1 + f_{V,mech} \frac{t_{V,mech}}{24\,h}\right)$	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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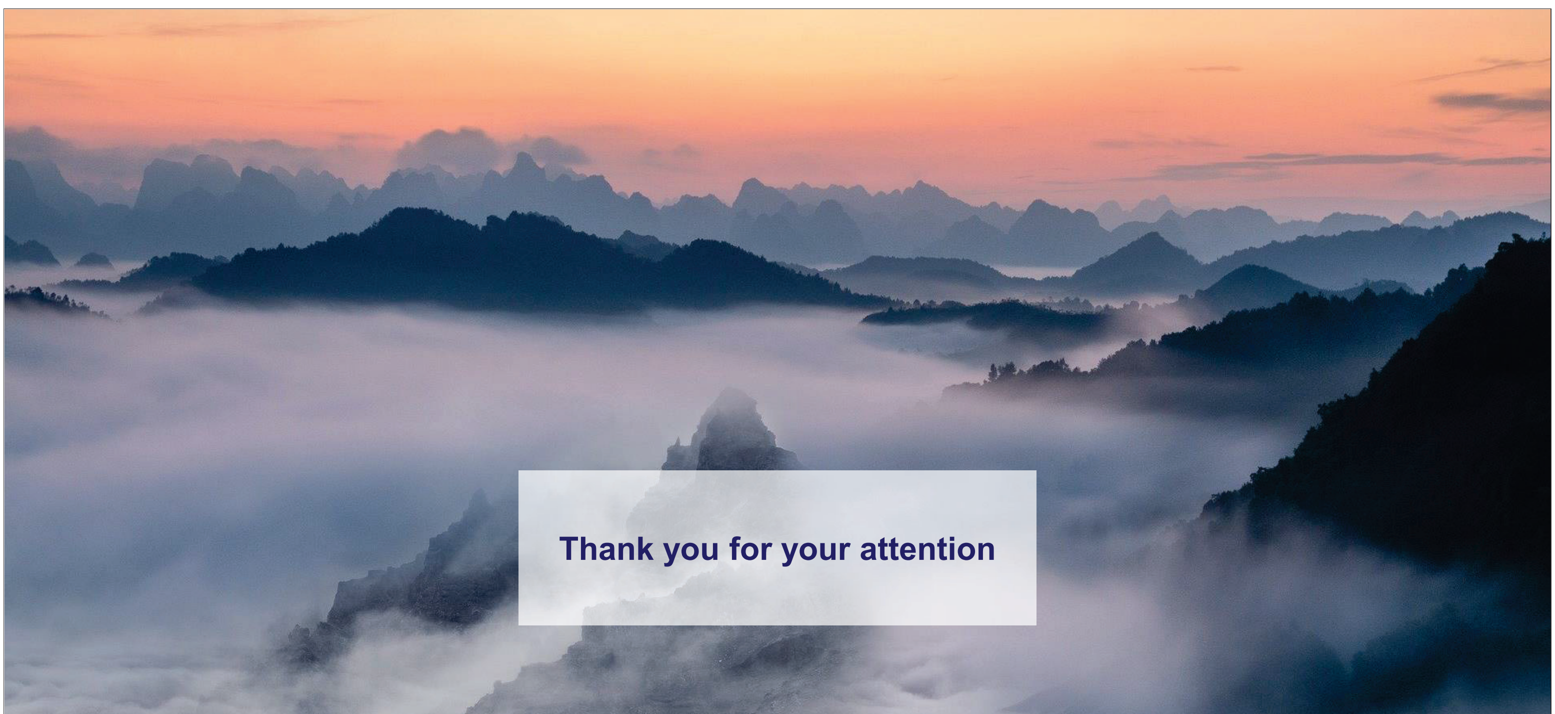

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University of Nottingham
UK | CHINA | MALAYSIA

How is building airtightness factored into the energy performance assessment of homes in the UK?

Xiaofeng (Ken) Zheng
Buildings, Energy and Environment Research Group, Faculty of Engineering, University of Nottingham, United Kingdom

AIVC & TightVent webinar Dec 2024

1

Outline

Energy impact of building airtightness

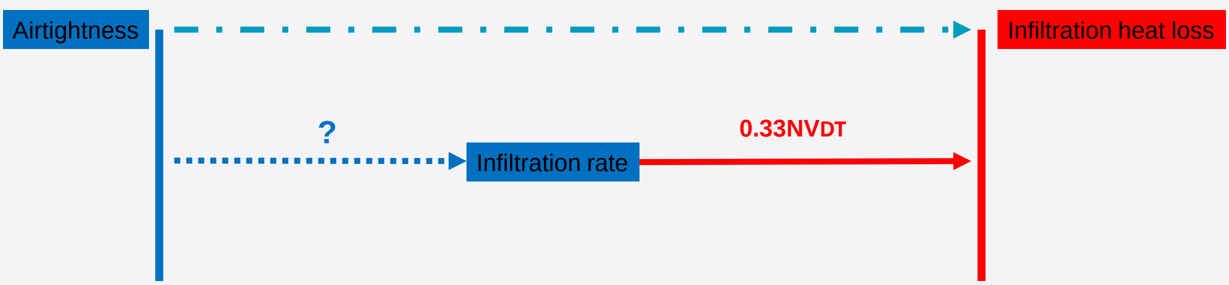
UK adaptation

Inclusion of Pulse in SAP 10.2

Space for improvement

2

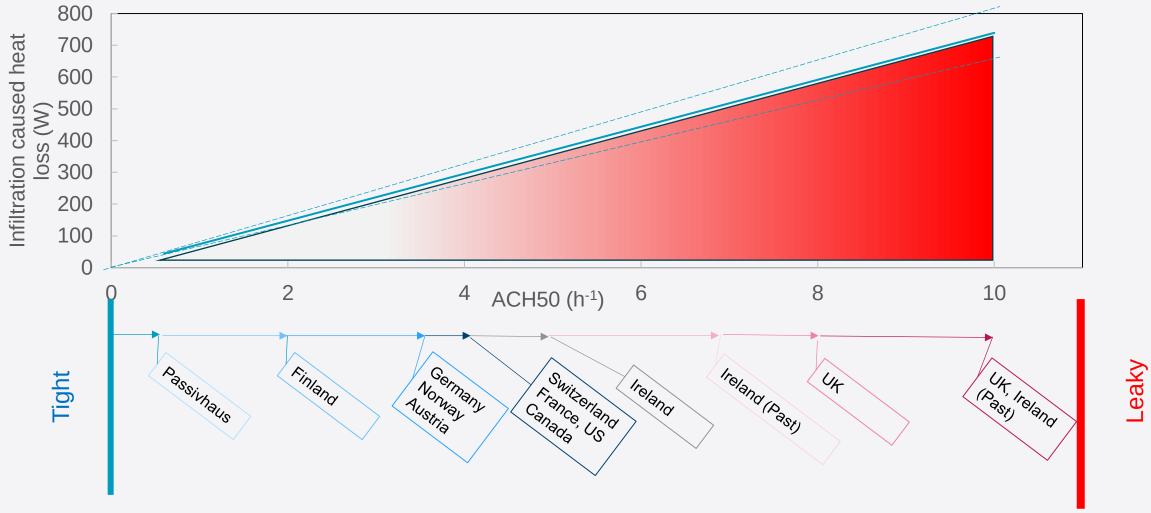
Energy impact of airtightness



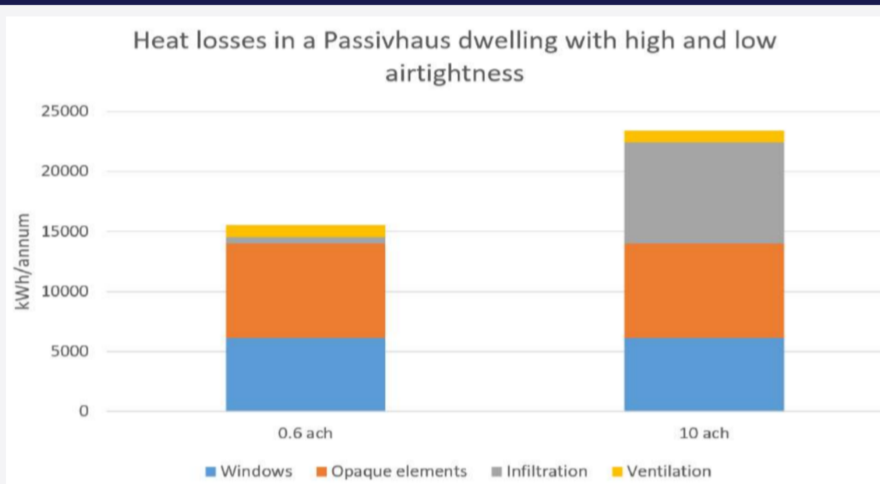
Correlation between air leakage and infiltration

Infiltration: air movement through cracks and gaps in the building thermal envelope, driven by the wind and buoyancy effect.

Energy impact of airtightness



Energy impact of airtightness



Source: Good practice guide to airtightness by Passivhaus Trust

Energy impact of airtightness

Future scenario

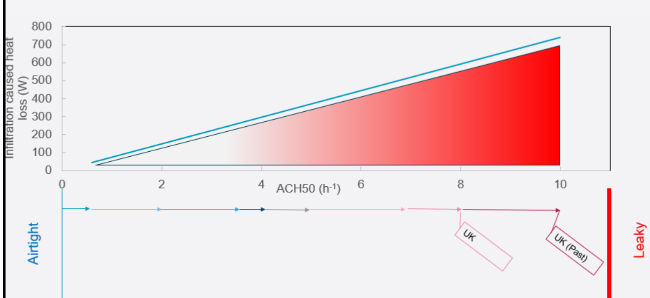
Source: Secret Bunker, New York Time, Web Urbanist

Is highly airtight and mechanical ventilated home the future?

The growing demand for low-carbon buildings highlights the need for highly airtight homes with mechanical ventilation systems in the future. However, concerns have been raised about the dependency of super-airtight buildings on the proper functioning of ventilation systems, which could pose risks under certain circumstances.[1]

[1]. D. Etheridge **A perspective on fifty years of natural ventilation research**
Building and Environment. Volume 91, September 2015, Pages 51-60

Energy impact of airtightness in the UK



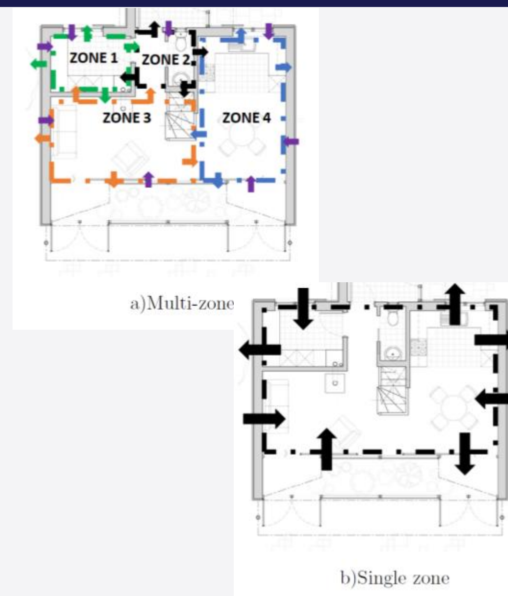
Given the fact UK building regulations are unlikely to impose highly stringent airtightness requirements in the foreseeable future. Relatively leaky homes remain prevalent, which highlights the importance of gaining a deeper understanding of the energy impact of building airtightness in the UK context.

Infiltration models

International context

Table 1 Summary of infiltration predicting models

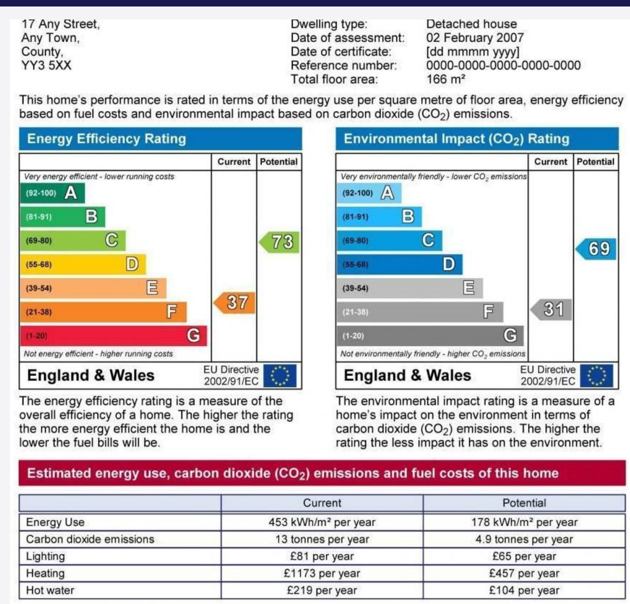
Model	Complexity	Main use	Zonal definition	Valida-tion
LBL	Simplified	Infiltration prediction	Single	Yes
AIM-2	Simplified	Infiltration prediction	Single	Yes
AIDA	Complex	Infiltration prediction	Single	
CONTAM	Complex	Pollutant transport	Multi-zone	Yes
DOMVENT3D	Complex	Stock modelling	Single	No



Standard Assessment Procedure (SAP)

SAP explained

- The calculation is based on the energy balance, taking into account a range of factors that contribute to energy efficiency:
  - materials used for construction of the dwelling
  - thermal insulation of the building fabric
  - **air leakage**, ventilation characteristics of the dwelling, and ventilation equipment
  - efficiency and control of the heating system(s)
  - solar gains through openings of the dwelling
  - the fuel used to provide space and water heating, ventilation and lighting
  - energy for space cooling, if applicable
  - renewable energy technologies


17 Any Street,
Any Town,
County,
YY3 5XX

Dwelling type: Detached house
Date of assessment: 02 February 2007
Date of certificate: [dd mmmm yyyy]
Reference number: 0000-0000-0000-0000-0000
Total floor area: 166 m²

This home's performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions.

Energy Efficiency Rating — Current: 37 (F), Potential: 73 (C). England & Wales, EU Directive 2002/91/EC.

The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills will be.

Environmental Impact (CO_2) Rating — Current: 31 (F), Potential: 69 (C). England & Wales, EU Directive 2002/91/EC.

The environmental impact rating is a measure of a home's impact on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating the less impact it has on the environment.

Estimated energy use, carbon dioxide (CO_2) emissions and fuel costs of this home

	Current	Potential
Energy Use	453 kWh/m² per year	178 kWh/m² per year
Carbon dioxide emissions	13 tonnes per year	4.9 tonnes per year
Lighting	£81 per year	£65 per year
Heating	£1173 per year	£457 per year
Hot water	£219 per year	£104 per year

UK adaptation-SAP 10.2

Consideration of airtightness in SAP 10.2

No measurement

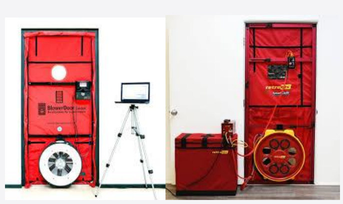
Infiltration rate
1. Additional infiltration due to storeys in the dwellings
2. Structural infiltration
3. Ground floor construction
4. Draught lobby
5. Percentage of windows and doors draught proofed

UK adaptation-SAP 10.2: Step 1 Input of airtightness

Consideration of airtightness in SAP 10.2

With a measurement

Air permeability value at 50 Pa by a fan pressurisation test	Air permeability value at 4 Pa By a low-pressure pulse test



UK adaptation

UK context @50 Pa

Divide-by-20 rule

Original Divide-by-20 rule	Adapted version in the UK
$N_{50}/20$	$Q_{50}/20$

Where, N_{50} is the building air change rate measured at 50 Pa, h^{-1}
Q_{50} is the building air permeability at 50 Pa, $m^3/h/m^2$;

UK adaptation-SAP 10.2

Step 1: Input of airtightness measurement

Air permeability value, AP_{50}, ($m^3/h/m^2$)		(17)
Air permeability value, AP_4, ($m^3/h/m^2$)		(17a)
If based on air permeability value at 50 Pa, then (18) = [(17) ÷ 20] + (8)		
If based on air permeability value at 4 Pa, then (18) = $[0.263 \times (17a)^{0.924}] + (8)$		(18)
If no air permeability test data, then (18) = (16)		
Air permeability value applies if a pressurisation test has been done, or a design or specified air permeability is being used		
Number of sides on which dwelling is sheltered		(19)
Shelter factor	(20) = 1 - [0.075 × (19)] =	(20)
Infiltration rate incorporating shelter factor	(21) = (18) × (20) =	(21)

Source: The Government's Standard Assessment Procedure for Energy Rating of Dwellings. Version 10.2

UK adaptation-SAP 10.2

Step 1: Input of airtightness (Pulse: $0.263\times(AP4)^{0.924}$)

AP50 Bin	Count	Average n	Average AP4 multiplier	AP4 Predicted Average
0-1	625	0.72	6.36	0.12
1-2	2943	0.68	5.65	0.30
2-3	18620	0.67	5.50	0.50
3-4	72584	0.66	5.46	0.69
4-5	134585	0.66	5.46	0.88
5-6	40330	0.64	5.18	1.10
6-7	14171	0.63	5.02	1.33
7-8	5286	0.63	4.94	1.55
8-9	2073	0.62	4.89	1.78
9-10	1146	0.62	4.92	2.00
10-11	248	0.61	4.79	2.24
11-12	111	0.62	4.82	2.44
12-13	69	0.62	4.95	2.65
13-14	38	0.62	4.89	2.83
14-15	24	0.62	4.89	3.04
15-16	18	0.63	4.99	3.21
16-17	13	0.62	4.97	3.55
Total	**292,884**	**0.64**	**5.16**	**1.78**

- Based on a sample of 100 UK homes
- Validation against the n exponent profile of 293k blower door tests

UK adaptation-SAP 10.2

Step 2: Shelter factor

A side of a building is sheltered if there are adjacent buildings or tree-height hedges which effectively obstruct the wind on that side of the building.

Air permeability value, AP_{50}, ($m^3/h/m^2$)		☐	(17)
Air permeability value, AP_4, ($m^3/h/m^2$)		☐	(17a)
If based on air permeability value at 50 Pa, then (18) = [(17) ÷ 20] + (8)			
If based on air permeability value at 4 Pa, then (18) = $[0.263 \times (17a)^{0.924}] + (8)$		☐	(18)
If no air permeability test data, then (18) = (16)			
Air permeability value applies if a pressurisation test has been done, or a design or specified air permeability is being used			
Number of sides on which dwelling is sheltered		☐	(19)
Shelter factor	(20) = 1 - [0.075 × (19)] =	☐	(20)
Infiltration rate incorporating shelter factor	(21) = (18) × (20) =	☐	(21)

Source: The Government's Standard Assessment Procedure for Energy Rating of Dwellings. Version 10.2

UK adaptation-SAP 10.2

Step 3: Wind factor

Infiltration rate modified for monthly wind speed:

Monthly average wind speed from Table U2

	Jan	Feb	Mar	Apr	May
$(22)_m$ =	$(22)_1$	$(22)_2$	$(22)_3$	$(22)_4$	$(22)_5$

Wind Factor $(22a)_m = (22)_m \div 4$

$(22a)_m$ =	$(22a)_1$	$(22a)_2$	$(22a)_3$	$(22a)_4$	$(22a)_5$

Adjusted infiltration rate (allowing for shelter and wind sp

$(22b)_m$ =	$(22b)_1$	$(22b)_2$	$(22b)_3$	$(22b)_4$	$(22b)_5$

Table U2: Wind speed (m/s) for calculation of infiltration rate

Region		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	**UK average**	**5.1**	**5.0**	**4.9**	**4.4**	**4.3**	**3.8**	**3.8**	**3.7**	**4.0**	**4.3**	**4.5**	**4.7**
1	Thames	4.2	4.0	4.0	3.7	3.7	3.3	3.4	3.2	3.3	3.5	3.5	3.8
2	South East England	4.8	4.5	4.4	3.9	3.9	3.6	3.7	3.5	3.7	4.0	4.1	4.4
3	Southern England	5.1	4.7	4.6	4.3	4.3	4.0	4.0	3.9	4.0	4.5	4.4	4.7
4	South West England	6.0	5.6	5.6	5.0	5.0	4.4	4.4	4.3	4.7	5.4	5.5	5.9
5	Severn Wales / Severn England	4.9	4.6	4.7	4.3	4.3	3.8	3.8	3.7	3.8	4.3	4.3	4.6
6	Midlands	4.5	4.5	4.4	3.9	3.8	3.4	3.3	3.3	3.5	3.8	3.9	4.1
7	West Pennines Wales / West Pennines England	4.8	4.7	4.6	4.2	4.1	3.7	3.7	3.7	3.7	4.2	4.3	4.5
8	North West England / South West Scotland	5.2	5.2	5.0	4.4	4.3	3.9	3.7	3.7	4.1	4.6	4.8	4.7
9	Borders Scotland / Borders England	5.2	5.2	5.0	4.4	4.1	3.8	3.5	3.5	3.9	4.2	4.6	4.7
10	North East England	5.3	5.2	5.0	4.3	4.2	3.9	3.6	3.6	4.1	4.3	4.6	4.8
11	East Pennines	5.1	5.0	4.9	4.4	4.3	3.8	3.8	3.7	4.0	4.3	4.5	4.7
12	East Anglia	4.9	4.8	4.7	4.2	4.2	3.7	3.8	3.8	4.0	4.2	4.3	4.5
13	Wales	6.5	6.2	5.9	5.2	5.1	4.7	4.5	4.5	5.0	5.7	6.0	6.0
14	West Scotland	6.2	6.2	5.9	5.2	4.9	4.7	4.3	4.3	4.9	5.4	5.7	5.4
15	East Scotland	5.7	5.8	5.7	5.0	4.8	4.6	4.1	4.1	4.7	5.0	5.2	5.0
16	North East Scotland	5.7	5.8	5.7	5.0	4.6	4.4	4.0	4.1	4.6	5.2	5.3	5.1
17	Highland	6.5	6.8	6.4	5.7	5.1	5.1	4.6	4.5	5.3	5.8	6.1	5.7
18	Western Isles	8.3	8.4	7.9	6.6	6.1	6.1	5.6	5.6	6.3	7.3	7.7	7.5
19	Orkney	7.9	8.3	7.9	7.1	6.2	6.1	5.5	5.6	6.4	7.3	7.8	7.3
20	Shetland	9.5	9.4	8.7	7.5	6.6	6.4	5.7	6.0	7.2	8.5	8.9	8.5
21	Northern Ireland	5.4	5.3	5.0	4.7	4.5	4.1	3.9	3.7	4.2	4.6	5.0	5.0

Source: The Government's Standard Assessment Procedure for Energy Rat

UK adaptation-SAP 10.2

Step 4: Effective air change rate

Effective air change rate is then determined based on the ventilation type:

- Balanced mechanical ventilation with heat recovery
- Balanced mechanical ventilation without heat recovery
- Whole house extract ventilation or positive input ventilation from outside
- Natural ventilation or whole house positive input ventilation from loft

+Chimneys, flues, fans, PSVs,

Then the infiltration heat loss is calculated using

0.33NVDT

UK adaptation-SAP 10.2

Comparison with LBL

Factors	LBL	UK-SAP
Airtightness	Yes	Yes
Wind	Yes	Yes
Temperature difference	Yes	No
Shelter factor	No	Yes
Building height	Yes	Yes
Terrain class	Yes	No
Leakage distribution	Yes (Assumption)	No

UK adaptation-SAP 10.2

Home Energy Model Consultation

	Very sheltered [City]	Sheltered [Urban]	Normal [Country with scattered windbreaks]	Exposed [Open flat country]
House: 1-storey	41.2	30.7	20.6	13.7
House: 2-storey	34.0	25.4	17.0	11.3
Flat (Storeys 1-5)	34.6	25.8	17.3	11.5
Flat (Storeys 6-10)	30.2	22.5	15.1	10.1
Flat (Storeys 11+)	29.3	19.9	13.7	9.3

Table 1 – Divisors used to convert the N50 pressure test figure into an infiltration rate

Space for improvement

When the ratio is favoured

- Divide-by-rule should be based on UK data.
- Divide-by-rule for LPP, should have its own equivalent value, rather than taking up to 50 Pa.
- Enhanced understanding of the leakage distribution of UK homes.
- Perhaps the temperature difference should be considered too.

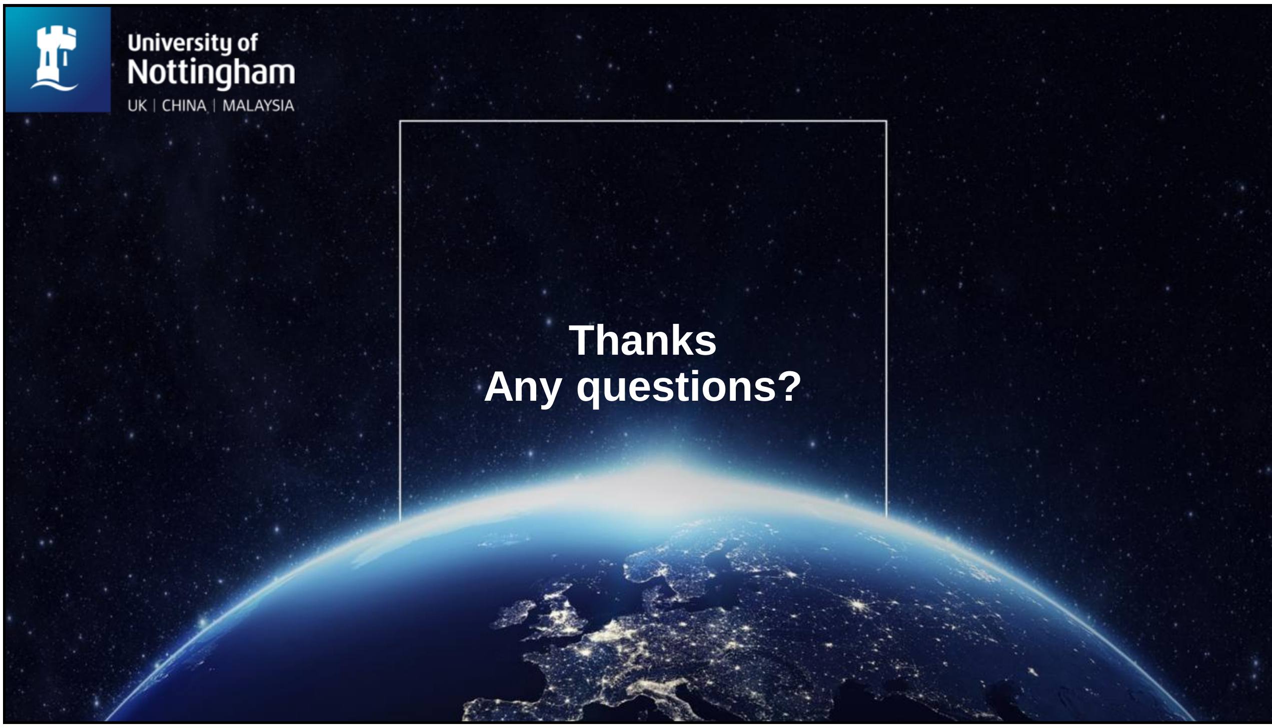
An academic perspective

- A better leakage-infiltration correlation should be considered.

UK Field Study Results

UK field study- A PhD research

- The sample of field trial test properties is representative of UK housing stock, in terms of dwelling size, form, construction, ventilation system type and air leakage levels.
- The leakage-infiltration ratio has been assessed and the initial results showed that the ratios obtained in the field test should be double of what is used in the latest SAP (10.2). i.e. Divide-by-40 for the blower door, and divide-by-8.6 for the Pulse method.
- In comparison with the simple leakage-infiltration ratio, LBL model improves the accuracy of predicting infiltration by at least a factor of two.


University of Nottingham
UK | CHINA | MALAYSIA
Thanks
Any questions?

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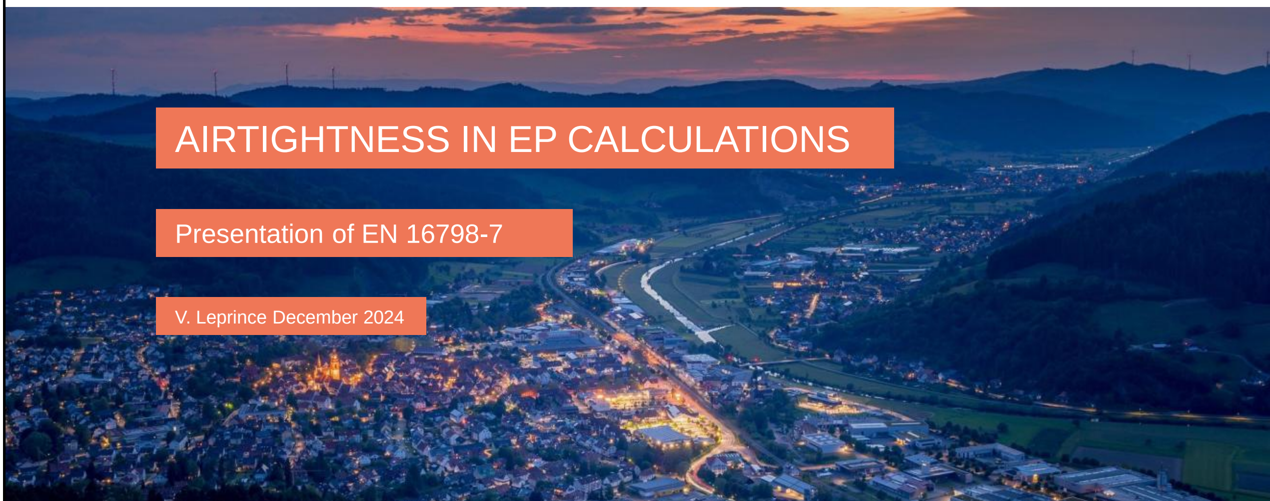

AIRTIGHTNESS IN EP CALCULATIONS

Presentation of EN 16798-7

V. Leprince December 2024

SCOPE

1 Scope

This European Standard describes the methods to calculate the ventilation air flow rates for buildings to be used for energy calculations evaluation, heating and cooling loads.

This European Standard applies to buildings with:

- Mechanical ventilation systems (mechanical exhaust, mechanical supply or balanced system);
- Passive duct ventilation systems for residential and low-rise non-residential buildings;
- Combustion appliances;
- Windows opening by manual operation;
- Kitchens where cooking is for immediate use (including restaurants)

This European Standard is applicable to hybrid systems combining mechanical and passive duct ventilation systems in residential and low-rise non-residential buildings.

This European Standard applies to buildings smaller than 100 m and rooms where vertical air temperature difference is smaller than 15 K.

The results provided by the standard are:

- the air flow rates entering or leaving a ventilation zone;
- the air flow rates required to be distributed by the mechanical ventilation system, if present.

This European Standard is not applicable to:

- Buildings with kitchens where cooking is not for immediate use
- Buildings with automatic windows (or openings)
- Buildings with industry process ventilation.

The definition of ventilation and airtightness requirements (as indoor air quality, heating and cooling, safety, fire protection…) is not covered by this standard.

The following information can be found in other standards and technical reports:

- guidance to estimate pressure drops in ducts (CR 14378:2002)

Table 1 shows the relative position of this standard within the EN EPB package of standards.

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Part of the European Energy Performance of Buildings Standards - Ventilation (EN 16798 family) (former EN 15242)

Energy performance of buildings - Ventilation for buildings - Part 7 : calculation methods for the determination of air flow rates in buildings including infiltration (Modules M5-5)

Objective of the standard:

- To calculate the air exchange rates in a building
  - To include them in the energy performance calculation.

The scope specifies the limits of the standard

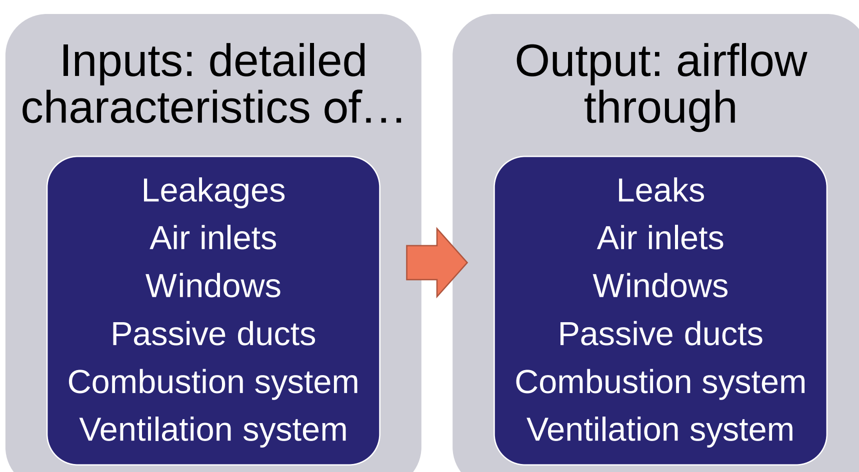
CALCULATION OF AIRFLOWS IN EN 16798-7

Two Methods Described:

- **Method 1:** Uses detailed building data for precise airflow rates (Equilibrium Pressure Model, EPM)
- **Method 2:** Simplified calculations by relying on national averages.

Countries can choose the approach based on local conditions.

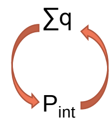
METHOD 1: MAIN INPUT AND OUTPUT



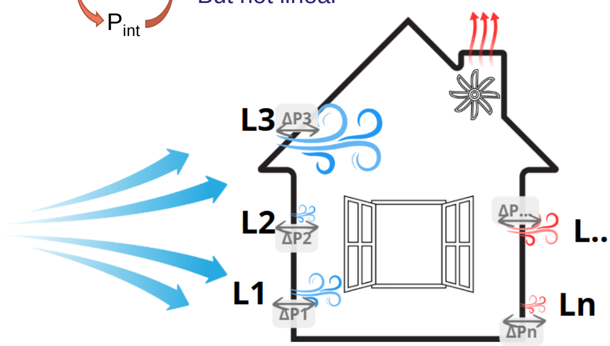
METHOD 1: THE EQUILIBRIUM PRESSURE MODEL

A dynamic method for calculating air infiltration in buildings.

- Based on a **mass balance equation** to determine pressure distribution.
- Requires inputs on:
  - Pressure distribution across the building envelope.
  - Leakage characteristics and airflow paths.



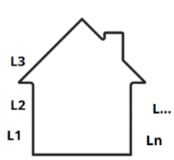
1 equation with 1 unknown variable…
But not linear



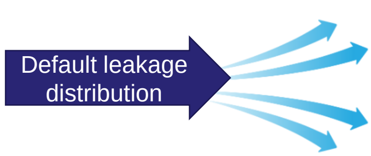
DETERMININING THE LEAKAGE DISTRIBUTION

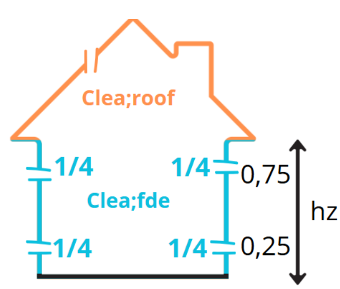
6.4.3.6.3 Envelope leakage distribution

The envelope leakage shall be distributed assuming pre-defined locations of the leakage paths: B.3.3.16 gives default values for the flow characteristics of the airflow paths for default airflow path heights and wind orientation.



$$C_{\text{lea}} = q_{V;\Delta p_{\text{lea;ref}}} \cdot \frac{A_{\text{lea}}}{\Delta p_{\text{lea;ref}}^{n_{\text{lea}}}}$$





$$C_{\text{lea;fde}} = C_{\text{lea}} \cdot \frac{A_{\text{fde}}}{A_{\text{fde}} + A_{\text{roof}}}$$

n_{50} or Q_{50} => Clea
General for the tested zone => no information on how much leakage there is and the characteristics of each

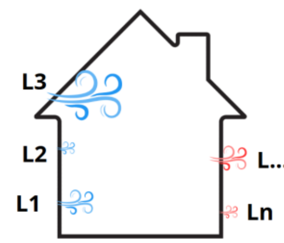
Default value for n_{lea} : 0,667

DETERMINING FLOWRATE THROUGH LEAKAGE

$$q_{V;\text{lea;path},i} = C_{\text{lea;path},i} \cdot sign\left(\Delta p_{\text{lea;path},i}\right) \cdot \left|\Delta p_{\text{lea;path},i}\right|^{n_{\text{lea}}}$$

What is the pressure difference at each leakage?

⇒Different from one leakage to another



$$\Delta p_{\text{path},i} = p_{\text{e;path},i} - p_{\text{z;path},i}$$

Wind impact

$$p_{\text{e;path},i} = \rho_{\text{a,ref}} \cdot \frac{T_{\text{e;ref}}}{T_{\text{e}}} \cdot \left(0,5 \times C_{\text{p;path},i} \cdot u_{\text{site}}^2 - h_{\text{path},i} \cdot g\right)$$

$$p_{\text{z;path},i} = p_{\text{z;ref}} - \rho_{\text{a,ref}} \cdot h_{\text{path},i} \cdot g \cdot \frac{T_{\text{e;ref}}}{T_{\text{z}}}$$

Thermal draft

?? Internal equilibrium pressure => result of the full calculation

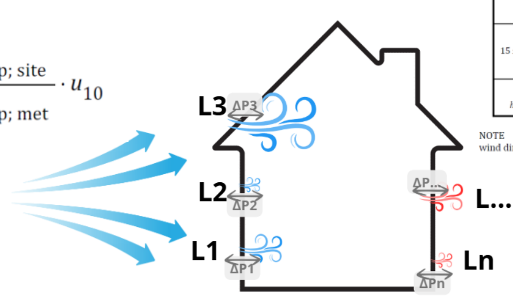
WIND IMPACT ON THE PRESSURE AT EACH LEAK

Pressure coefficient depends on:

- Its height on the facade
- The facade exposure to wind

Wind speed

$$u_{\text{site}} = \frac{C_{\text{rgh; site}} \cdot C_{\text{top; site}}}{C_{\text{rgh; met}} \cdot C_{\text{top; met}}} \cdot u_{10}$$



B.3.3.3 Pressure coefficients associated to an air flow path

Table B.7 gives C_p values for ventilation zone that can be cross-ventilated (f_{cros} = 1) depending on the height of the air flow path on the façade and its shielding class.

Table B.7 — Dimensionless wind pressures coefficients

Height of air flow path on façade	Shielding class	Dimensionless wind pressures C_p				
		Windward Cp1	Leeward Cp2	Roof (depending on slope) Cp3		
				< 10°	10°-30°	> 30°
Low h_{path} < 15 m	Open	+ 0,50	- 0,70	- 0,70	- 0,60	- 0,20
	Normal	+ 0,25	- 0,50	- 0,60	- 0,50	- 0,20
	Shielded	+ 0,05	- 0,30	- 0,50	- 0,40	- 0,20
Medium 15 ≤ h_{path} < 50 m	Open	+ 0,65	- 0,70	- 0,70	- 0,60	- 0,20
	Normal	+ 0,45	- 0,50	- 0,60	- 0,50	- 0,20
	Shielded	+ 0,25	- 0,30	- 0,50	- 0,40	- 0,20
High h_{path} ≥ 50 m	Open	+ 0,80	- 0,70	- 0,70	- 0,60	- 0,20

NOTE The wind pressure coefficients given are valid for a wind sector of approx. ± 60° to the facade axis. The wind direction is not considered more specifically.

CALCULATION OF THE EQUILIBRIUM PRESSURE

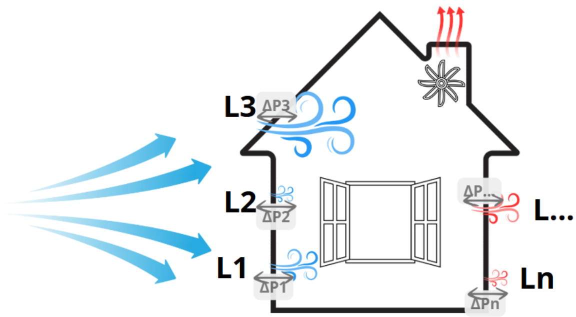
6.4.3.9 Implicit mass balance formula for determining internal reference pressure

The internal reference pressure used to calculate the air mass flow rates shall be calculated by solving the following mass balance formula:

$$q_{m;V;SUP;dis} + q_{m;V;ETA;dis} + q_{m;V;comb;in} + q_{m;V;comb;out} + q_{m;V;pdu;in} + q_{m;V;pdu;out} + q_{m;V;arg;in} + q_{m;V;arg;out} + q_{m;V;vent;in} + q_{m;V;vent;out} + q_{m;V;lea;in} + q_{m;V;lea;out} = 0 \quad (67)$$

with the internal reference pressure $p_{z;ref}$ as unknown.

The air volume or mass flow rate entering or leaving the ventilation zone through each air flow path described in 6.1 can be obtained by substituting the calculated $p_{z;ref}$ in the relevant formulae.



⇒ The impact of leakage

- ⇒ Depends on every other opening and on the ventilation system
- ⇒ Varies along the year
  - ⇒ The more wind, the more themperature difference… the more impact

WHY EPM IS MORE ACCURATE THAN SIMPLIFIED METHODS?

Provides dynamic infiltration rates, often calculated **hourly**.

Considers real-time factors like:

- Wind speed and direction.
- Indoor and outdoor temperature differences.
- Aligns with methodologies from airflow simulation tools like CONTAM.

Method used at least in France and Czech Republic

KEY BENEFITS AND CHALLENGES OF EPM

Benefits:

- Higher accuracy than simplified infiltration models.
- Matches well with measured data (e.g., tracer gas methods).

Challenges:

- Requires detailed data on building cracks and pressure distribution.
- Requires computational calculation

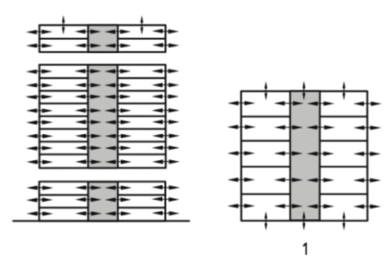
FUTUR CHALLENGE FOR EN 16798-7

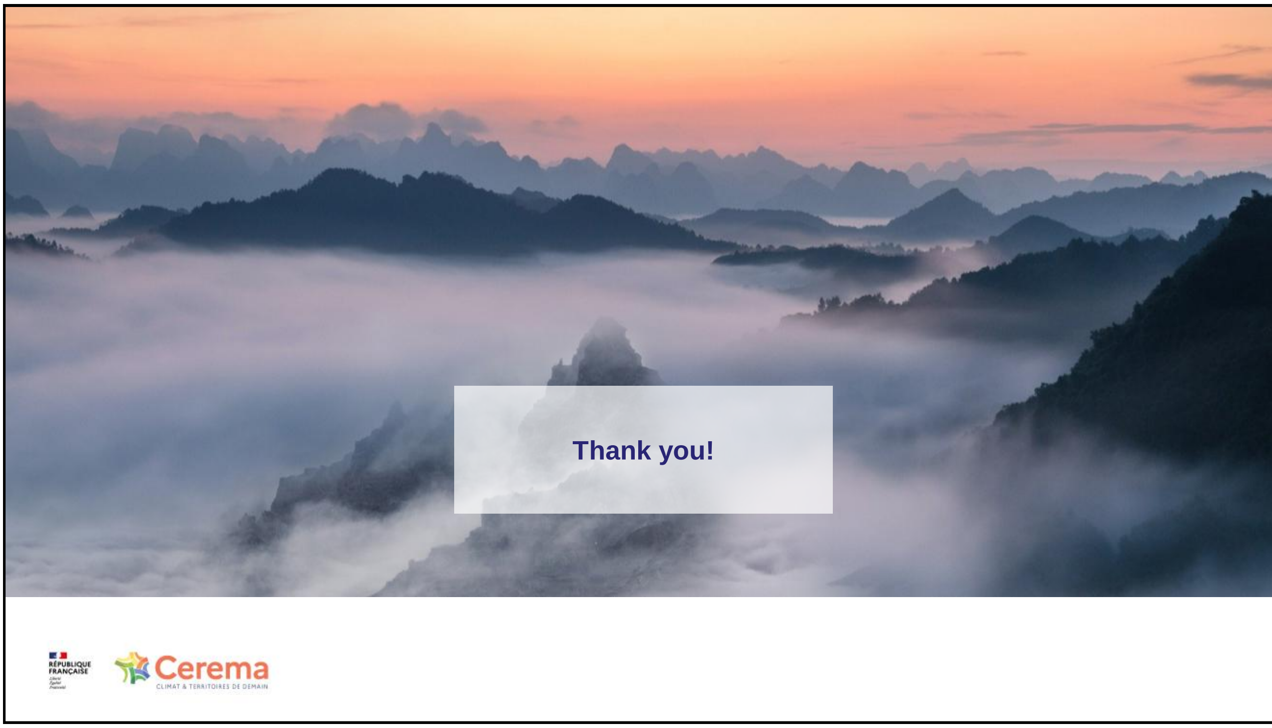
Include multizone calculation

- Huge impact on actual airflow rate crossing the envelope

Include simplified calculation both for heating and cooling seasons

- All existing equations are meant to be safe-side for heating period




Thank you!
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Building Airtightness in EP Calculation – Situation in Czech Republic

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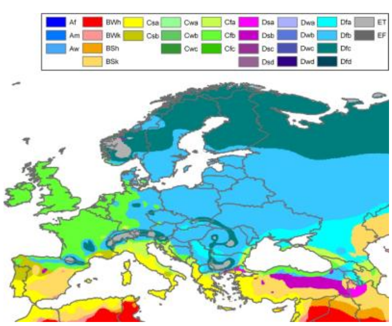
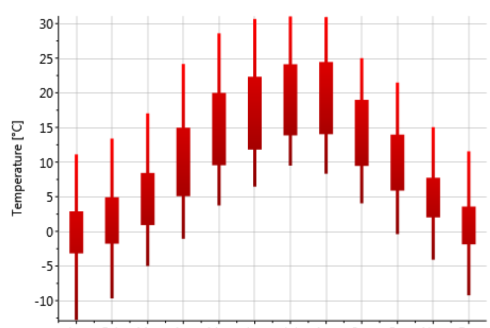
ČVUT UCEEB
ASOCIACE BLOWER DOOR_CZ

Importance of building airtightness

Climatic conditions





Impact of air leakage

- cold / mild climate
- convective air transfer

→

- excessive heat loss
- risk of interstitial condensation

Building airtightness

Requirements

- indicator: n_{50} [h^{-1}]
- limit values set in a technical standard (ČSN 730540-2)
- applicable for all of buildings, new construction, refurbishment
- proof of compliance not mandatory

Type of ventilation	$n_{50,N}$ [h^{-1}]	
	level 1	level 2
Natural	4,5	3,0
Mechanical	1,5	1,2
Mechanical with heat recovery	1,0	0,8
Mechanical with heat recovery, buildings with very low heat demand	0,6	0,4

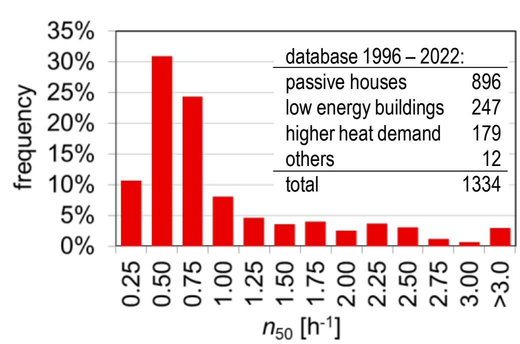
Building airtightness

Reasons for testing

- avoiding structural damage   (timber structure buildings)
- avoiding excessive heat loss (energy efficient buildings – PH)
- complying with a certification scheme (e.g. BREEAM, ADMD)
- obtaining financial support – EP programme NZÚ

Buildings tested

- exact number unknown
- no more than 15 % of new residential buildings are tested



EP – national calculation method

Legal framework

EPBD		• imposes obligation to reduce the energy consumption of buildings
	Law No. 406/2000 Coll.	• implementation of EPBD in CZ • imposes obligation to fulfil EP requirements • imposes obligation to issue EPC
	Ordinances no. 264/2020 Coll. 222/2024 Coll	• specify the EP requirements • specify the methodology for assessing the EPB • specify the content of an EPC
ČSN EN ISO 52016-1		• specifies the EP calculation method (energy needs for heating and cooling)

EP – national calculation method

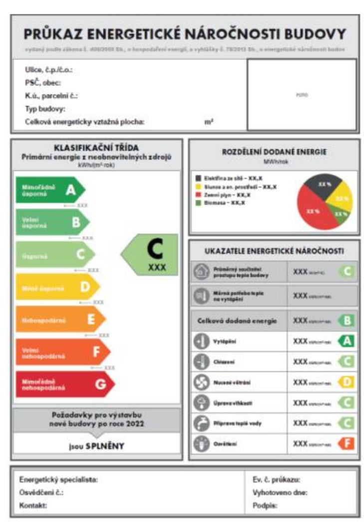
Legal framework

EPBD

Law No. 406/2000 Coll.

Ordinances no. 264/2020 Coll. 222/2024 Coll

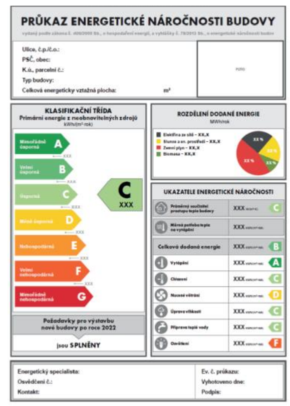
ČSN EN ISO 52016-1



EP – national calculation method

EP certificate

- until 2024:
  - issued as a part of application for building permit
  - airtightness can be only estimated



- since 2024:
  - issued at commissioning
  - measured airtightness can be set into the EP calculation

EP – national calculation method

Calculation method (energy needs)

- ČSN EN ISO 52016-1 + related EPB standards
- hourly method (monthly method still allowed)
- input values:
  - default values from Annexes of EN ISO standards
  - Ordinances no. 264/2020 Coll., 222/2024 Coll

Ventilation heat loss

- ČSN EN ISO 52016-1:

$$H_V = \rho_a \cdot c_a \cdot q_V \text{ [W/K]}$$

q_V:
- ventilation → Ord. no. 264/2020 Coll
- infiltration → ČSN EN ISO 16798-7

Implementation of ČSN EN ISO 16798-7

General settings

- estimation of infiltration flow rates only
- method 1
  - determination of air flow rates based on the detailed building characteristics
  - equilibrium pressure method – mass balance
- calculation time step – 1 hour
- input values:
  - no further guidance in legal documents
  - no National Annex

↓

  - default values according to Annex B

Implementation of ČSN EN ISO 16798-7

Calculation procedure and input values

calculation step	input values	source	software
on-site wind velocity	meteo. wind velocity u_{10}	climatic data	variable
	shielding coeffs. C_{rgh}, C_{top}	Annex B	fixed
leakage paths characteristics	building airtightness n_{50}, $q_{E,50}$	estimated	variable
	leak. coeff. and exp. C_{lea}, n_{lea}	Annex B	fixed
leakage paths distribution	distribution scheme (calculation procedure)	Annex B	fixed
wind pressure coefficients	values of C_p	Annex B	fixed

Implementation of ČSN EN ISO 16798-7

Estimation of building airtightness

- rules are not defined in the national EP calculation method (Ordinances no. 264/2020 Coll., 222/2024 Coll)
- no default values in legal or technical documents
- guidelines in technical standards:
  - limit values acc. to ČSN 73 0540-2 can be used as an assumption for EP calculation
  - guidelines for estimation of pre- and post-renovation n_{50} (TNI 73 0329)
- real airtightness – no reliable statistical data available...

Conclusion

Positive

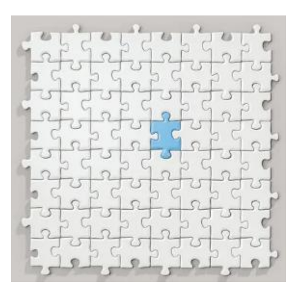
- building airtightness
- air infiltration

taken into account in EP calculation

- an advanced calculation method used (equilibrium pressure method, ČSN EN 16798-7)
- software tools include the determination of air infiltration – it cannot be avoided...

Limits and challenges

- reliable input data – still unavailable
- limited competence of EP experts
  - correct use of the calculation method...
  - reliability of results...



Thank you

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