

## Passive House measurement after 16 years

is air-tightness of the envelope still intact?

Lars Due, ISOLINK, Denmark  
20th anniversary of Blower-Door testing



## Experiences from teaching

- ISOLINK has many years of experience in teaching carpenters how to ensure an airtight building envelope.



## Experiences from teaching

- In the years of teaching, there are also products on the Danish market that are assessed as questionable
- In Denmark, there is a somewhat strange idea, that if it's cheap, it's good.
- A view I challenged years ago

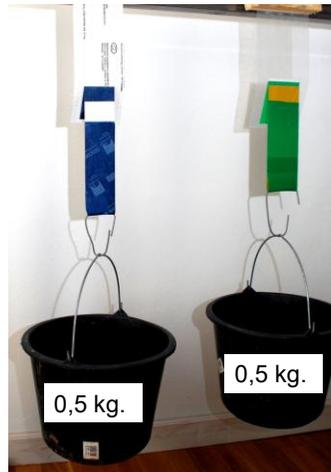


## Experie

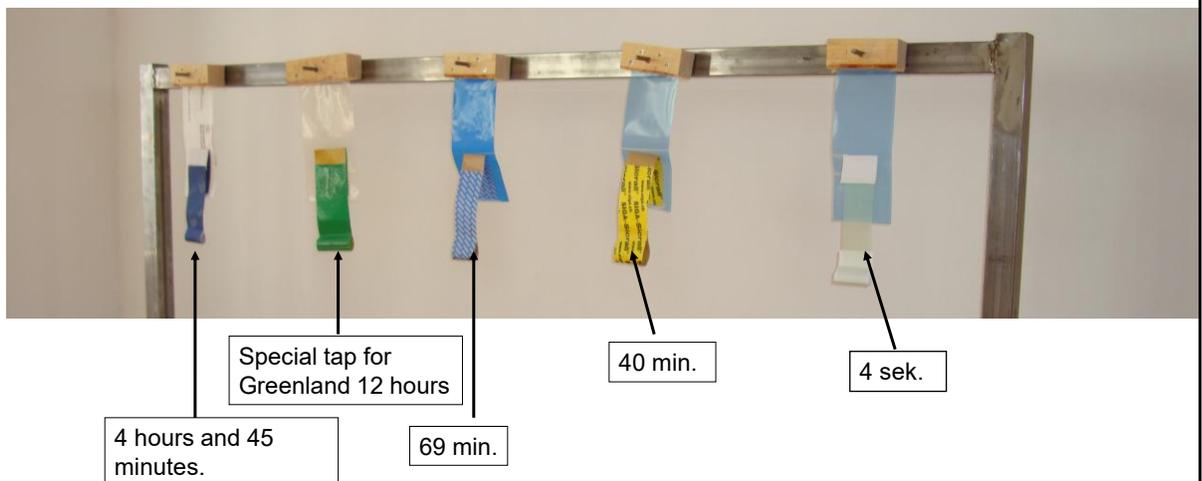


## Experiences from teaching and testing

- In the simple setup, pull with 0.5 kg in a 180 degree pull



## Experiences from teaching and testing



## Experiences from teaching and testing

- Experience from the Danish market shows an extremely large gap between the tape's ability to stick vapor barriers together.
- There is also a correlation between adhesiveness and price.



## Experiences from teaching and testing

- Examples of challenges with specific products from the Danish market
- After 2-3 years of installation, it is seen that the adhesive is apparently leaking out of the JOINT.



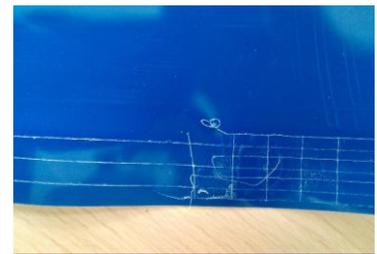
## Experiences from teaching and testing

- Examples of challenges with specific products from the Danish market
- Some of the tapes apparently have an unacceptably large back-draft.



## Experiences from teaching and testing

- Examples of challenges with specific products from the Danish market
- After 2-3 years, the tape delaminates so that the backing and adhesive are no longer connected.



## Re-testing passive house after 16 years

- In relation to the experiences with good and bad materials, it is interesting to be allowed to retest a house again after so many years.



## Re-testing passive house after 16 years

- First measurement in 2008
  - $n_{50} = 0,09$  1/h
- Second measurement in 2024
  - $n_{50} = 0,12$  1/h
- The windows were the same and it was found that they needed readjustment and new sealing strips.
- By sealing all windows and doors, the same value as measured in 2008 could be achieved



## Re-testing passive house after 16 years

- The building is built with quality materials and it is gratifying to note that if quality is prioritized, the airtightness of the envelope will also last throughout the lifetime of the building.



# Airtightness of multifamily residential buildings in Czech Republic

## Theory vs. reality

**Jiří Novák**

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## Introduction

### Single-family houses



- long experience with:
  - airtightness testing
  - airtight construction
- technical solutions exist
- good results achieved

### Residential buildings



- limited experience
- good airtightness expected
- ↓
- know-how from single-family houses
- favourable  $A_E/V$

!!!

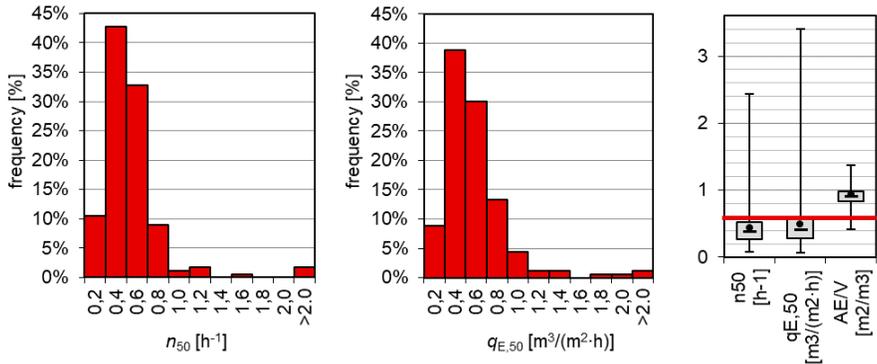
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## Reality

### Single-family passive houses

- database A.BD\_CZ
- 180 buildings
- measured between 2010 and 2024



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## Theoretical expectations...

### Building size effect

$$n_{50} = \frac{A_E}{V} \cdot q_{E50}$$



$$A_E/V = 1.0 \text{ m}^2/\text{m}^3$$

$$q_{E50} = 0.6 \text{ m}^3/(\text{h}\cdot\text{m}^2)$$

$$n_{50} = 0.6 \text{ h}^{-1}$$



$$A_E/V = 0.56 \text{ m}^2/\text{m}^3$$

$$q_{E50} = 0.6 \text{ m}^3/(\text{h}\cdot\text{m}^2)$$

$$n_{50} = 0.34 \text{ h}^{-1}$$



$$A_E/V = 0.18 \text{ m}^2/\text{m}^3$$

$$q_{E50} = 0.6 \text{ m}^3/(\text{h}\cdot\text{m}^2)$$

$$n_{50} = 0.11 \text{ h}^{-1}$$

- good airtightness in large buildings? → easy...!

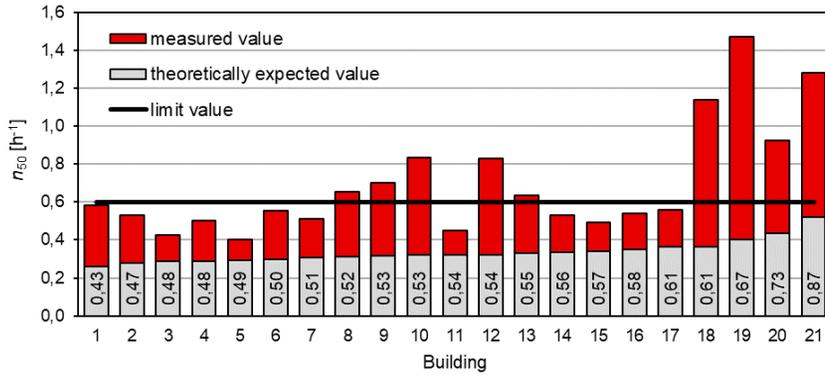
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## Reality

### Multifamily residential passive houses

- database A.BD\_CZ
- 21 buildings
- measured between 2022 and 2024

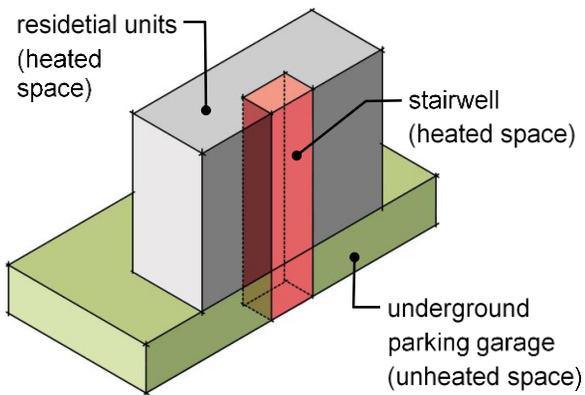


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## Reality

### Multifamily residential passive houses



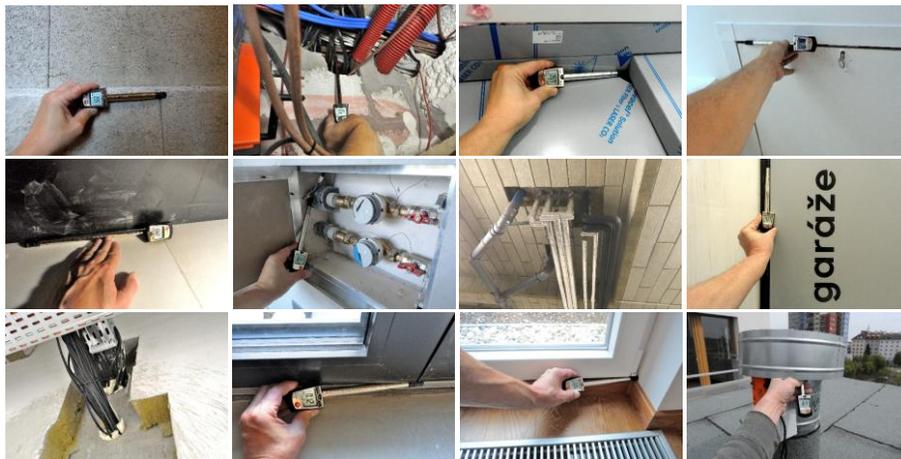
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## Leakage detection

### Method

- anemometer,  $\Delta p \approx -50$  Pa



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## Leakage detection

### Results – common areas

Leakage path detected	Loc.	Occ.
Doors to adjacent underground unheated spaces	C	11
Smoke exhaust vents in the stairwell	C	2
Ventilation equipment or opening for the elevator shaft	C	10
Penetrations of large ventilation ducts from common areas to adjacent underground unheated spaces	C	6
Service penetrations from common areas to adjacent underground unheated spaces	C	7
Service penetrations from common areas to roof	C	3
Roof access hatch	C	4
Entrance door (functional joint)	C	6
Unrendered masonry walls between common areas and adjacent unheated spaces	C	2

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## Leakage detection

### Results – residential units

Leakage path detected	Loc.	Occ.
Penetrations from installation shafts inside residential units to roof and adjacent underground unheated spaces	R	8
Junction between external wall and ceiling slab	R	2
Window-to-wall junction	R	4
Electrical boxes in external wall	R	2
Other penetrations through the internal plaster layer	R	4

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## Leakage paths - common areas

### Causes

- design proces - airtightness is not addressed
- construction proces - solutions based on experience with single-family house construction
- **leakage paths in common areas – not present in single-family houses**



Leakage path detected	Loc.	Occ.
Doors to adjacent underground unheated spaces	C	11
Smoke exhaust vents in the stairwell	C	2
Ventilation equipment or opening for the elevator shaft	C	10
Penetrations of large ventilation ducts to unheated spaces	C	6
Service penetrations to adjacent unheated spaces	C	7
Service penetrations from common areas to roof	C	3
Roof access hatch	C	4
Entrance door (functional joint)	C	6
Unrendered masonry walls to adjacent unheated spaces	C	2
Penetrations from install. shafts to roof and unheated spaces	R	8
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Other penetrations through the internal plaster layer	R	4

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## Leakage paths - common areas

### Method – reductive sealing

- 2 successive building airtightness tests:
  - with a leakage path unsealed  $q_{50,u}$  [m<sup>3</sup>/h]
  - with a leakage path sealed  $q_{50,s}$  [m<sup>3</sup>/h]
- airtightness of the leakage path  $q_{50} = q_{50,u} - q_{50,s}$  [m<sup>3</sup>/h]
- uncertainty!



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## Leakage paths - common areas

### Results

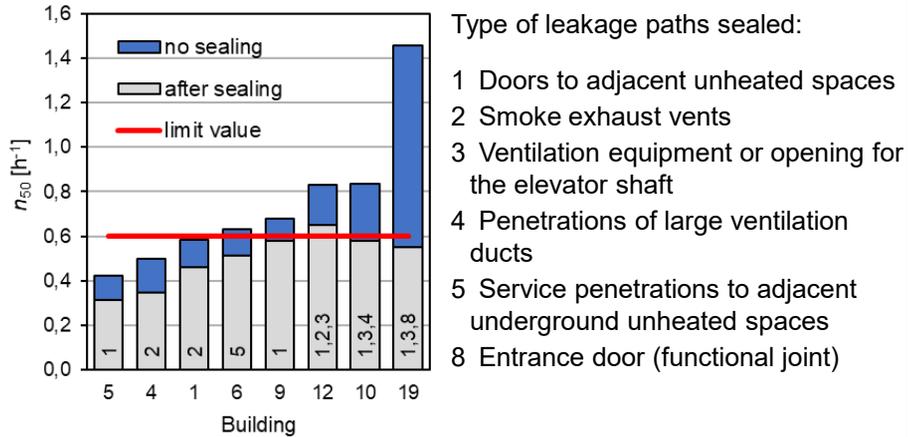
Leakage path	Air leakage rate $q_{50}$ [m <sup>3</sup> /h]
Door to adjacent underground unheated spaces	250 ±90
Smoke exhaust vent - with self-closing louvres	1 400 ±900
Smoke exhaust vent - mechanical exhaust equipment	300 ±300
Elevator shaft ventilation system - mechanical exhaust equipment	200 ±200
Elevator shaft ventilation system – simple ductwork (natural ventilation)	600 ±200
Penetration of large ventilation ducts from common areas to adjacent underground unheated spaces	700 ±200
Service penetration from common areas to adjacent underground unheated spaces	500 ±300

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## Leakage paths - common areas

### Contribution to the total air leakage



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## Conclusions

### A lesson learned

- identified issues could have been resolved in design phase
- different building types → different airtightness issues !
- proven solutions from one building typology cannot be directly applied to another without critical adaptation !!!

### Progress needed

- improved technical solutions (details elements, equipment)
- raising awareness (designers)
- design methods, guidelines, tools
- identification of potential risks → airtightness strategy (airtightness concept)
- requirements on airtightness-related information in the building design documentation

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**Thank you for your attention**

**Questions?**

**Jiří Novák**

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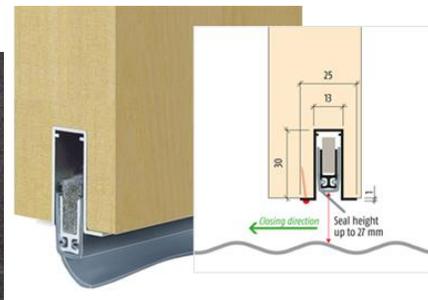


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## Leakage paths - common areas

### Doors to adjacent underground unheated spaces

- $q_{50} = 250 \pm 90 \text{ m}^3/\text{h}$



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## Leakage paths - common areas

### Smoke exhaust vents - with self-closing louvres

- $q_{50} = 1\,400 \pm 900 \text{ m}^3/\text{h}$



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## Leakage paths - common areas

### Smoke exhaust vents - mechanical exhaust equip.

- $q_{50} = 300 \pm 300 \text{ m}^3/\text{h}$



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## Leakage paths - common areas

### Elevator shaft ventilation - mechanical exhaust

- $q_{50} = 200 \pm 200 \text{ m}^3/\text{h}$



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## Leakage paths - common areas

### Elevator shaft ventilation – simple ductwork

- $q_{50} = 600 \pm 200 \text{ m}^3/\text{h}$



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## Leakage paths - $q_{50}$ estimation

### Penetrations – large rectangular ducts

- $q_{50} = 700 \pm 200 \text{ m}^3/\text{h}$



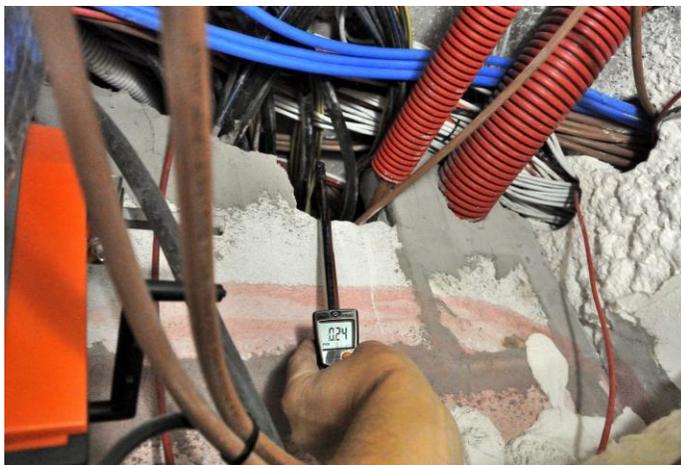
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## Leakage paths - common areas

### Penetrations – service penetrations

- $q_{50} = 500 \pm 300 \text{ m}^3/\text{h}$



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# Acoustic Leak Detection in Building Envelopes – Laboratory and Field Tests

Airtightness in Practice: Long-Term Performance, Field Evidence, and Innovative Detection Methods

Markus Diel, German Aerospace Center (DLR), markus.diel@dlr.de



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## Introduction

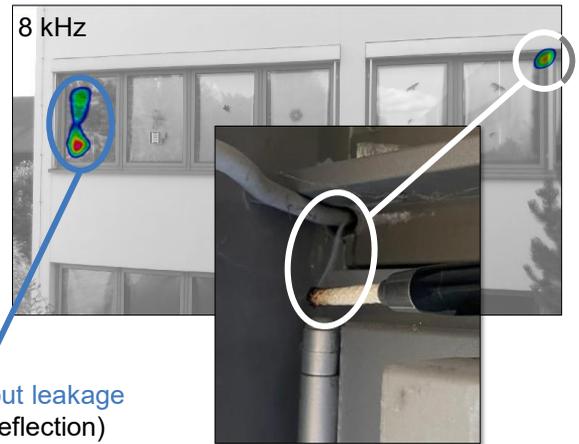
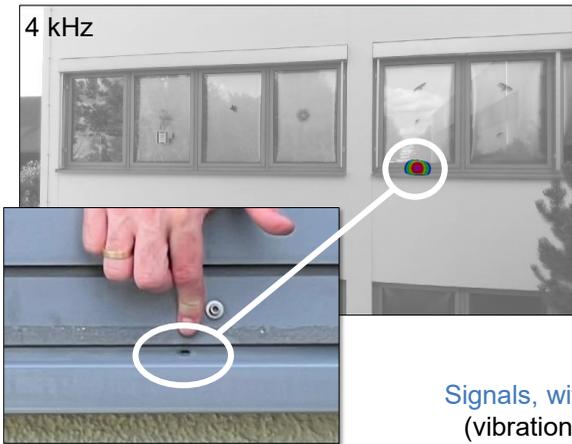
- **Leak detection: Why acoustic?**
  - Sound propagates through air leaks
  - Scanning applications in the construction industry
  - Source localization using an acoustic camera
- **Possible advantages**
  - No  $\Delta p$  or  $\Delta T$  required
  - Large areas can be tested / no manual search
  - → Time savings
- **Promising field tests**
  - Details in presentation [1] and paper [2]



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2

# Introduction



Signals, without leakage  
(vibration / reflection)

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# Laboratory: Airtight test facility ATLAS

Dimensions:  
(2 x 2,5 x 3) m<sup>3</sup>  
Residual leakage:  
q<sub>50</sub>=0.1 m<sup>3</sup>/h

Exchangeable  
test specimens

Measuring fan



Acoustic camera

IR camera

Loudspeaker

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# Laboratory: Soundproofing of ATLAS

Outside:



Inside:  
Before soundproofing



Inside:  
After soundproofing

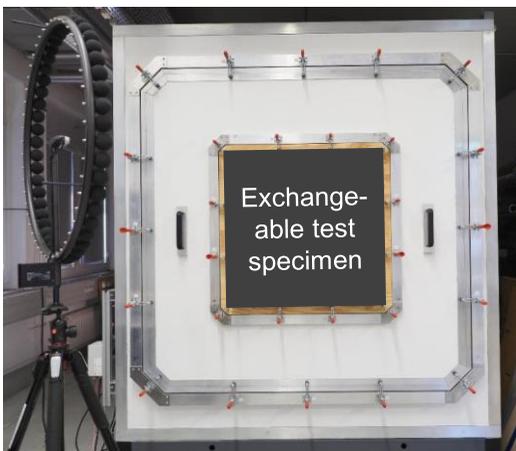


→ Significantly higher sensitivity & better results

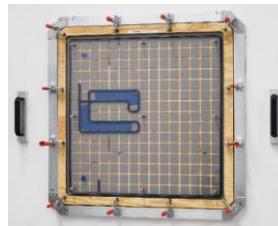
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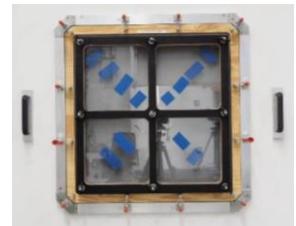
# Exchangeable test specimens



Labyrinth system



Sandwich system

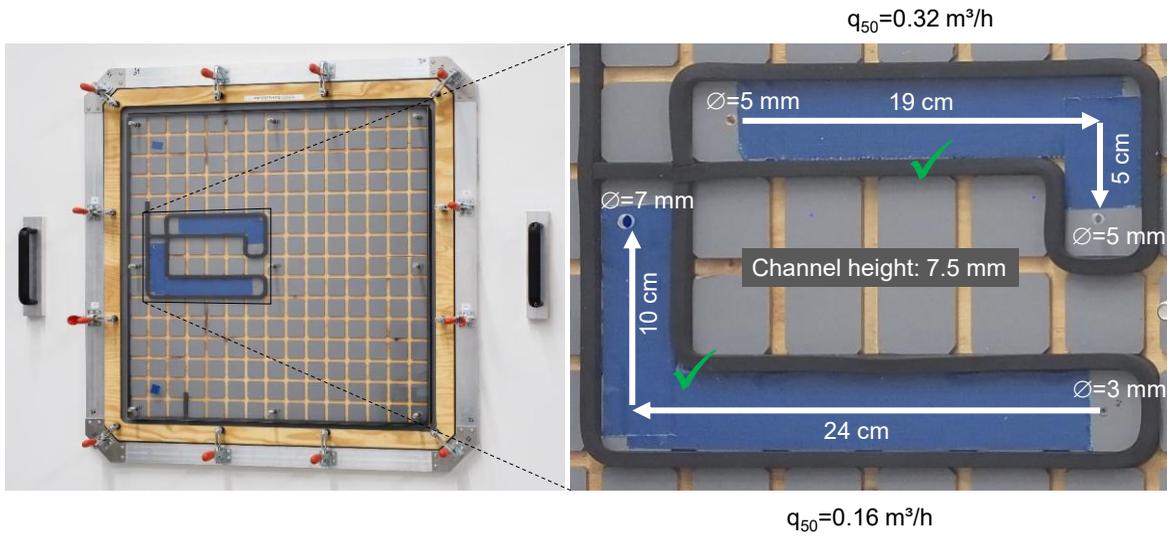


Detailed explanation of test specimens in [3]

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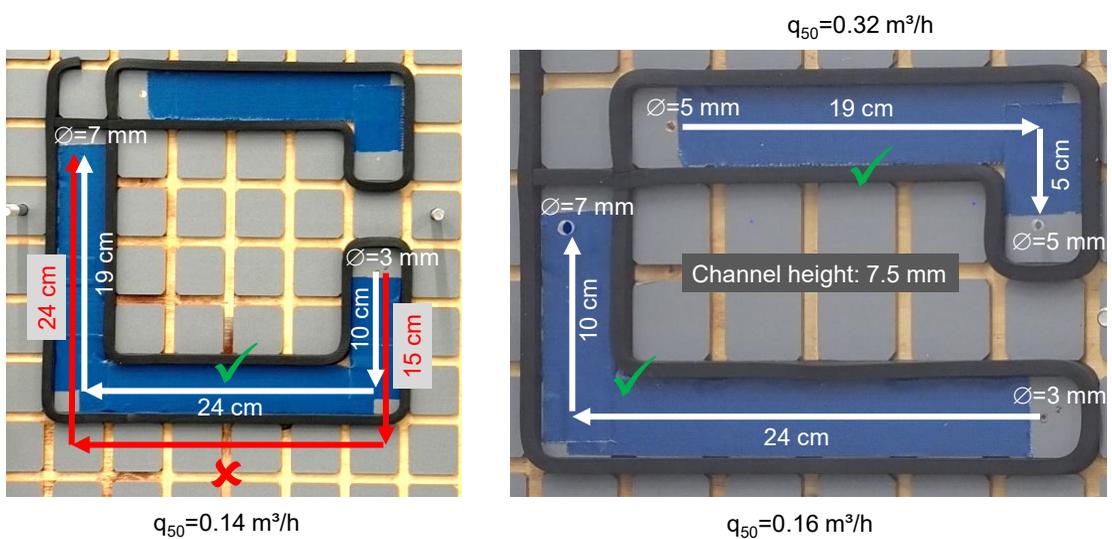
# Results Labyrinth system



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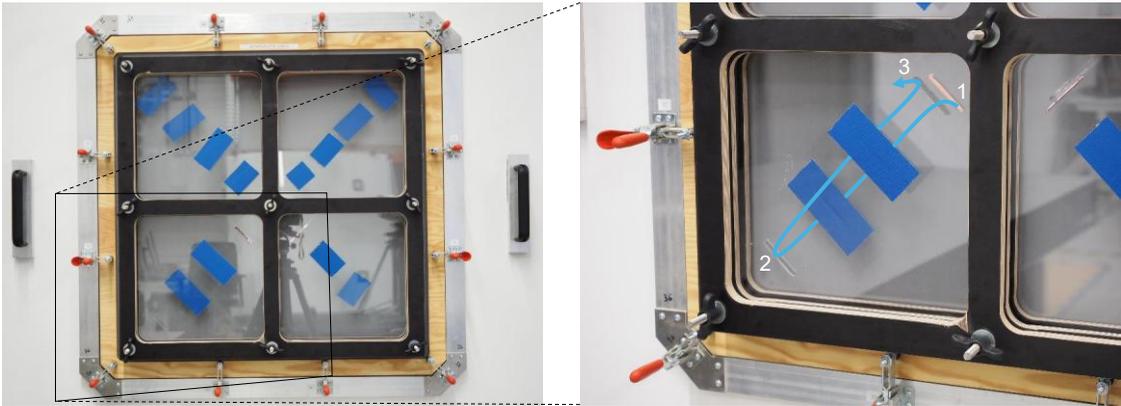
# Results Labyrinth system



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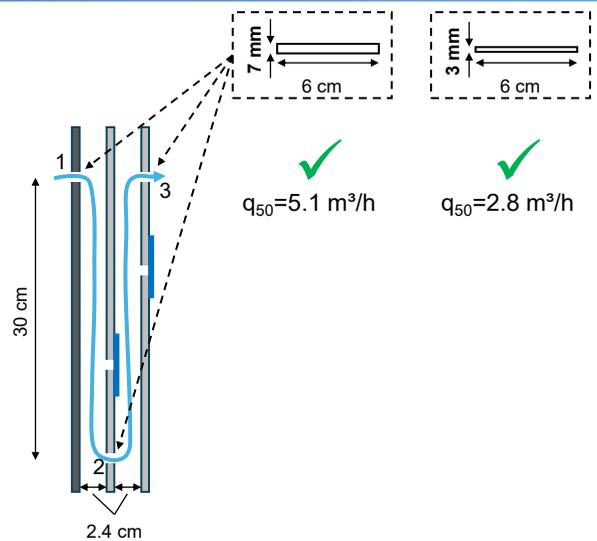
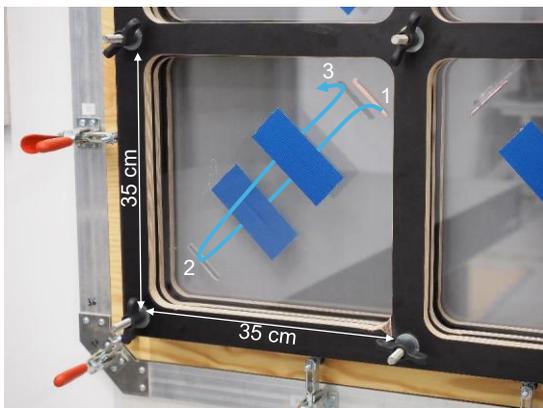
# Results Sandwich system (multilayered)



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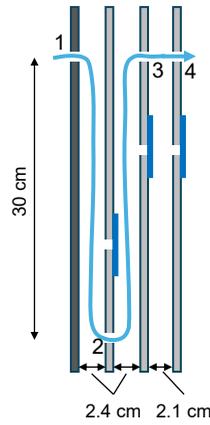
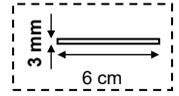
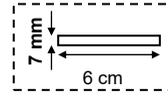
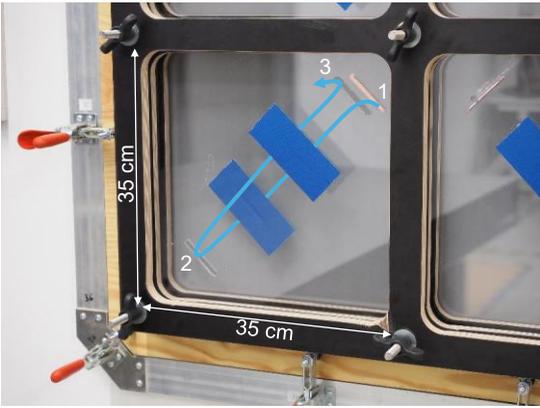
# Results Sandwich system (multilayered)



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# Results Sandwich system (multilayered)



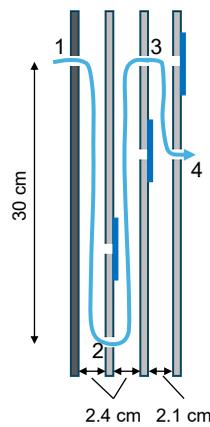
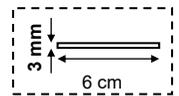
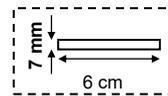
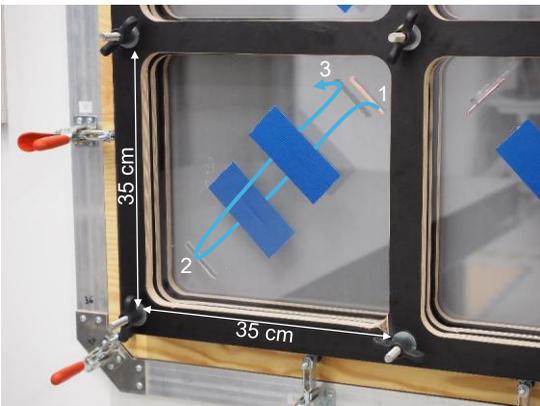
✓  
 $q_{50}=4.8 \text{ m}^3/\text{h}$

✗  
 $q_{50}=2.5 \text{ m}^3/\text{h}$

7

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# Results Sandwich system (multilayered)



✓  
 $q_{50}=4.8 \text{ m}^3/\text{h}$

✗  
 $q_{50}=2.5 \text{ m}^3/\text{h}$

✗  
 $q_{50}=4.5 \text{ m}^3/\text{h}$

7

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## Field tests: Speaker setup



Ultrasonic  
spherical transmitter  
40 kHz

Low-frequency dodecahedron  
white noise  
90 Hz to 9 kHz

High-frequency  
linear frequency sweep  
10 – 22 kHz



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## Field test example: Attic



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# Field test example: Attic

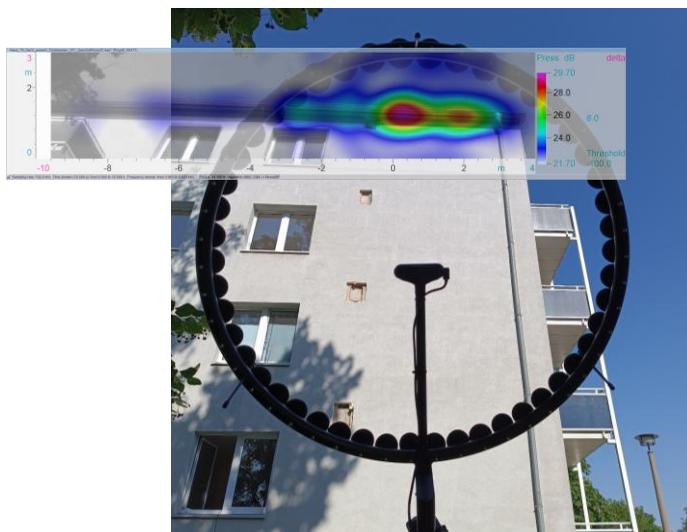


Low-frequency  
dodecahedron  
4 – 9 kHz

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# Field test example: Attic

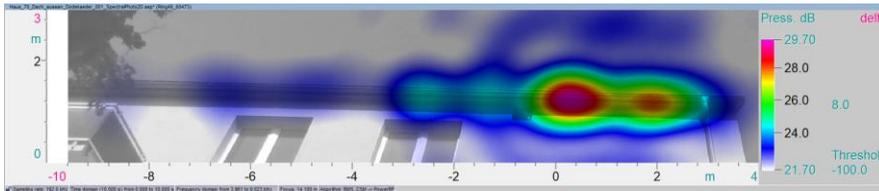


Low-frequency  
dodecahedron  
4 – 9 kHz

9

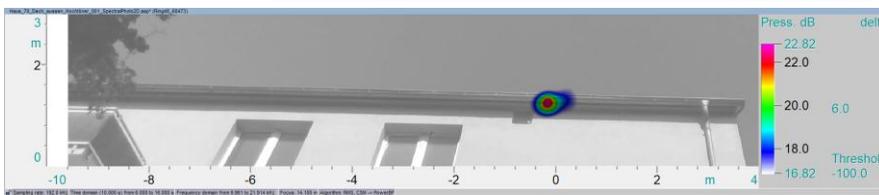
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# Field test: Speaker frequency



Low-frequency dodecahedron  
4 – 9 kHz

→ Results depend on speaker frequency

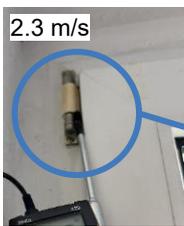


High-frequency tweeter  
10 – 22 kHz

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17

# Field test example: Window



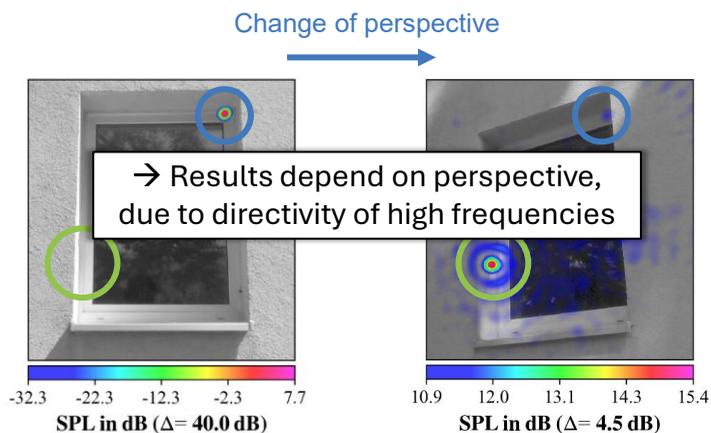
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# Field test: Directivity & Perspective



High-frequency  
tweeter  
10 – 22 kHz



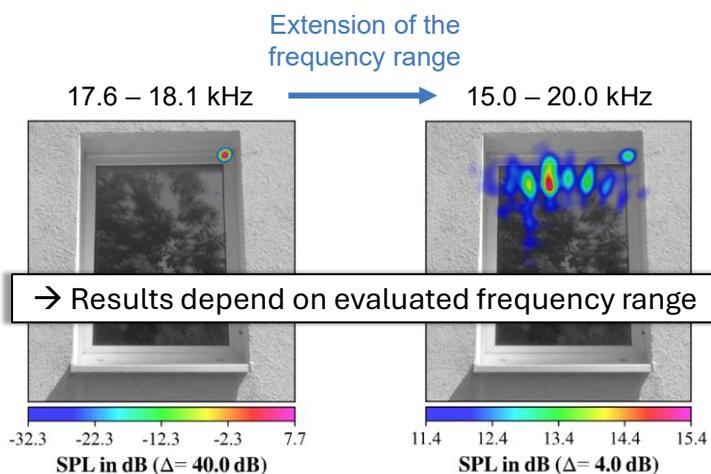
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# Field test: Evaluated frequency range



High-frequency  
tweeter  
10 – 22 kHz

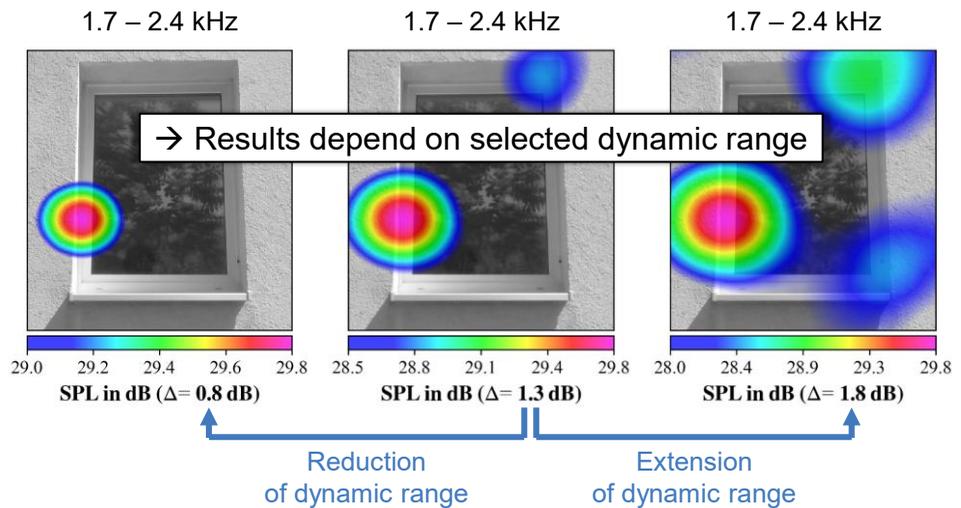


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## Field test: Selected dynamic range


  
 Low-frequency dodecahedron  
 90 Hz – 9 kHz

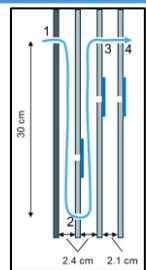


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## Conclusion & Outlook

- Leakages with complex paths are detectable
  - Including small holes, several bends, cavities and multilayered paths
- Successful trials on real buildings
  - Large areas, distances of 15 m
  - Evaluation and interpretation require experience
- Promising method for reliable and efficient leak localization
  - No pressurization needed, no manual search for leaks
- Currently investigating
  - Suppress interference signals
  - Increase automation in evaluation process
  - Combination of acoustic and thermographic methods



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# Acknowledgments

## Co-authors and contributions:

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– German Aerospace Center (DLR)
- **Alexander Jahnke** and **Michael Markus Ackermann**  
– Society for the Advancement of Applied Computer Science (GFal, Germany)

## Funding:

- **German Federal Ministry for Economic Affairs and Energy**,  
grant number 03EN1079

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- [1] Schiricke, B., & Kölsch, B. (2023). Acoustic method for measurement of airtightness – field testing on three different existing office buildings in Germany. 43rd AIVC – Copenhagen, Denmark, 4–5 October 2023. Presentations file, pages 131–141. [https://aivc.org/sites/default/files/AIVC2023\\_Presentations.pdf](https://aivc.org/sites/default/files/AIVC2023_Presentations.pdf)
- [2] Schiricke, B., Diel, M., & Kölsch, B. (2024). Field Testing of an Acoustic Method for Locating Air Leakages in Building Envelopes. *Buildings*, 14(4), 1159. <https://doi.org/10.3390/buildings14041159>
- [3] Diel, M., Schiricke, B., & Pernpeintner, J. (2024). Test facility for building envelope leakage type analysis and improvement of acoustic and thermographic airtightness measurement methods. 44th AIVC – Dublin, Ireland, 9–10 October 2024, Presentations file, pages 147–163. [https://aivc.org/sites/default/files/AIVC2024\\_Presentations.pdf](https://aivc.org/sites/default/files/AIVC2024_Presentations.pdf)

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Questions?

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## Updates on Building Airtightness in Germany

Fachverband Luftdichtheit im Bauwesen e.V.  
(Airtightness in buildings association)

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solcher@flib.de  
www.flib.de, www.luftdicht.info



1

### Building Energy Act

#### § 13 tightness

A building is to be erected in such a way that the heat-transferring surface including the joints **is permanently sealed airtight in accordance with the recognized rules of technology.**

#### § 26 Testing the tightness of a building

If the airtightness of a building to be constructed **is tested** before its completion **in accordance with DIN EN ISO 9972: 2018-12 Annex NA, the measured net air exchange rate may be used when determining the annual primary energy demand** in accordance with Section 20 (1) or (2) and in accordance with Section 21 Paragraphs 1 and 2 in accordance with Paragraphs 2 to 5 as the air exchange rate.

**No requirements regarding airtightness for refurbishments**

internal volume  
 $\leq 1.500 \text{ m}^3$

without  
mechanical  
ventilation

$$n_{L50} \leq 3.0 \text{ 1/h}$$

with  
mechanical  
ventilation

$$n_{L50} \leq 1.5 \text{ 1/h}$$

internal volume  
 $> 1.500 \text{ m}^3$

without  
mechanical  
ventilation

$$q_{E50} \leq 4.5 \text{ m}^3/(\text{h m}^2)$$

with  
mechanical  
ventilation

$$q_{E50} \leq 2.5 \text{ m}^3/(\text{h m}^2)$$

2

### Federal funding for efficient buildings

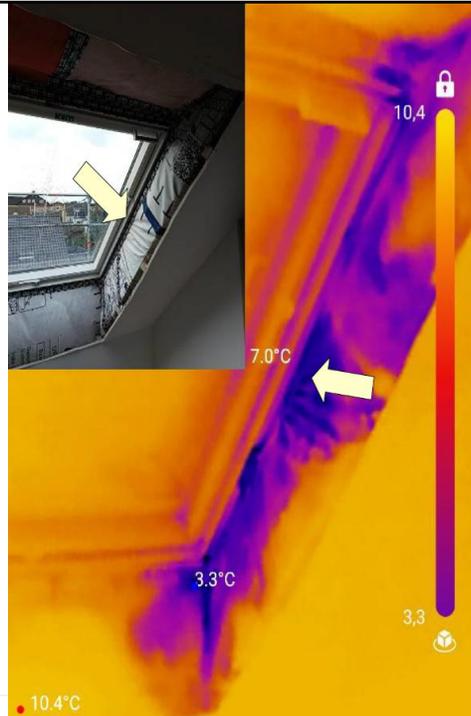
#### no mandatory air tightness test

**mandatory only** if test is used for reduction of airing heat loss in **EP-calculation** and with **EE-Class funding** (renewal energy)

At residential and non-residential buildings, attention must be paid to an **airtight design with reduced thermal bridges for all measures.**

Energy consultant must give an **air tightness concept**

**Evidence** for the thermal bridge-reduced and **airtight execution**



### Coalition agreement of government 2025

#### Energy-efficient construction and refurbishment

**We will continue to promote energy-efficient construction and refurbishment as a key contribution to the energy transition** and want to ensure that high-quality, energy-saving housing remains affordable for everyone. The economic efficiency requirement, openness to technology and the renunciation of forced refurbishment remain fixed cornerstones of the energy concept.

**We will not tighten the current regulatory requirements and will evaluate their effects.**

**We will continue to support new technologies for even greater energy efficiency in buildings** and for increasing the generation and use of renewable energies in the building sector. **We will continue and bundle state funding for energy counselling in the building sector.**



Ergebnis Vor Ab Prüfung (1 Punkt Messung)  
nL<sub>50 1Punkt</sub> ≈ 13 1/h

Ergebnis Abschlussmessung  
nL<sub>50</sub> = 2,2 1/h  
Verbesserung um 83 %

## DIN 4108-7:2026-04 Airtightness of buildings

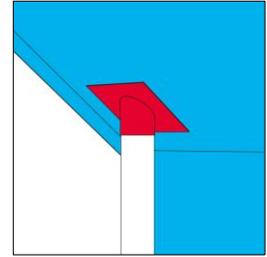
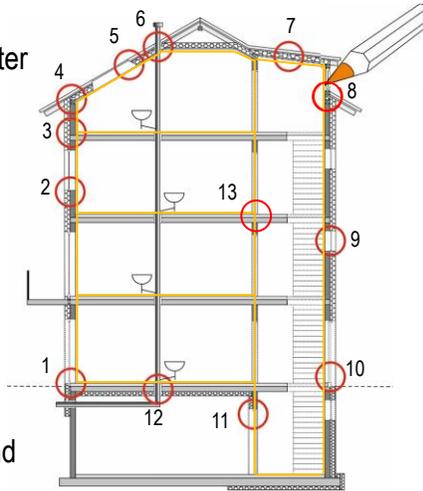
Publication April 2026

**Airtightness concept** as new chapter

- Location of **air tightness layer**
- Rough description of the **connections**
- **materials** of air tightness layer
- planned **quality assurance measures**

**Quotable air tightness concept**

Standard gives **further information** on airtight materials, connections and examples for airtight design and execution



The plumbing pipe is connected to the airtight layer (membrane, sheet material, etc.).

A gap of about one hand's width is left between the pipe and adjacent walls or structural elements.

A smooth-walled pipe is used in the penetration area.

Figure 4 — Example of a rough description of the airtight design of connection detail 6 from Figure 2

5

## WTA Guidelines have been published 2026-01

**Airtightness of (existing) buildings –**

6-9: General principles of planning

6-10: Detailed planning and execution

6-11: Measuring procedure

- Measuring time 1: **Before the refurbishment** - as-built analysis
- Measuring time 2: **During the refurbishment** - execution check
- Measuring time 3: **After the refurbishment** - final measurement



6

### Goals of the FLiB

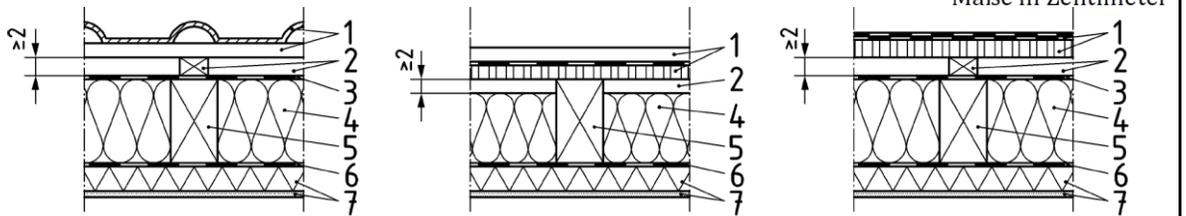
Support of **air tightness testers, planners and craftsmen**

Main focus is currently the **roof refurbishment**

- good example for **trades interface**
- airtightness is **obligatory**
- Airtightness test during construction as **quality measure**



### Workshop to roof refurbishment



## Workshop to roof refurbishment

Energy consultants  
are responsible for the air  
tightness concept

Craftsmen  
are responsible for the  
building connection

**Who plans the building  
connection?**



## What must happen?

**Air tightness measurement during construction must get mandatory**

### Goals

Identify and easily seal existing  
leaks

Has the airtight connection to  
neighbouring trades been made?

Leaks can be detected and  
visualised using the test pressure.

Leaks can be repaired  
immediately

<p><b>Fensteranschluss</b> „Am oberen und unteren Abschluss von der Blende des Fensters im Bereich der Emporen in Kind 1 und 2 kam es zu Einströmungen.“</p>		<p><b>Durchdringungen</b> „Anschluss mit dem Klebeband im Bereich der Kabeldurchführung ist undicht.“</p>	
<p><b>Fensteranschluss</b> „In den unteren Fenster-Eckbereichen konnten Einströmungen nachgewiesen werden: am Abschluss vom Kompriband bzw. an der Proflluft.“</p>		<p><b>Durchdringungen</b> „Luftdurchgang über Wanddurchbruch zum angrenzenden Technikkur (Luftverbund vorhanden) Schließen der Wandöffnung erforderlich (z.B. Kabelschott)“</p>	
<p><b>Fensteranschluss</b> „Anschlüsse Rahmen-Wand mittels Kompriband An zahlreichen Stellen gab es direkte Fehlstellen an der Abdichtung mittels des eingesetzten Kompribandes, wie hier im Eckanschluss.“</p>		<p><b>Dachflächenfenster</b> „Anschluss umlaufend – gelöste Abklebung“</p>	

**Research report on leaks:** [https://www.flib.de/publikationen/12\\_forschungsbericht/FLiB\\_Forschungsbericht\\_2016.pdf](https://www.flib.de/publikationen/12_forschungsbericht/FLiB_Forschungsbericht_2016.pdf)



**Dicht + Gut**

**Thank you for the attention**

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**FLiB-Workshop:**  
**„Wie die Dach-  
modernisierung gelingt“**

**Qualitätssicherung als Bindeglied zwischen  
Planung, Beratung und Ausführung**

**45127 Essen**  
**Donnerstag, 23. April 2026**  
Haus der Technik

