Air tightness of structural elements and internal air leakages in a multi-apartment building

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Economical Decision-making in Suburban Renovation Projects *(EVAKO)*

Initiated by the **TUT Building Production and Economics Unit**

•Expedient, energy efficient and economical renovations in the suburbia

•An experimental renovation venture in a quarter of tenement buildings

•Comfort and habitability of an individual apartment
⇨ a survey of the current problems
⇨ Infiltration of smells and noises from the neighbouring apartments

Need to examine the air tightness between the apartments + the proportions of leakage in the different structural elements

METHOD

The fan pressurization method: air permeability of the building envelope (SFS-EN 13829)

Limitation: the proportions of leakage is not recognized

⇨ A series of measurements in order to eliminate potential air leak sources one by one and thus determine their share of the total air leakage

The main target: internal air tightness, (the air tightness of the structural elements separating the apartments)

In addition: the leakage proportions of the different elements of the building envelope

MEASURING PRINCIPLES

A set of pressurization tests in an apartment: between tests different structural elements are sealed, so that

- in the beginning air flows through all the elements
- in the end air flows through only the outer building envelope

2 series of measurements:

- equipment mounting point at the apartment's staircase door
- equipment mounting point at the balcony door

Tests performed according to the standard SFS-EN 13829

- a series of different pressures (i. e. 10 … 60 Pa by steps of 10 Pa)
- both pressurization and depressurization methods

Result: the air change rate n_{50} to represent air tightness

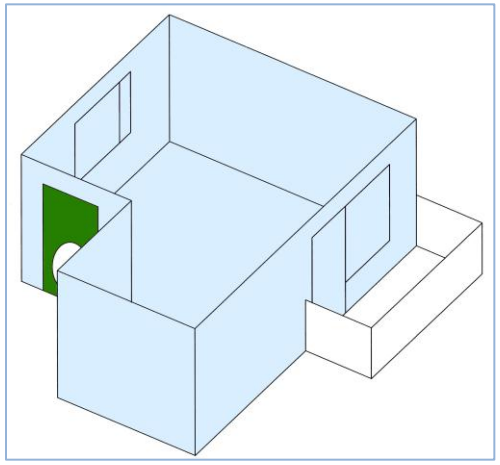
1st stage: extensive set of measurements

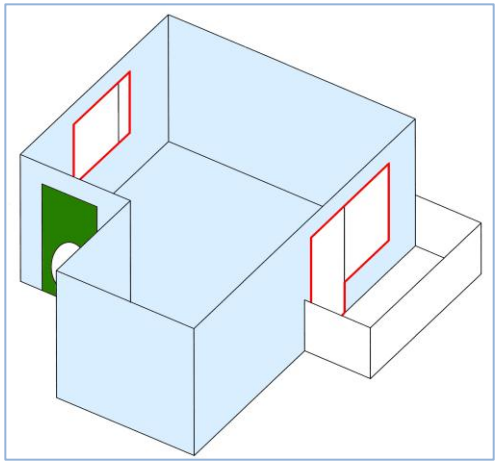
Presumption: some of the 7 variations may later be excluded without a drop in reliability

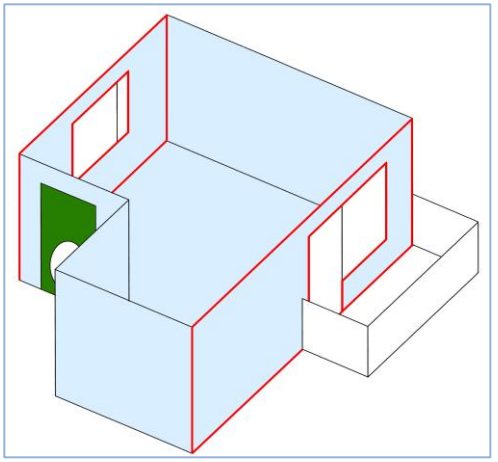
VARIATIONS

Measurements A … C
measurement point at the staircase door

Var.	Sealed openings	Objective
A	The intentional routes of ventilation system; standard test	Determining the total air leakage of the apartment
B	Sealing A + window and balcony door seams	Determining the influence of windows and balcony door to the total air leakage
C	Sealing B + seams of the building envelope	Determining the influence of building envelope joints to the total air leakage



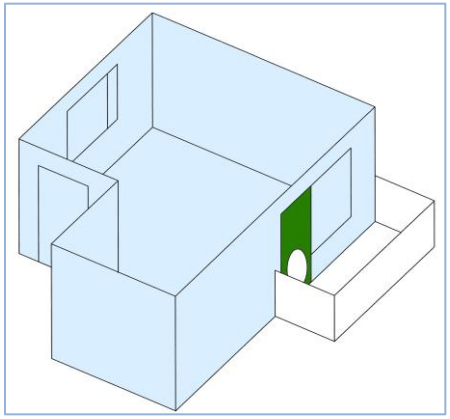
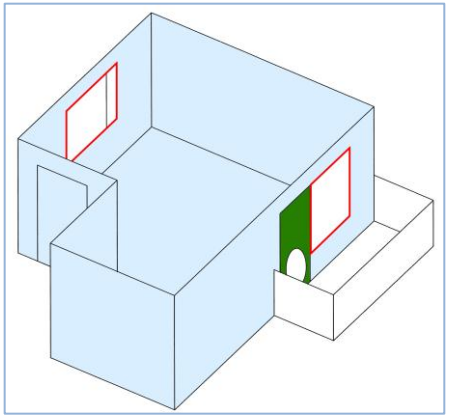
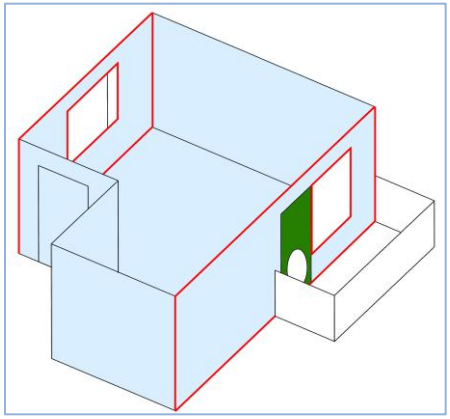
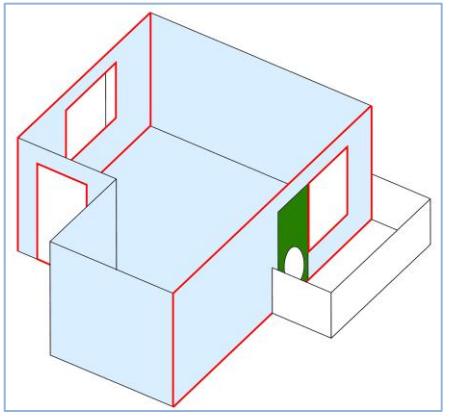




VARIATIONS

Measurements D … G
measurement point at the balcony door

Var.	Sealed openings	Objective
D	The intentional routes of ventilation system; standard test	Comparison material to variation A, determining the balcony door influence
E	Sealing D + window seams	Comparison material to variation B
F	Sealing E + seams of the building envelope	Comparison material to variation C
G	Sealing F + staircase door	Determining the staircase door influence

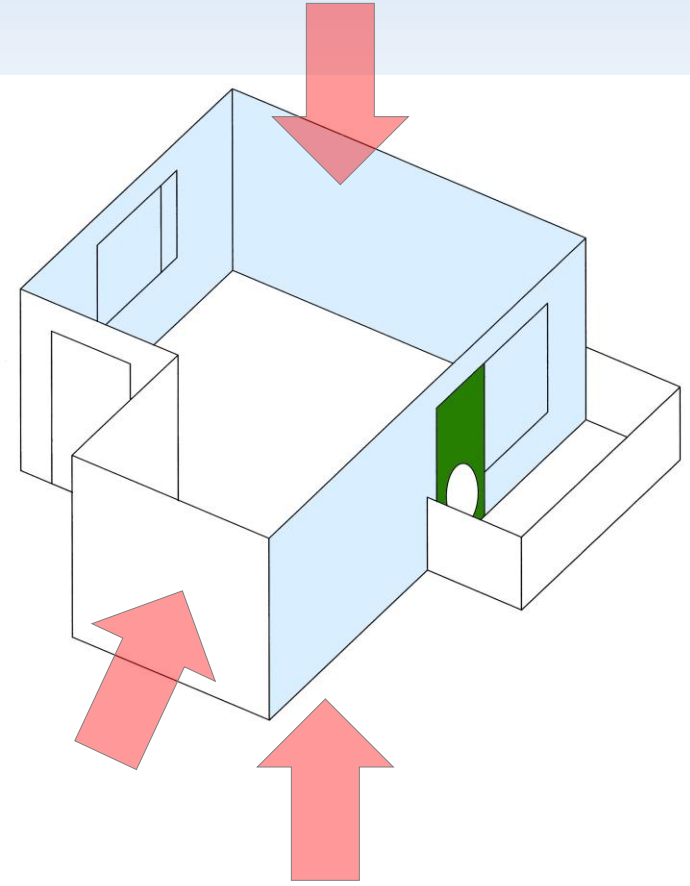





VARIATIONS

Counter-pressure measurement H_{CP}
measuring point at the balcony door

Variations A…G determine only the air leakage proportions of the outer building envelope elements
⇨ need to distinguish the internal leaks out of the residual leakage

• A standard test; the intentional routes of ventilation system sealed
• In addition, an equivalent **counter-pressure** is created into the bordering spaces
⇨ air leakage only through the building envelope body



COUNTER-PRESSURE

EXECUTION

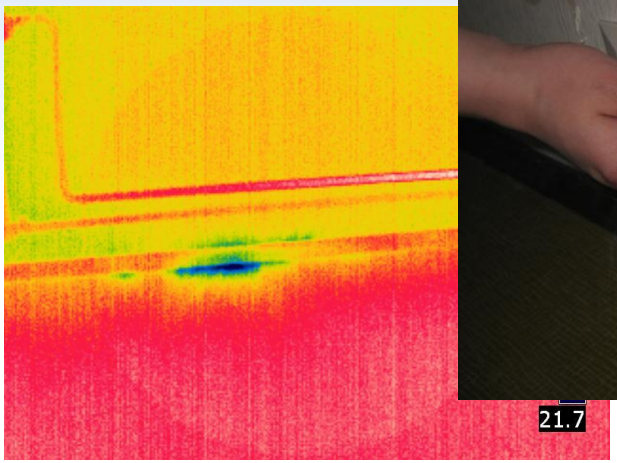
Under EVAKO renovation in 2011: two residential buildings
•built in 1978
•concrete and concrete sandwich elements
•3-storey, 21 and 27 apartments

19 apartments measured before renovation
•12 with series A…G
•3 with tests D and H
•4 with full series A …H

(Follow-up measurements after renovation)

EXECUTION

Air leakages detected by
•sensory impression
•smoke pen
•anemometer
•thermal camera



Typical sources of air leakage:
•windows and doors
•mail drop slit in the staircase door
•duct through-holes between apartments

CALCULATIONS

Combining the variations A…G

Equipment at the staircase door	
A	The measured air leakage rate through the whole envelope (excluding the staircase door)
A–B	The share of windows and balcony door
B–C	The share of the building envelope joints
C	The residue leakage, incl. the leaks through the building envelope body and the internal leaks
Equipment at the balcony door	
D	The measured air leakage rate through the whole envelope (excluding the balcony door)
D–E	The share of windows
E–F	The share of the building envelope joints
F–G	The share of the staircase door
G	The residue leakage, incl. the leaks through the building envelope body and the internal leaks

CALCULATIONS

Choosing the variations A…G

The pressurization test equipment leaves its mounting location out of the measurement
⇨ **”theoretical air leakage”** *A + (F – G)* takes this into account
All the further shares are respective to this value

The share of the balcony door: *(A – B) – (D – E)* **or** *A + (F – G) – D*
⇨ differences very small; either method can be used

The share of the building envelope joints: *(B – C)* **or** *(E – F)*
⇨ differences very small; either method can be used

The residue leakage: *C* **or** *G*
⇨ not directly proportional; the shares of (different) measurement points missing
As the staircase door (excl. in C) leaks more than balcony door (excl. in G), the more prudent choice is G

CALCULATIONS

The final calculation process

Calculation	Result
A+(F–G)	The theoretical air leakage rate including the whole envelope of the apartment
D–E	The share of windows
A+(F–G)–D	The share of the balcony door
E–F	The share of the building envelope joints
F–G	The share of the staircase door
G	The residue leakage, incl. the leaks through the building envelope body and the internal leaks

The effect of counter-pressure

The share of the building envelope: $D - H_{cp} = H$

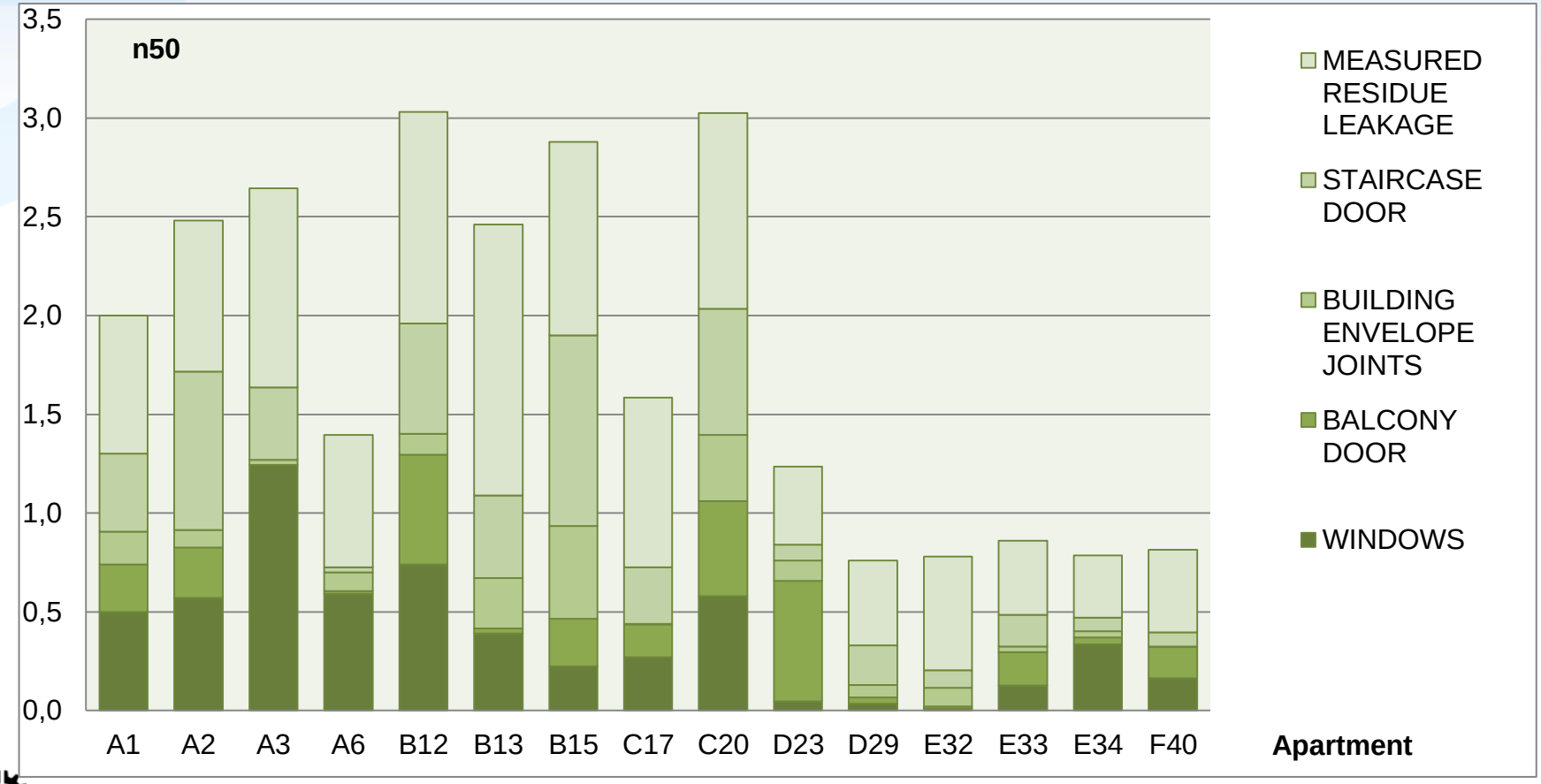
The share of the building envelope body:

$H - (D - E) - (A + F + G - D) - (D - F)$

The share of internal leakage: $G - H$

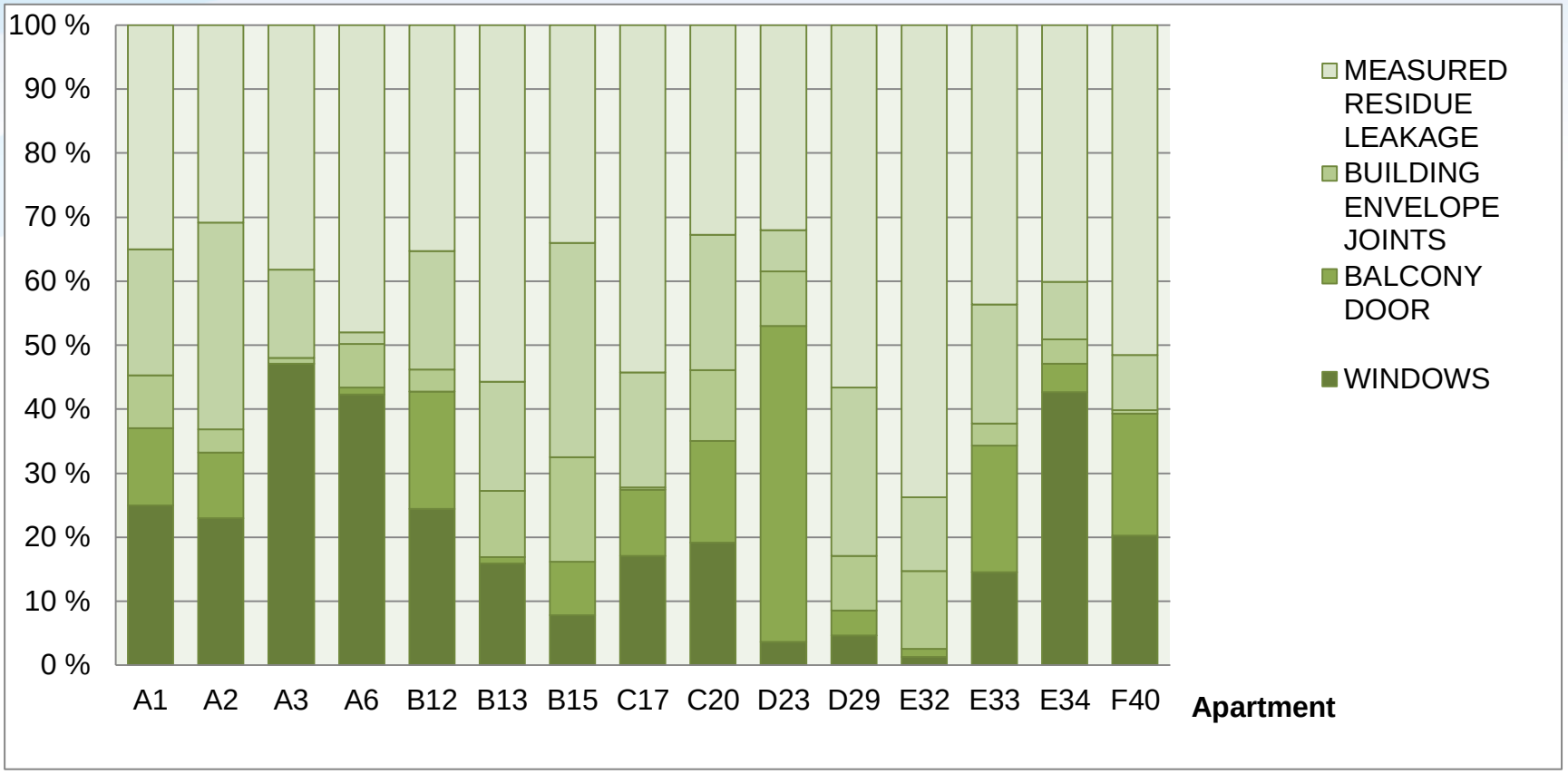
RESULTS

As the calculations are performed, the results can be presented in different manners: Shares compared to the total n_{50}-value…



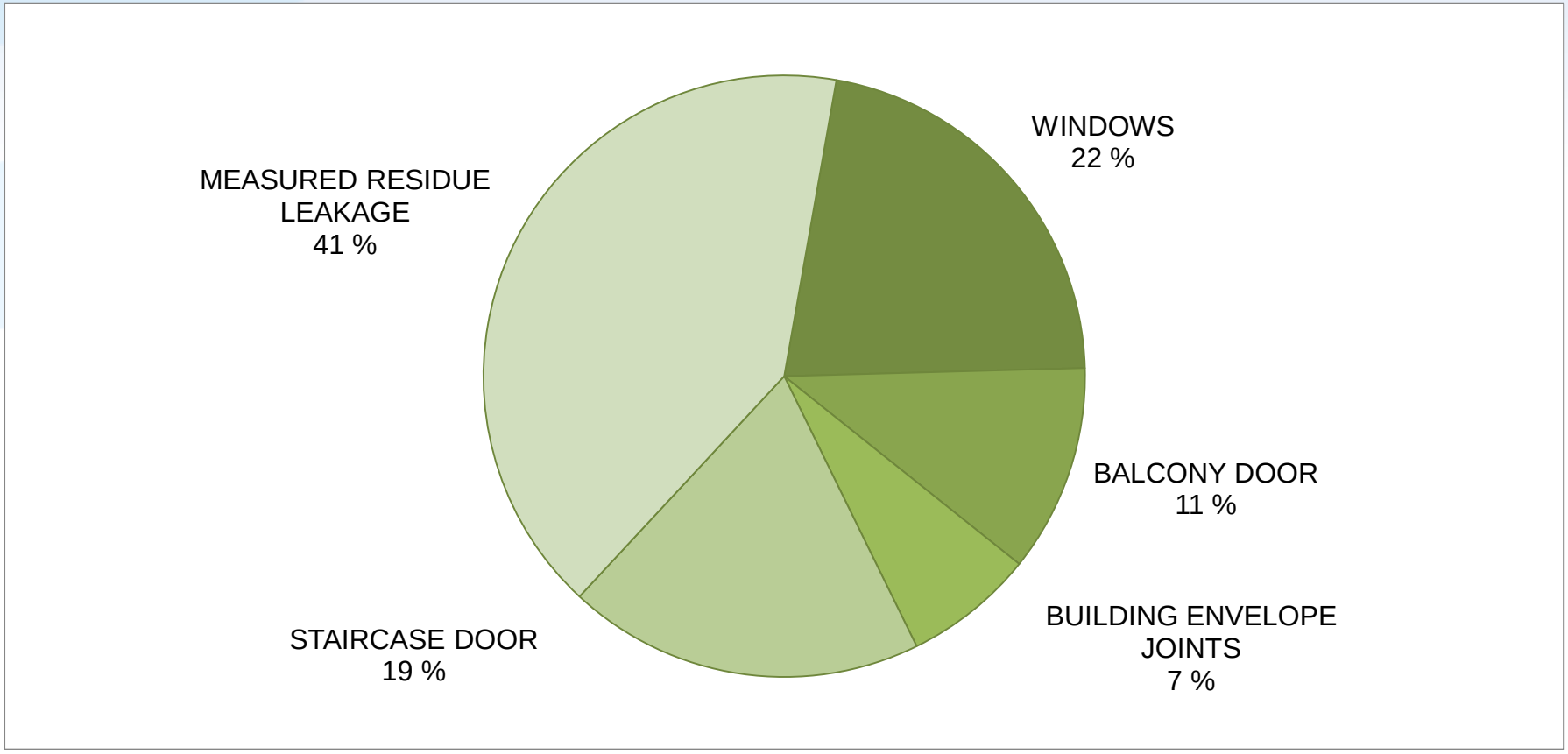
RESULTS

Shares by percent in different apartments…



RESULTS

… or by the mean values of the whole building



LIMITATIONS AND CHALLENGES

Error evaluation

- the sample too small to use statistical methods
- small measured entities with good air tightness

⇨ even small uncertainties have big effect

- calculation process accumulates errors

Uncertainty high ⇨ results rather cursory

Counter-pressure concept

- can be executed properly only in a uninhabited staircase
- if apartment has boundary walls to the neighbouring staircase, a third set of test equipment would be required
- results maybe not quite enlightening enough compared to the laboriousness of the method

CONCLUSIONS

The original aim: to define the internal air tightness between apartments

⇨the share of unsolved residue leakage still rather large

⇨ not unravelled by this method?

The shares of structural elements: results interesting and enriching

Future development:

- considerably larger sample of measurements
- applying the method to different structures and types of housing

⇨ e. g. timber-framed detached houses

Thank you for your attention!