Quality framework for airtightness testing in the Flemish Region of Belgium – feedback after three years of experience

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ABSTRACT

Since January 1st, 2018, airtightness testing has become implicitly mandatory for every new residential building in Flanders. There is no minimum requirement for airtightness. However, there is one for the global performance of the building envelope (S-level, taking into account thermal insulation, airtightness, solar gains, etc.), and a poor airtightness would jeopardize the chance to reach the required S-level. Before 2018, the Flemish Region was already promoting airtightness tests by using a very disadvantageous default value in the Energy Performance Calculation when the test was not performed.

To guarantee the reliability of airtightness tests, each test must be declared conform according to STS-P 71-3 requirements and legal requirements. This means that the tester shall be qualified and its company recognised to perform the test. BCCA (Belgian Construction Certification Association) has set up a quality framework to recognise airtightness testers and their companies.

This paper describes the requirements of the Flemish Energy Agency for the organizer of such a quality framework and, more specifically, requirements for the airtightness testers themselves. Among others, these requirements include the inspection of airtightness testers onsite, through desktop inspection, and the obligation to register every test in a database.

This article will describe the inspection process and its output. Desktop and onsite inspections represent both 10% of tests performed. These are done by a dozen of qualified inspectors all around Flanders. The tester has to inform BCCA of every measurement at least the day before and send a text message when the test actually starts and ends. The tester is informed within 5 minutes after the end of the test when there will be an inspection. 634 onsite inspections have been performed in 2017, of which less than 1% has resulted in a difference of more than 10% with the first measurement (and those were performed at little flowrate). Furthermore, 11 major non-conformities (2%) and 40 small non-conformities have been reported through onsite inspection. Therefore, this inspection process seems relevant to deter testers from manipulating results.

With the desktop inspection, BCCA spots non-conformities in the reports. In 2017, out of the 631 desktop inspections, 52 major non-conformities and 111 small non-conformities have been pointed out.

The database gathers around 7000 tests per year. Information in the database includes: administrative data, main destination (residential, school, ...), time and location of the test, leakage rate (m^3/h), heat loss area (m^2) and/or internal volume (m^3) and the full test report. Statistics show a skew-normal distribution of measurement results with an average of v_{50}= 3.36 $m^3/h/m^2$.

This paper concludes that it is possible to develop a qualification framework at limited cost for the testers, with an efficient inspection process that avoids manipulation of results and hence improves the reliability of results.

KEYWORDS

Airtightness measurement, quality framework, database

1 INTRODUCTION

Building airtightness is a key issue to achieve low- and very low-energy targets. Therefore, an increasing number of tests is performed in European countries and qualification schemes for airtightness testers are being developed all over Europe (Leprince, Carrié, and Kapsalaki 2017).

In Flanders, there is no minimum requirement for airtightness. However, since January 1st, 2018, there is one for the global performance of the building envelope (S-level, taking into account thermal insulation, airtightness, solar gains, etc.), and a poor airtightness would jeopardize the chance to reach the required S-level. If no airtightness test is performed, a default value of v_{50}= 12 m^3/h/m² shall be used in the Energy Performance Calculation, with which the mandatory S-level is almost impossible to achieve. Therefore, airtightness testing has become implicitly mandatory for every new building in Flanders.

Before 2018, Flanders was already promoting airtightness testing by using a very disadvantageous default value in the Energy Performance Calculation when the test was not performed. As a result, at the end of 2016, almost 90% of new residential buildings were tested, while it was less than 5% in 2006.

In the context of the Flanders' regulation, the test has to be performed by a qualified tester of a recognised company, to be registered in a database and to be declared conform to the STS-P 71-3 requirements.

The objectives of this article are to:

- Describe the Flemish quality framework for airtightness testing
- Explain the efficient inspection process to improve the reliability of results
- Give output and lessons learned from the quality framework

2 METHOD

2.1 STS-P 71-3 : the key document

The STS are "Unified technical specifications". They are edited by the Belgian Federal Public Service for Economy to optimise and standardise construction quality. Various STS exist on the construction field, STS-P 71-3 is for airtightness testing (SPF Economie 2014).

To guarantee the reliability of airtightness tests, tests must be declared conform to STS-P 71-3 requirements according to the Flemish regulation (Vlaamse Overheid 2007).

The STS-P 71-3 include (SPF Economie 2014):

- Possible objectives of the airtightness test and requirements according to the objective
- Steps of an airtightness test and "who does what"
- Details, in addition to NBN EN 13829:2011, on
  - Definitions
  - Building preparation
  - Pressure steps, etc.
  - Leakage detections
  - Measurement devices and calibration
  - Calculation process
  - Report
- A general description of a quality framework (Annex 6)

Annex 6 on a quality framework for the airtightness tests is informative but its application is imposed by the Flemish regulation, therefore in this context, there should be a collective monitoring system, the tester must be qualified, its company recognised and the tests registered in a database.

2.2 The Flemish regulation

The Flemish regulation has been promoting airtightness testing since 01/01/2006 by using a very disadvantageous default value in the Energy Performance Calculation, when the test was not performed. Since 1/1/2015, it imposes also that the test is performed according to the STS-P 71-3 and that the tester is qualified according to Annex 6 of the STS-P. Since 1/1/2018, airtightness testing has become implicitly mandatory for every new building in Flanders.

In December 2017, the Flemish government has tightened the requirements on a quality framework for airtightness testers:

- The organizer of a quality framework must have a qualification procedure for airtightness testers, which include at least
  - an optional training,
  - a mandatory theoretical and practical exam.
- The organizer of a quality framework must guarantee the quality of the airtightness measurements by running desk and onsite inspections combined with effective enforcement.
  - Minimal random annual desk and onsite inspection is 10% each.
  - Random checks are supplemented by targeted checks so that 90% of the active airtightness testers are checked at least once a year.
- The organizer of a quality framework shall develop a database gathering all measurement data that can be consulted by the government.
- The organizer of a quality framework is impartial: he should not have any members or directors who also carry out airtightness measurements in the context of the regulation.
- The organizer of a quality framework must have an accreditation in accordance with NBN EN ISO 17065 (certification of products or services).

A quality framework has to be approved by the Flemish Government.

The tester shall be qualified and its company recognised by an approved qualification body to perform a test in this context.

2.3 The BCCA quality framework

Since the new requirements on qualification bodies, the quality framework for airtightness testers of BCCA (Belgian Construction Certification Association) is approved by the Flemish government. BCCA provides a complete quality framework for a company which includes the qualification procedure for the tester.

The qualification procedure for the tester includes:

- Optional theoretical training (1 day)
- Theoretical exam (multiple choice questionnaire with 50 questions)
- Practical exam (performing a complete test with test report in presence of an examiner)
- At least 5 reports (not older than 1 year) from tests performed following the rules of the STS-P 71-3

To be recognised, a company must:

- have an insurance covering possible damage by airtightness tets
- have calibrated devices and software conform to STS-P 71-3
- have at least one qualified tester.

To retain the recognition the company must perform at least 5 tests each year to maintain the practice of performing tests and to allow inspection. The qualification is valid for 5 years. However, non-conformities during testing or reporting may put it on standby.

As required by the Flemish regulation, the quality framework includes onsite and desktop inspections for 10% of tested buildings (for each) and lodgement of all measurements in a database.

The process of an onsite inspection

The onsite inspection is either performed:

- Option 1: During the building preparation or during the measurement
- Option 2: After the communication of the test result with a check on this result by a second (partial) measurement (at least half of onsite inspections are performed in Option 2).

To allow this inspection, at least one day before the test is performed, the company shall fill in the BCCA system some required information that includes:

- Information on the building (location, volume, building destination, etc.)
- Information on the qualified tester
- The foreseen timing of the test.

Exceptionally, the timing can be notified the day of the test. In this case, an additional e-mail shall be sent to BCCA. In this case, the information shall be registered at least 1 hour before the test starts and the test shall finish at least 3 hours after the e-mail has been sent. When a new test is planned in the BCCA system, the system automatically provides a file number.

When the tester is onsite, before starting the preparations of the building, he sends a "START" text message to BCCA with the following information

- File number
- Foreseen ending time of the test (at least 30 minutes after the START message)

At the end of the test, the measurer shall send a "STOP" text message with the result (the flowrate at 50 Pa) or a "QSTOP" if it is not possible to performe the test. The tester shall remain available until the foreseen ending time even if he ends the test before that.
After the "STOP" message, the measurer shall remain available for 5 minutes, to allow the inspector to contact the measurer. When an inspection is performed, the inspector is onsite within 15 minutes after the phone call.
If the tester is not reachable the inspector will leave a message and send a text, in this case, the inspector has up to 30 minutes after the STOP message to set an inspection. If the inspection is not possible, this is considered as a "non-conformity" (see below) so the test has to be redone.

During his inspection, the inspector checks

- the qualification of the tester and the company
- the equipment
- the building preparation
- the compliance with the STS-P 71-3

He also performs a second test to check the flowrate at 50 Pa (with the tester equipment). It is done either by a one-point measurement or by a complete measurement.

BCCA has several qualified inspectors, distributed over the area of Flanders to perform inspections all over Flanders. Inspectors have at least the same qualification as testers plus a specific training for inspections. Furthermore, inspectors are checked onsite by their manager and internal meetings are set up.

The process of a desktop inspection

After performing the airtightness test, when the report is finished, the tester has to upload the report in the BCCA database before the conformity declaration can be issued.
If a desktop inspection is done, the inspector will check at least the following:

- The report is complete and made according to the STS-P 71-3
- The timing is correct (lodgement of information, etc.)
- Text messages have been sent according to the schedule
- Required data for the conformity declaration
- The information in the report is consistent (e.g. description of the measured zone and pictures included in the report)

Non-conformities and sanctions
Non-conformities are classified into 4 categories:

- **Unacceptable non-conformities (ONC)**: such as deliberate manipulation of results in the reported flowrate, repeated "major non-conformities" with no correction
- **Major non-conformities (GNC)**: anomalies with regard to the STS-P 71-3 with an important impact on the test result, repeated "minor non-conformities"
- **Minor non-conformities (KNC):** anomalies with regard to the STS-P 71-3 that have a small impact on the result, repeated remarks
- **Remarks (REM)**

For a minor non-conformity, the frequency of desktop or onsite inspection is increased.
For a major non-conformity, also the test report and/or the measurement shall be redone.
In case of major non-conformity, due to calibration validity, the recognition may be withdrawn temporarily.

Cost
The first year of qualification the company of the tester has to pay 400€ to enter the system. Then, the tester pays for each test performed, for which a conformity declaration is issued on the BCCA system. The cost depends on the volume and on the external area of the building. It rates from 40€ (single dwelling or building volumes up to 16000m^3) to 240€ (building volumes larger than 250000m^3). If there were not enough conformity declarations issued during a year, the measurer may have to pay an additional fee the next year.
The optional training (including participation in the theoretical exam) costs 285EUR. The theoretical exam without training costs 150EUR, the practical exam costs 490EUR.

Database
Information gathered through the process described above is inserted in the BCCA database. Therefore it includes:

- Administrative data (address, ...)
- Main destination (residential, school, ...)
- For multifamily buildings: if tested as a whole or as individual units
- Timing of the test
- Leakage rate (m^3/h)
- Heat loss area (m^2) and/or internal volume (m^3)
- Full test report (.pdf, ...)
- Pictures of the tested building with the testing equipment installed

From January 2015 to May 31th 2018, 22588 airtightness tests have been performed by qualified testers and inserted into the database.

3 RESULTS

3.1 Qualified tester

In February 2018, 142 companies were recognised with a total of 189 qualified testers. The number of conformity declarations per year is given in Figure 1. More than 6000 tests are reported per year.

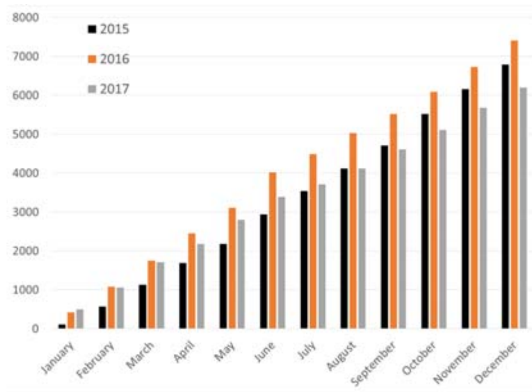


Figure 1: Cumulative number of conformity declarations in the last three years

The decrease in number of conformity declarations registered in the BCCA database, in 2017 can be explained by two phenomena. Firstly, more multifamily buildings are tested as a whole instead of testing each dwelling separately. Secondly, a second organisation for inspection was founded.

3.2 Desktop inspection

In 2017, 631 desktop inspections have been performed (10.1% of reported tests). All recognised companies were inspected at least once. Figure 2 gives the inspection rate for each active company and indicates the average caseload (number of tests per year) for each category. For 65% of the recognised companies 5 to 15% of the tests reported have gone through a desktop inspection. For companies performing few tests per year, the share of inspection logically increases.

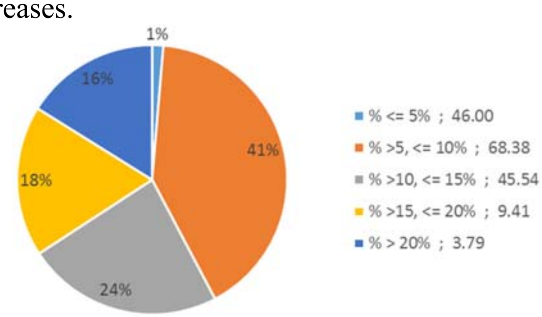


Figure 2: desktop inspection rate of active companies

In 2017, 52 desktop inspections have led to detect major non-conformities (see Table 1). Table 2 gives the top 10 of major non-conformities detected through the desktop inspection.

Table 1: number of non-conformities and compliance detected through desktop inspection

	Major non-conformities	**Minor non-conformities**	**No non-compliance**
Desktop	52 (8%)	111 (18%)	467 (74%)

Table 2: Top 10 of major non-conformities detected by desktop inspections, on the left the number of occurrence

20	GNCR1 – Calibration data of the thermometer and/or manometer are missing in the test report
12	GNCR6 - The software and software version used to calculate the result is not mentioned in the test report
9	GNCM1 - Non-lockable openings were still sealed in an unauthorised manner with an expected large impact on the result.
8	GNCR15 - Fan serial number is missing in the test report.
7	GNCR5 – The administrative company details are missing in the test report
7	GNF - The test report was not added to the dossier in the web-application before validation of the dossier.
5	GNCM5 - The required meteorological conditions were not respected: the natural pressure difference as reported by the measurer was too high.
3	GNCM12 - The flow coefficient n is too low or too high.
3	GNCM14 - There is a difference between the indicated sealed/closed openings compared to the rules in STS-P 71-3 with an expected impact greater than or equal to 5%.
3	GNCR14 - The description of the measured zone is missing.

Those desktop inspections have led to:

- 149 increased monitoring frequency
- 43 adjustments of test reports
- 13 new measurements

3.3 Onsite inspection

In 2017, 634 onsite inspections have been performed (10.2% of the reported tests). 140 companies (92%) were audited. 66% of those inspections have been performed after sending the "STOP" text message (Option 2). Inspections are also performed during the weekend.
The average duration of inspection is 21.5 min. The average time for an inspector to get onsite after the "STOP" text message is 2.8 min. This means that no more than 25 minutes are needed in average (waiting time included) to perform an inspection. As 10% of tested buildings are inspected, this means, on average, 2.5 min per tested building.
Figure 3 gives the inspection rate for each active company and indicates the average caseload (number of test per year) for each category. For 54% of the companies 5 to 15% of the tests reported have gone through an onsite inspection. Similar as for the desktop inspections, for companies performing few tests per year, the share of inspection logically increases. 9% of the companies have not gone through onsite inspection as they are performing very few tests per year. Companies performing less than 5 tests per year lose their recognition the next year.

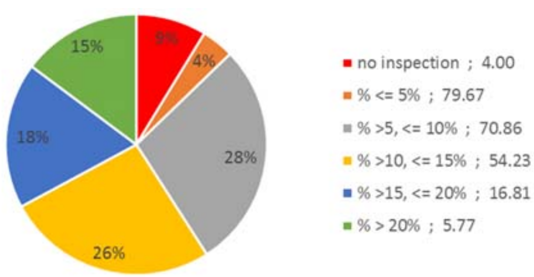
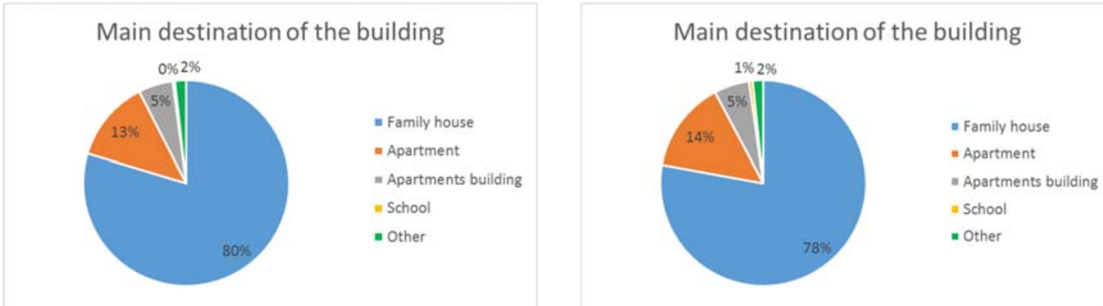


Figure 3: Onsite inspection rate of active companies

Inspected buildings are representative for the tested buildings. As shown in Figure 4 the same repartition of building destination is observed in inspected buildings as in all the measurements performed. Figure 5 shows that the same share of large buildings is observed in inspected buildings as in all measured buildings. Moreover, the inspections are performed all over the area of Flanders as shown in Figure 6. Figure 7 shows that the same repartition of the testing day is observed in inspected buildings and in all measurement performed (even during the weekend).

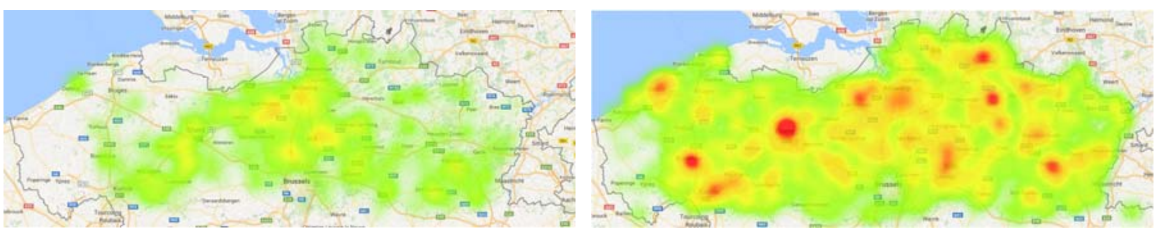


Inspected buildings Measured buildings

Figure 4: Repartition of building destination in inspected building and in all measured buildings

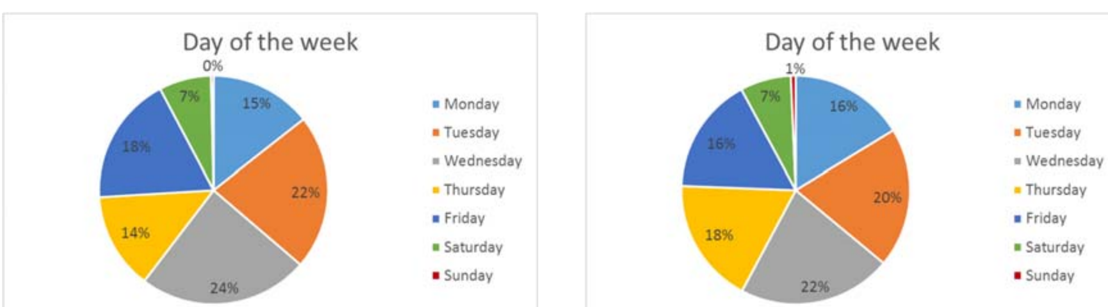
Inspected buildings Measured buildings

Figure 5: Share of large buildings (≥ 4000m³) in inspected buildings and in all measured buildings



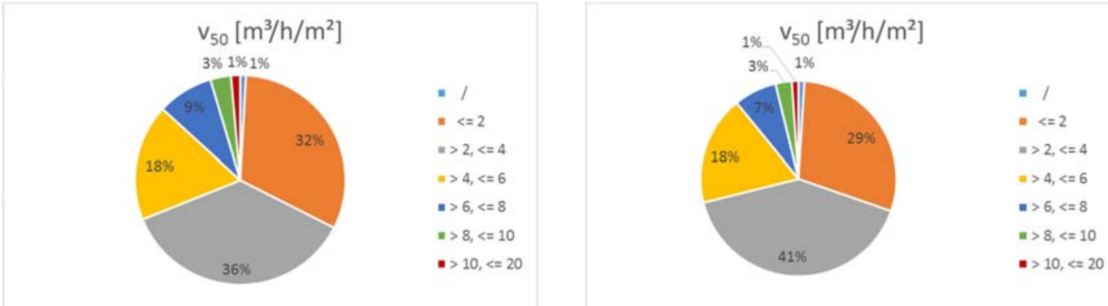
Inspections performed in 2017 Measurements performed in 2017

Figure 6: inspections and measurements performed in 2017



Inspected buildings Measured buildings

Figure 7: Repartition of the testing day for inspected buildings and for all measured buildings



Inspected buildings Measured buildings

Figure 8: Repartition of v_{50} for inspected buildings and for all measured buildings

Finally, the repartition of the inspected measurements and all measured buildings for the v_{50}-value is shown in Figure 8. This shows that not only the very leaky or very tight buildings are inspected, but that the inspections are evenly spread over the measured buildings.
Those results have been obtained by making the inspectors aware that they should not avoid some kind of building (for example large buildings) and that they should also work in the weekends. The inspections were not targeted towards those parameters.
In 2017, 11 inspections have led to detected major non-conformities (see Table 3). Table 4 gives the list of major non-conformities detected through the onsite inspection.

Table 3: number of non-conformities and compliance detected through onsite inspection

	Major non-conformities	**Minor non-conformities**	**No non-compliance**
In situ	11 (2%)	40 (6%)	583 (92%)

Table 4: Major non-conformities detected with onsite inspection, on the left the number of occurrence

4	GNCM1 - Non-lockable openings were still sealed in an unauthorised manner with an expected large impact on the result.
4	GNCM5 - The required meteorological conditions were not respected: the natural pressure difference as reported by the measurer was too high.
4	GNCM14 - There is a difference between the indicated sealed/closed openings with STS-P 71-3 with an expected impact greater than or equal to 5%.
2	GNCA2 - The calibration of the thermometer is more than six months overdue.
1	GNCM2 - The coefficient of determination r^2 is less than or equal to 0.95.
1	GNCM - deviation from the procedure with suspected major impact on the measurement result by breaking down the inspection

Those onsite inspections have led to:

- 46 increased monitoring frequency
- 7 new measurements
- 2 temporarily qualification withdrawals (due to non-valid calibration)

When an inspection is performed in "Option 2" (418 inspections out of 634 in 2017), the inspector performed a new test (either a 1 point test or a complete measurement). For each test, the flowrate at 50Pa obtained by the tester and the inspector is compared in Figure 9. The percentage difference is given in Figure 10.

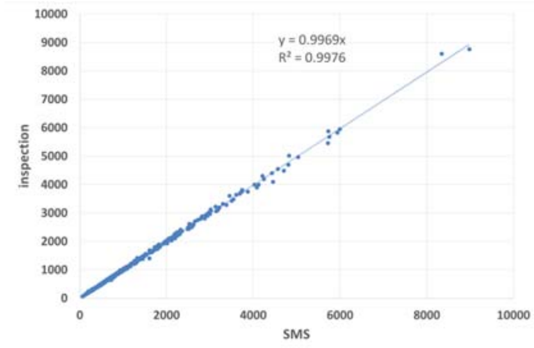


Figure 9: Comparison of the flowrate at 50Pa obtained by the tester (SMS) and the inspector

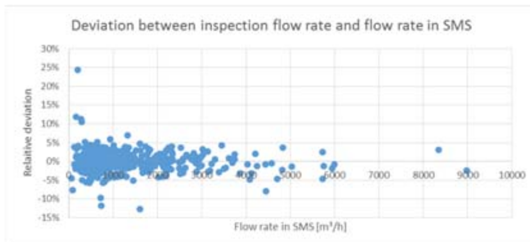


Figure 10: Percentage difference between tester and inspector result according to the flowrate

96% of inspector tests are within 5% of the first test result. Some larger deviation is observed at very small flowrates, when the measurement uncertainty is larger. The flowrate measured by the inspector is in 53% cases over the initial flowrate and in 47 % under the initial flowrate so it may be due to measurement uncertainty rather than manipulation from testers.

3.4 Key results of the database

The average airtightness value is v_{50}= 3.36 m³/h/m², the standard deviation is 4.52 m³/h/m² and the median value is 2.84 m³/h/m². The distribution for the measured buildings is given in Figure 11.

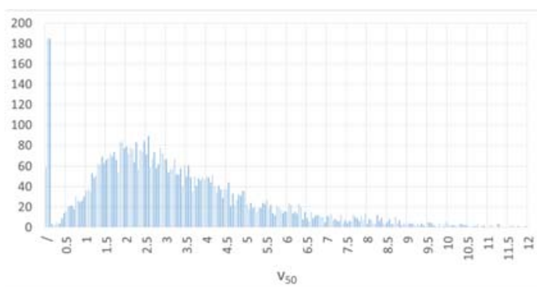


Figure 11: v_{50} distribution for measured buildings

As there is no limit value for airtightness, the distribution is close to a skew-normal distribution with no gap as observed in the French and British database (Bailly, Guyot, and Leprince 2016) (Cope 2017) (Love et al. 2017).

4 DISCUSSION

The inspection process set up for qualified airtightness testers in Flanders seems efficient to detect non-conformities and avoid manipulation of results from testers.

26% of the desktop inspections have led to the detection of a major or minor non-conformity and therefore to the improvement of tests and to the constant training of airtightness testers. When major non-conformities are detected, BCCA can ask either to correct the report or to perform a new measurement; this last option has been done in 13 buildings out of the 631

inspected (2%). This proportion is consistent with the number of major non-conformities detected during onsite inspections.
The low proportion of major non-conformity that may have a large impact on the test result and the very good agreement between tester and inspector test (for 96% a difference below 5%) shows that the inspection process is effective to deter testers from manipulating the results.
The inspection process has also proven to be low time consuming, with less than 25 minutes (on average) needed for the inspector to get onsite and perform the inspection. Inspection is performed on every company and everywhere in Flanders.

Furthermore, onsite inspections are also a good way to point out problems experienced by testers. For example, testers get the issue, when measuring at very low flowrate (very tight and/or small buildings), to reach the 10 Pa point measurement. At very low flowrates, the measurement device may have difficulties to stabilise which may lead to a non-accurate measurement. This resulted in a minor non-conformity for that test. Therefore the commission has decided to adapt the requirement for the low-pressure point and to allow not going below 25 m^3/h when the low-pressure point remains below 25 Pa.

The main drawback of this inspection process may be the extra cost, however, it remains limited to around 15% of a test cost and it is proportional to the number of tests performed.

In Flanders, it is also mandatory to perform a report of the ventilation system of every new residential building with a building permit delivered after the1st of January 2016. BCCA has also set a quality framework for residential ventilation systems similar to the system described in this paper. Results will be discussed as soon as relevant data is obtained.

5 CONCLUSION

The new energy performance levels, as imposed by the Flemish Energy Agency now implicitly require that the airtightness of every new building is tested by a qualified tester.
BCCA has set a quality framework for airtightness testing. This quality framework includes desktop and onsite inspections that both represent 10% of tests performed.
The inspection process has proven to be efficient to avoid the manipulation of results with low time consumption for the tester. 634 onsite inspections have been performed in 2017, less than 4% has resulted in a difference of more than 5% with the first measurement (and those were performed at very low flowrates). Furthermore, 11 major non-conformities (2%) and 40 small non-conformities have been reported through onsite inspection.
With the desktop inspection, BCCA spots non-conformities through the reports. In 2017, out of the 631 desktop inspections made, 52 major non-conformities and 111 minor non-conformities have been pointed out.
The quality framework also includes lodgement of every test performed in the context of the Flemish regulation. The database gathers around 7000 tests per year. Statistics show a skew-normal distribution of measurements results with an average of v_{50}= 3.36 $m^3/h/m^2$.
The results given in this paper show that it is possible to develop a qualification framework at limited cost for the testers, with an efficient inspection process that avoids manipulation of results and improves the reliability of results. A similar system has been developed for ventilation system reporting.

6 ACKNOWLEDGEMENTS

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