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Technical Note AIVC 66

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close collaboration with TightVent Europe**

Building air leakage databases in energy conservation policies:

analysis of selected initiatives in 4 European countries and the USA

Air Infiltration and Ventilation Centre
Operating Agent and Management
INIVE EEIG

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analysis of selected initiatives in 4 European countries and the USA

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International Energy Agency (IEA)

The IEA was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-four IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems (ECBCS)

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use in buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods as well as air quality and studies of occupancy.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial.

To date the following have been initiated by the Executive Committee (completed projects are identified by *):

1 Load Energy Determination of Buildings *
2 Ekistics and Advanced Community Energy Systems *
3 Energy Conservation in Residential Buildings *
4 Glasgow Commercial Building Monitoring *
5 Air Infiltration and Ventilation Centre
6 Energy Systems and Design of Communities *
7 Local Government Energy Planning *
8 Inhabitant Behaviour with Regard to Ventilation *
9 Minimum Ventilation Rates *
10 Building HVAC Systems Simulation *
11 Energy Auditing *
12 Windows and Fenestration *
13 Energy Management in Hospitals*
14 Condensation *
15 Energy Efficiency in Schools *
16 BEMS – 1: Energy Management Procedures *
17 BEMS – 2: Evaluation and Emulation Techniques *
18 Demand Controlled Ventilation Systems *
19 Low Slope Roof Systems *
20 Air Flow Patterns within Buildings *
21 Thermal Modelling *
22 Energy Efficient communities *
23 Multizone Air Flow Modelling (COMIS)*
24 Heat Air and Moisture Transfer in Envelopes *
25 Real Time HEVAC Simulation *

26 Energy Efficient Ventilation of Large Enclosures *
27 Evaluation and Demonstration of Residential Ventilation Systems *
28 Low Energy Cooling Systems *
29 Daylight in Buildings *
30 Bringing Simulation to Application *
31 Energy Related Environmental Impact of Buildings *
32 Integral Building Envelope Performance Assessment *
33 Advanced Local Energy Planning *
34 Computer-aided Evaluation of HVAC Systems Performance *
35 Design of Energy Hybrid Ventilation (HYBVENT) *
36 Retrofitting of Educational Buildings *
36 WG Annex 36 Working Group Extension 'The Energy Concept Adviser' *
37 Low Exergy Systems for Heating and Cooling of Buildings *
38 Solar Sustainable Housing *
39 High Performance Insulation systems (HiPTI) *
40 Commissioning Building HVAC Systems for Improved Energy Performance *
41 Whole Building Heat, Air and Moisture Response (MOIST-EN)
42 The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (COGEN-SIM)
43 Testing and Validation of Building Energy Simulation Tools
44 Integrating Environmentally Responsive Elements in Buildings
45 Energy-Efficient Future Electric Lighting for Buildings
46 Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
47 Cost Effective Commissioning of Existing and Low Energy Buildings
48 Heat Pumping and Reversible Air Conditioning
49 Low Exergy Systems for High Performance Buildings and Communities
50 Prefabricated Systems for Low Energy Renovation of Residential Buildings
51 Energy Efficient Communities
52 Towards Net Zero Energy Solar Buildings
53 Total Energy Use in Buildings: Analysis & Evaluation Methods
54 Analysis of Micro-Generation & Related Energy Technologies in Buildings

Annex 5: Air Infiltration and Ventilation Centre (AIVC)

The Air Infiltration and Ventilation Centre was established by the Executive Committee following unanimous agreement that more needed to be understood about the impact of air change on energy use and indoor air quality. The purpose of the Centre is to promote an understanding of the complex behaviour of air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

The Participants in this task are Belgium, Czech Republic, Denmark, France, Germany, Greece, Italy, Japan, Republic of Korea, Netherlands, New Zealand, Norway, Portugal, Sweden and United States of America.

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1 Abstract

We collected information on existing envelope air leakage databases from countries that are involved in the AIVC-TightVent project "Development and applications of building air leakage databases". This document summarizes the information from five countries: Czech Republic, France, Germany, UK, and USA. Even though our summary is not exhaustive of all existing data on whole-building envelope air leakage, it provides an overview of recent efforts from a number of countries. There are many reasons why different countries are collecting these data. We will summarize their motivations, which drive some of the differences in the types of data being gathered and how the data are analysed. Detailed information from each country is provided at the end of this document in the form of tables.

2 Motivation

In countries that have building envelope airtightness requirements, building pressurization measurements are collected to demonstrate compliance with regulations. When testing is mandatory, potentially a large number of tests will be performed. However, many of these mandatory programs are still in their infancy, so large comprehensive datasets have yet to emerge. Required reporting of the data must be enforced to support data analysis. It is sometimes the case that test results are viewed as private information. If there is no mechanism in place to make these data available for analysis, then evaluation of data will be very difficult. Therefore, it is important for regulatory bodies of the airtightness requirements to manage the data reporting process and clarify the rules on data privacy. Mandatory programs are more likely to have the leverage to ensure consistency in testing and reporting, which should help improve data quality and program evaluation.

Even in the absence of a mandatory program to test for air leakage, measurements are commonly collected to evaluate building design and construction practices. For example, measurements are collected on a program level to evaluate effectiveness of certain measures in improving airtightness. Data are also used to evaluate if a construction technique or building technology makes an impact on air leakage. Such data are often collected by studies that have a more narrow focus on a single issue. The data collected tend to be more detailed, but often from a small sample of buildings with specific characteristics that are not representative of the building stock. If an air leakage database consists of many of these individual datasets, it is necessary to collect a large number of data in order to improve data coverage and representation. For example, blower door measurements collected from pre- and post-retrofit projects are a useful comparison for evaluating project effectiveness. However, homes that participate in energy improvement or weatherization programs and are retrofitted usually have to meet certain eligibility criteria. Building owners also self-select to participate in such programs, so the participating homes may not form a representative sample. Therefore, even in aggregation, the ensemble of existing datasets may not resemble the national building stock.

Another purpose of constructing a national air leakage database is to gather needed information for energy calculations and other modelling needs. This can be difficult if the measurements do not form a representative sample of the building stock. This is usually the case, because data are often collected from new constructions to demonstrate compliance with airtightness requirements. While these data are well-suited for energy modelling and other analyses that focus on new constructions, they are not enough for a comprehensive nationwide assessment of the existing building stock. The same limitations would result from data that are collected from focused research studies.

3 Data collection

A few countries are in the process of establishing a common mechanism to collect air leakage data on an on-going basis. However, such efforts face many challenges. To start, there needs to be a continuous commitment from the responsible agency to gather and manage the data. It is necessary to establish guidelines on how air leakage tests should be performed, how the data should be reported, and what level of quality check is required. These guidelines may need to be revised periodically to keep up with changes in building practices, as well as other regulations that may have an impact on building airtightness. Cooperation from contractors who perform these air leakage tests is crucial to ensure that the guidelines are followed. Working with test equipment manufacturers to unify the data reporting procedure can help streamline this process. This last task is one of the objectives of this AIVC Tight-Vent project.

Many of the air leakage datasets that exist thus far are one-time efforts. Some of these projects have been revisited over the years, which helps to build the volume of data available for analysis. It also enables time trend analysis of building air leakage. In some countries, due to how building codes and standards are implemented by sub-regions, a national requirement to report air leakage measurements collected by different programs is difficult. In these cases, collecting air leakage data every few years might be the only viable option. It is unclear which is more costly: to establish and maintain a data reporting system, or to periodically collect data for analysis. In terms of data comprehensiveness, the former is preferable, but there are still many challenges to successfully implementing the required reporting system. On the other hand, the latter approach is more flexible and allows efforts to focus on topics of interest.

Not surprisingly, there are substantial differences in the types of data being collected by different countries. We summarize here the major categories that are included in one or more national databases: air leakage measurements, test descriptions, house characteristics, and other related information. We broadly describe the common variants that are collected in each of the data categories. Omission of some data fields might limit the analysis one can perform using the database. This is an important consideration, especially if there is an intention to consolidate databases for international evaluation. In this case, even minor differences in details, such as the metric of air leakage parameter recorded, may introduce incomparability that would lead to greater uncertainty in the assessment.

Most databases focus predominantly on residential buildings, including both single and multi-family homes. Data on commercial building air leakage are sometimes contained within the residential dataset, but there are also cases where the data are collected and analysed separately. In order for data from both commercial and residential buildings to exist in a unified database, it is important to establish a database structure that will allow easy identification and query of the data by type. There are benefits to keeping all air leakage data together, regardless of whether they are from commercial or residential buildings, because the two share many common features. This would make data analysis simpler, especially for assessments that consider the whole building stock. Aside from some clear differences in building characteristics between commercial and residential buildings, there can also be substantial differences in the test protocols that need to be documented. Some of these considerations are addressed below.

3.1 Air Leakage Measurements

There are many different metrics of whole-building envelope air leakage being used in databases. The most common ones are air change rates at 50 Pa (n50 or ACH50) and normalized leakage (NL). Both of these are parameters normalized to the building size, either building volume or the floor area. Air permeability is also used, which is defined as airflow at a reference pressure normalized by the surface area of the building envelope. The underlying measure that is used to compute these different air leakage metrics is the airflow measured at a given pressure difference. 50 Pa is the most common reference pressure, but other reference pressures are also used (e.g. 4 Pa in France). The airflow measurements are typically included in most databases as well. Theoretically, this would allow computation of other air leakage metrics as desired. In practice, however, the conversion from one metric to another is likely to introduce some error because of inconsistencies in how building volume, floor area, and envelope surface area are recorded. In sum, guidelines on how to measure and report building dimensions are necessary to have consistent datasets with regard to the reference values used for the derived quantities.

Flow coefficient and pressure exponent as expressed in a power-law equation can be computed from air leakage tests performed at multiple pressure differences. These multi-point tests require somewhat longer time to perform, so in some cases they are not conducted. But there are good reasons to conduct these multi-point measurements, and to record the resulting flow coefficients and exponents, as well as the regression fit to the power-law equation in the database. When constructing an air leakage database, it is important to consider how to accommodate disparity in the level of detail when only a small subset of data are results from multi-point tests, and the majority of data are single-point measurements from blower door tests performed at 50 Pa.

3.2 Test Descriptions

Many air leakage databases lack information on how the tests were conducted. For example, information on the test equipment and test protocols used is helpful. Weather conditions, such as outside temperature and wind speed, are generally recorded during tests. However, these data parameters are sometimes lost in the reporting process or as datasets are combined. Some datasets include useful data flags, such as whether the test was a repeat following the retrofit of a dwelling. Information about the contractor who conducted the test, or an identifier describing from where the data was obtained, is also useful for data analysis.

Details on how the test was performed are particularly important in countries where standard test procedures for certain buildings types, such as multi-family dwellings and commercial buildings, have yet to be established. This is because there can be large differences in how the buildings were prepared for an air leakage test when there are adjacent units and/or internal partitioning that could influence the results.

3.3 Building Characteristics

Location, construction year, and physical dimensions (e.g., floor area, volume, number of storeys) are the most readily available building characteristics in air leakage databases. Other useful parameters to include are foundation types, envelope materials, insulation types and/or ratings, and construction methods. Information on the mechanical ventilation system is also important to collect because there are specific leakage pathways that are associated with ducts and where they are located. Other common leakage pathways are also noted, such as flues, vents, and other building envelope penetrations.

The problem of missing data is inevitable if a database seeks to collect detailed information on building characteristics. A well-designed database that is clear on how parameters are defined, and yet not painstakingly exhaustive, should hopefully encourage accurate data collection. When smaller datasets are joined together to form a larger dataset, finding ways to re-categorize the data consistently and meaningfully can be a very time consuming task. A standardized data format can certainly save time and cost if it is widely used.

The descriptions of multi-family dwellings and commercial buildings will need to be more extensive to be informative. Because the meaning of various building types can be ambiguous, it helps for a database to establish concise definitions. It is difficult at this point to suggest a separate list of building characteristics that should be recorded for multi-family and commercial buildings. This is because it remains unclear what parameters are associated with a more or less airtight building envelopes. For multi-family buildings, the location of the unit in the building (e.g., floor level, corner unit, orientation) is often recorded. However, wall and construction materials, elevators and stairwells, underground parking, and information about the mechanical systems are also important parameters that can influence the whole building airtightness. This is probably true for commercial buildings as well.

3.4 Other Building and Occupant Data

There are other diagnostic tests besides air leakage testing that may be commonly performed in different countries for different purposes. It may make sense to also collect these data, such as duct leakage measurements and combustion safety test results, and link them with the air leakage databases. A comprehensive dataset would make whole-building evaluation easier.

Some additional types of data may extend to building occupants also. These include number of occupants, appliances and their usage, energy and other utility consumption, indoor air quality data, etc. For air leakage databases that are aggregates of many smaller datasets, it is common that some of these or other data are available. It is useful for a database to have the flexibility to append additional data types when needed. This feature could then support energy modelling and other assessments that require many input parameters beyond just building envelope air leakage.

3.5 Programs and Regulations

The context for why the air leakage measurements were collected is also very useful for data analysis. For example, there should be an indicator if the test was performed to meet an airtightness requirement for new constructions. Similarly, for pre- and post-retrofit comparisons, there should be a way to identify the homes that participated in the retrofit program; more detailed information on air sealing and other work performed would also be helpful. For example, air leakage tests performed on the same construction plan by a builder are useful as a check for consistency in workmanship. For this purpose, a unique data flag needs to be assigned to those homes. If a home was built to meet certain energy efficiency criteria, this also needs to be identified so that these homes do not skew the summary statistics unknowingly. Lastly, third-party verification test results should be identified so that they can be used to evaluate the measurement quality of the data.

4 Analyses and Implications

Analyses of air leakage databases have generated the necessary information to characterise a building stock and enable various assessments including energy use and occupant exposure. Summary statistics and regression analysis are the tools used to describe the central tendency and variability of air leakage measurements among buildings. Because whole-building envelope air leakage tends to vary greatly in a building stock, it is useful to identify factors that help explain some of the observed variability. For large datasets, it is beneficial if the database can be easily queried to select a subset of the data for analysis. This makes the manipulation of the data in statistical software easier to do, if certain groups of data parameters can be examined one at a time. This is especially true if data collection is on-going so that the size of the database is expected to grow over time.

Past experiences working with air leakage databases suggest that time trends are best revealed when data collection and analysis are repeated over time. This is needed to measure progress in meeting building energy efficiency objectives. Air leakage databases are necessary to demonstrate that buildings are built sufficiently tight, and to provide the basis to assess the ventilation needs of buildings. The ability to track changes is important also to support future decision making on building requirements.

5 Conclusion

Our analysis of the existing database developments in the Czech Republic, France, Germany, the UK and the USA summarises the underlying motivations as well as the tips and pitfalls regarding envelope airtightness data collection. It emphasises the importance of such databases for developing and monitoring building policies and programs where airtightness plays an important role. It also stresses the significance of having sound testing and reporting procedures to efficiently collect data and enable analyses.

This background information may be useful to organizations that are engaging in database development or seeking support to do so. It may also motivate policy makers and program developers to organize such efforts and find synergies with other building characteristics they wish to monitor for promoting energy efficiency and healthy homes.

6 Acknowledgements

The Air Infiltration and Ventilation Centre (www.aivc.org) was inaugurated through the International Energy Agency and is funded by the following countries: Belgium, Czech Republic, Denmark, France, Germany, Greece, Italy, Japan, Republic of Korea, Netherlands, New Zealand, Norway, Portugal, Sweden, and United States of America.

The TightVent Europe platform (www.tightvent.eu) aims at facilitating exchanges and progress on building and ductwork airtightness issues. TightVent Europe is facilitated by INIVE (with as members BBRI, CETIAT, CIMNE, CSTB, eERG, ENTPE, Fraunhofer IBP, SINTEF, NKUA, TMT US, TNO) and receives support of the following organizations: Building Performance Institute Europe, BlowerDoor Gmbh, European Climate Foundation, EURIMA, Lindab, Retrotec, Soudal, Tremco illbruck, and Wienerberger.

7 Annex: Database summary

7.1 Czech Republic

Database name	ABD.CZ (database of the Association Blower Door CZ)
Data type	Building airtightness test results are collected together with the information about the building tested. Types of buildings include single-family buildings (majority of the database), multi-family residential buildings, and office buildings. Mandatory information collected includes: building type (use), type of ventilation system, required airtightness (expressed in n_{50}), year of construction (or retrofit), internal volume, type of envelope structure–external walls, roof, floor (masonry, concrete, timber structure, etc.), part of the building tested (whole building, a flat, etc.), purpose of the test (airtightness check during construction, final test), test method (A/B according to EN 13829 or other), state of the building (completeness), test date, air flow rate at 50 Pa (V50 [m^3/h]), air change rate at 50 Pa (n_{50} [h^{-1}]). Some database records contain optional information on building dimensions (floor area, envelope area, building height), expected energy performance of the building tested, technical approach (namely the material) for the air barrier layer in external walls, roof and floor, presence of special elements influencing airtightness (e.g., attic hatch, chimney), and leakage paths detected during the test.
Purpose	• Monitoring the airtightness levels achieved in the Czech Republic and their evolution over time • Collecting information about typical air barrier systems and their reliability (airtightness levels commonly achieved by means of different systems), formulation of construction rules, recommendations for building practice • Monitoring the activities of airtightness test providers in a quality framework (quantity, quality...) • Collecting information to inform decisions on the level of airtightness requirements, limit values etc. and typical values for energy performance calculations
Data source	Data from commercial tests performed by the members of the Association Blower Door CZ (ABD.CZ) and limited data from research projects.
Availability of raw data	Not at the moment. It is intended to make the raw data available as well as the results of the analyses at the ABD.CZ website.
Analyses performed	Sorting of the database according to the following criteria: • Use of the building • Target energy performance • Target airtightness level (n_{50}) • Year of construction Influence of the following factors on airtightness: • Type of the building structure

	• Type of the air barrier system • Target energy performance
Foreseen analyses	It is intended to repeat periodically the analyses mentioned above and to analyse the change in airtightness levels achieved. (However, over the past several years, the numbers of available test results are too small to be statistically relevant.)
Dates of operation	2001 – Present
Status	ABD.CZ database is a continuing project. Data collection started in 2001 and it will continue in the future as well as the analyses. The database structure described above is not fixed; rather it is continuously being developed and updated (e.g., in the future, the extent of the mandatory information will probably be reduced).
Number of data points	419 database records. Majority of the data are collected in 2009 and 2010.
Database software	Spreadsheet
Comments	Majority of the test results collected in the database is from low-energy and passive houses, and timber structure houses. These types of buildings are not common in the standard production of the Czech building industry. Therefore, the results of statistical analyses do not represent the average airtightness of the building stock in the Czech Republic. The database is presented as an ABD.CZ project. However it is the Czech Technical University that takes care of the development of the database, data collection, processing, and analyses. The plan is to make the database available for interested parties to support their analyses.
URL	http://www.asociaceblowerdoor.cz/
Contact	Jiri Novak, jiri.novak.4@fsv.cvut.cz Department of Building Structures (K124) Faculty of Civil Engineering, Czech Technical University
References	Novak, J., Tywoniak, J., Commonly achieved airtightness of Czech building stock, its causes and consequences. Proceedings of 1st European BlowerDoor Symposium 2006, Fulda, Germany, 2006. Novak, J., Airtightness of Czech passive houses. Proceedings of the 12th International Passive House Conference, Nurenberg, Germany, 2008. Novak, J., Tywoniak, J., Building airtightness in Czech technical standards and related documents – last updates. Proceedings of the 4th International Symposium on Building and Ductwork Air tightness (BUILDAIR), Berlin, Germany, 2009.

7.2 France

Database name	Web@set Database
Data type	Single- and multi-family housing, and some offices. Data include some pre- and post-retrofit measurements. Basic house characteristics, including year built, floor area, location, energy saving labels, building components, and heating and ventilating systems. Test methodology, and the main results of the infiltration test (Cl; n; French indicator $Q_{4pa\ surf}$; n_{50}; upper and lower confidence, etc.). The database also contains a list of codified leakage for each measure.
Purpose	• To allow pressurisation test operators to generate test reports using the Web@set Website. • To collect the data on a remote server. • To create a national leakage database that helps the legislator to assess the efficiency of measures and the progress that has been made.
Data source	For the moment, the database Web@set contains data from the work of CETE Southwest that have been done since 2005, under various research programs, low-energy programs, and regulatory compliance checks.
Availability of raw data	Not yet available. The Web@set platform is still under construction, but summary statistics may be available for subscribers and national institutions.
Analyses performed	Example analyses include influence of year of construction, building age, building type, construction type, improvement with regulations, influence of Quality Management approach, etc.
Foreseen analyses	The Web@set platform can perform online extraction of some results (e.g., query by constructive mode, year of construction).
Dates of operation	2005 – Present
Status	Under development
Number of data points	Approximately 150 detailed measures
Database software	Web@set platform will be a website
Comments	Reports and publications are expected in 2012
URL	Website under construction
Contact	Andrès Litvak (CDPEA) andres.litvak@cdpea.fr Fabrice Richieri (CETE-du-Sud-Ouest) Fabrice.Richieri@developpement-durable.gouv.fr

7.3 Germany

Database name	FLiB Statistik
Data type	Whole building: date of leakage test, temperatures, volume, leakage coefficient and exponent, n_{50}-value, type of building, year built, age, ventilation system, Standard / Method (A/B), type of test system, area/zip-code (first two digits)
Purpose	• Characterize air leakage of the building stock • Assess changes in air leakage over time • Inform regulations/standards • Evaluate improvements on buildings
Data source	Results delivered by members of FLiB
Availability of raw data	No
Analyses performed	Database was too small to analyse
Foreseen analyses	N/A
Dates of operation	2003 – 2009
Status	Not maintained
Number of data points	3,000
Database software	Spreadsheet
Comments	Data delivery was not effective. Statistical analyses will be resumed when data delivery has become easier, such as by using common blower door test software for reporting.
URL	www.flib.de
Contact	Oliver Solcher solcher@flib.de FLiB

7.4 UK

Database name	Two examples of reported air-tightness databases relating to dwellings are used for providing information for this document: • Database reported by Pan (2010); • BRE database reported by Stephen (2000). Other airtightness datasets exist in UK, largely in commercial organisations (e.g. testing consultancies and in-house R&D departments of large building firms) and in research domains. For example, according to the UK Building Regulations Part L (energy efficiency) and Part F (ventilation) 2010 consultation paper, a large number of pressure tests (approx. 3000) were carried out (DCLG 2009). However, there were no details of these results or the sampling available in the public domains because of the confidential and commercial nature of those tests.
Data type	Dwellings, which are normally categorised using the dwelling types that are specified in Part L1, i.e. detached, semi-detached, end-terrace, mid-terrace, mid-floor flat, ground-floor flat, and top-floor flat. Data types (or variables) often fall into groups including design, specification, construction, and testing. Specific variables include: year built, floor area, building envelope area, number of storeys, build method, and dwelling type. There are also some others, e.g. in Pan (2010), such as the number of significant penetrations through the building envelope, design target, management context, and season. Testing variables are often considered in more experimental studies.
Purpose	• *Regulatory*: Airtightness testing has been made a legal requirement for nearly all new non-domestic buildings and a sample of new dwellings since the revision of Building Regulations Part L in 2006 (England and Wales). • *Policy*: Building energy efficiency has been realised to be critical to achieving the UK Government's targets for all new homes to be "zero carbon" from 2016. • *Premium standards*: The worst possible air permeability allowable is 10 $m^3/(h\ m^2)$ at 50 Pa; sites with commitment to higher environmental standards may have a requirement for lower air permeability rates and will require additional measures to achieve the standards. • *Risks of failure to comply*: Failure to comply with required airtightness standards will generate significant additional costs because of rectification, and will also introduce considerable risks to business due to potential delays and increased dwelling sample size for testing. • *Certainties / consistency of practice*: Too low built air permeability will require rethinking the ventilation strategy for ensuring good indoor air quality. It is important to strike a balance between air-tightness and ventilation and to achieve designed air permeability in a consistent manner. Ideally, airtightness could be predicted consistently.
Data source	Research programmes; Building Regulations Part L compulsory testing; data provided by testing consultancies and building firms

Availability of raw data	Not publicly
Analyses performed	• One-way ANOVA analysis for examining air permeability • In relation to the individual factors around design, specification and construction (detailed above). • Two- and three-way ANOVA analyses for examining the interactions between the factors/ variables. • Linear regression technique for developing a predictive model for estimating air permeability of dwellings.
Foreseen / potential analyses	• Comparative studies drawing on larger/ national level databases in a more structured way. • Expanded analysis using linear regression techniques for evaluating the predictive model, in order to estimate air permeability of dwellings in a more consistent way. • Analysis of airtightness in relation to ventilation, cost-effectiveness and energy consumption in occupied structures.
Dates of operation	Pan (2010): post-2006 BRE database (Stephen 2000): unknown
Status	Most likely maintained individually, while further development is needed if better value is to be elicited.
Number of data points	Pan (2010): n=287; built post-2006 BRE database (Stephen 2000): n=384; built pre-1994
Database software	Spreadsheet
Comments	Non-domestic buildings are not covered herein, while Part L 2006 introduced airtightness testing as a legal requirement for nearly all new non-domestic buildings as well. Airtightness testing in Scotland and North Ireland is not covered in this document.
URL	N/A
Contact	Wei Pan wei.pan@plymouth.ac.uk Plymouth University
References	• Pan, W. (2010) Relationships between air-tightness and its influencing factors of UK post-2006 new-build dwellings. Building and Environment, 45(11), 2387-99. • Stephen, R. (2000) Airtightness in UK dwellings. Watford: BRE. Information paper IP1/00. • DCLG (2009) Proposals for amending Part L and Part F of the building regulations - consultation. London, Department for Communities and Local Government (DCLG).

7.5 USA (Commercial and Institutional Buildings)

Database name	NIST Commercial and Institutional Building Envelope Leakage Database
Data type	Whole buildings, including some multi-family buildings. Some data include pre- and post-retrofit measurements. Basic building characteristics, including year built, floor area, number of storeys, location, and wall construction type for many buildings.
Purpose	To establish default values, to estimate the energy savings potential of improvements via standards and codes, and to identify progress needed.
Data source	Research programmes, low-energy programmes, data provided by pressurization companies, and others.
Availability of raw data	Not publicly available
Analyses performed	Influence of year of construction, age, building type, wall construction type, improvement with regulations
Foreseen analyses	Pre- and post-retrofit
Dates of operation	1985 – Present
Status	On-going
Number of data points	Over 250
Database software	Spreadsheet
Comments	New publication expected in 2012
URL	N/A
Contact	Steven Emmerich steven.emmerich@nist.gov National Institute of Standards and Technology
References	Emmerich, S.J., Persily A.K. 2011. U.S. Commercial building airtightness requirements and measurements. Proceedings of the 32nd Air Infiltration and Ventilation Centre Conference. Emmerich, S.J. 2007. Impacts of airtightness on energy use. Journal of Building Enclosure Design, publication of Building Enclosure Technology and Environment Council of the National Institute of Building Sciences Emmerich, S.J., Anis, W., McDowell, T.P. 2007. Simulation of the impact of commercial building envelope airtightness on building energy utilization. ASHRAE Transactions, Vol. 118 (2). Emmerich, S.J., Persily, A.K. 2005. Airtightness of commercial buildings in the U.S. Proceedings of the 25th Air Infiltration and Ventilation Centre Conference.

7.6 USA (Residential Buildings)

Database name	LBNL Residential Diagnostics Database (ResDB)
Data type	Whole building, single point data of single-family detached dwellings; also includes some multi-family and mobile homes. Many data include pre- and post-retrofit measurements. Basic house characteristics, including year built, floor area, number of storeys, location, foundation type, and duct system. Small fraction of the dataset contains more extensive information, including retrofit measures, appliances specifications, indoor air quality measurements, and energy bills.
Purpose	• Provide air leakage data for US Department of Energy's assessment of expected home energy savings (Home Energy Saver Programme/ Home Energy Score Online Tool). • Provide spatially resolved, house-characteristic dependent residential air leakage distribution for energy, indoor air quality, and exposure modelling. • Subsequent analysis will inform California building code Title 24 ventilation requirements.
Data source	Research programmes, EPA EnergyStar certifications, energy efficiency programmes, weatherization assistant programmes, state compliance checks, data provided by independent energy auditors.
Availability of raw data	No, but summary statistics will be available online.
Analyses performed	Influence of year of construction, age, building size (floor area, height), construction type (foundation type, duct system), pre- and post- retrofit measurements, climate zone, and programmatic/state-by-state differences.
Foreseen analyses	More spatially resolved and detailed analysis for California. Preliminary analysis of duct blaster measurements. Summary statistics for multi-family homes.
Dates of operation	1997 – Present
Status	Data collection completed 2011. Analysis completed in 2012.
Number of data points	Approximately 175,000 homes. Testing data since 1980's.
Database software	Open source date management system (PostgreSQL)
Comments	Reports and publications are expected in 2012. Future work subject to availability of continuing funding.
URL	http://resdb.lbl.gov
Contact	W. Rengie Chan wrchan@lbl.gov Lawrence Berkeley National Laboratory
References	Development of a mathematical air-leakage model from measured data. McWilliams and Jung, 2006, LBNL Report #59041. Analyzing a database of residential air leakage in the United States. Chan, Nazaroff, Price, Sohn and Gadgil 2005, Atmospheric Environment; 39, 3445-3455.

	Air-Tightness of U.S. Dwellings. Sherman and Dickerhoff, 1998, LBNL Report #35700. Residential ventilation and energy characteristics. Sherman and Matson, 1997, LBNL Report #39036.

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The Centre provides technical support in air infiltration and ventilation research and application. The aim is to provide an understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

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