



# Why is sound insulation between dwellings in renovated housing not upgraded like other qualities?

**Birgit Rasmussen**

Danish Building Research Institute (SBI), Aalborg University (AAU-CPH), Copenhagen, Denmark  
[bir@sbi.aau.dk](mailto:bir@sbi.aau.dk)

## **Abstract**

In Europe (EU-28), about 40% of the inhabitants live in flats in multi-family housing. According to social surveys in several European countries, many people in multi-family housing are annoyed by neighbour noise, which is considered a health problem. To protect health, building regulations in most countries specify minimum requirements for sound insulation in new housing. However, national acoustic regulations were typically implemented in the 1960's or later. About half of the European housing stock was built earlier and in most cases far from fulfilling the present national regulations, depending on the construction types, which vary across Europe and over time.

Renovation of housing has been quite extensive during the last decades. Typically, renovation and upgrading of housing have included repair or replacement of roof, windows, installations, kitchen, bath, balconies etc. and with strong focus on energy savings. Although no registrations, it's the impression among acoustic experts that renovation very seldom includes improvement of sound insulation between dwellings. There are a number of reasons for not upgrading or even considering upgrading sound insulation, e.g. lack of regulatory policies, lack of acoustic issues on check lists, lack of knowledge or simply lack of attention, implying that upgrading is opted out, before even evaluated on equal terms with other improvements.

The paper will discuss the above issues, describe examples from selected countries in Europe about efforts to change in a direction with acoustic issues taken into account. Furthermore, suggestions for joint efforts to improve the situation will be provided.

**Keywords:** sound insulation, requirements, housing, retrofitting, quality classes.

**PACS no.** 43.55.-n, 43.15.+s

## **1 Introduction**

WHO has defined health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity", cf. [1]. As a consequence, noise effects on health should not simply be understood as the adverse physical effects due to noise exposure, but also as disturbance of well-being, i.e. psychological effects of noise, which in the long term may lead to not only lack of well-being, but also to adverse physical effects. These effects can be medical conditions, but can also include sleep disturbance, stress etc. - Acoustical well-being can be characterized as absence of unwanted sound, presence of desired sounds with the right level and quality and opportunities for activities without being heard by other people or annoying them. Acoustical well-being is thus also related to own and neighbours' privacy and to freedom to practise activities within reasonable limits.



If the sound insulation between dwellings is insufficient, disturbance of activities and sleep disturbance are typical consequences, and reactions may go in different directions, e.g. annoyance may develop to hatred and conflicts or disturbance to tension, depression and tiredness, cf. description of the noise reaction process in [2]. Another consequence of insufficient sound insulation might be that occupants choose to renounce own activities and feel compelled to avoid certain activities from the household, because they fear neighbours' feelings or reactions - or they know by experience that neighbours get disturbed or annoyed. A typical example could be that parents prevent small children from playing in the home due to complaints from neighbours, and sooner or later they might choose to move to housing with better sound insulation or a one-family house. The brief explanations above illustrate a few of many examples on how the social well-being can suffer from insufficient sound insulation.

A potential, adverse influence on health is the main reason for having minimum airborne and impact sound insulation requirements in many countries, but the requirements are typically valid for new housing. However, a big part of the housing stock in Europe has been built before implementation of building regulations, and with a sound insulation typically much lower than for new housing. In addition, improvements of sound insulation are seemingly seldom included in housing renovation, e.g. due to lack of knowledge, focus, policies and regulations.

When considering promoting sound insulation improvements in renovation projects, the basis for discussion and development of tools is information about the existing housing stock, the current national requirements for new housing as well as the systems, decision processes and practices applied for renovation of existing housing. In Section 2 is given a brief introduction about the European housing stock and references for more information. Current sound insulation regulations are dealt with in Section 3. In Section 4 is found a summary with references about the neighbour noise annoyance in Europe, and tools for promoting sound insulation improvements are presented in Section 5.

## 2 The European population and housing stock

The population in EU-28 is over 500 million inhabitants, and there are above 200 million dwellings according to Eurostat or other sources. A profile of the housing stock in Europe is found in [3] and country descriptions in [4]. Eurostat has published census data about population and housing, see e.g. [5], [6] and [7]. The below Figure 1 (from [6]) shows distribution of dwelling types for the individual countries in EU28+, sorted according to decreasing % of flats in the countries. In 2014, 4 out of every 10 persons in the EU-28 lived in flats, see [5].

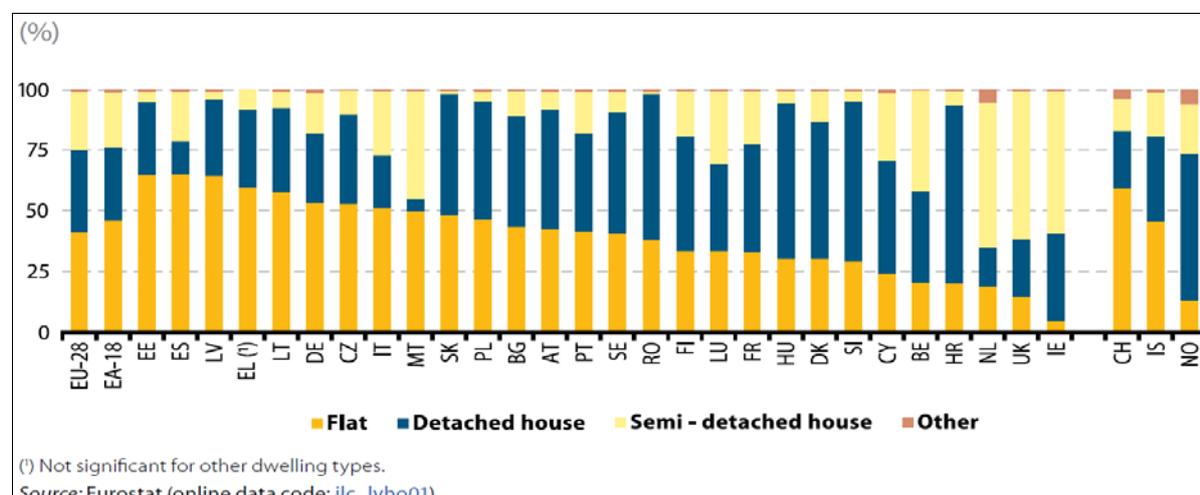


Figure 1 – Distribution of population by dwelling type in EU 28, 2012. Figure from [6].



It was the intention to get newer and absolute data from the Census Hub, which in December 2014 was announced as “a new, easy and flexible way to access population and housing census data from all EU countries”, cf. [5]. However, it turned out that data were not easy to find, and the main link in the leaflet in [5] just led to “Not found”. Diagrams found in [5], [6] and [7] were typically related to social issues and not to counting dwellings in total or types of dwellings. Nevertheless (by help from a colleague) some data for flats and total number of dwellings according to year/period of construction were found for countries in EU-28+ and summed up, see Figure 2 (and notes in the caption). The year of construction is important to identify construction types and evaluate sound insulation, especially from before regulations existed. As construction practice varies across Europe, this should be done on a national basis as e.g. in [24]. Examples from some other countries are found in [4].

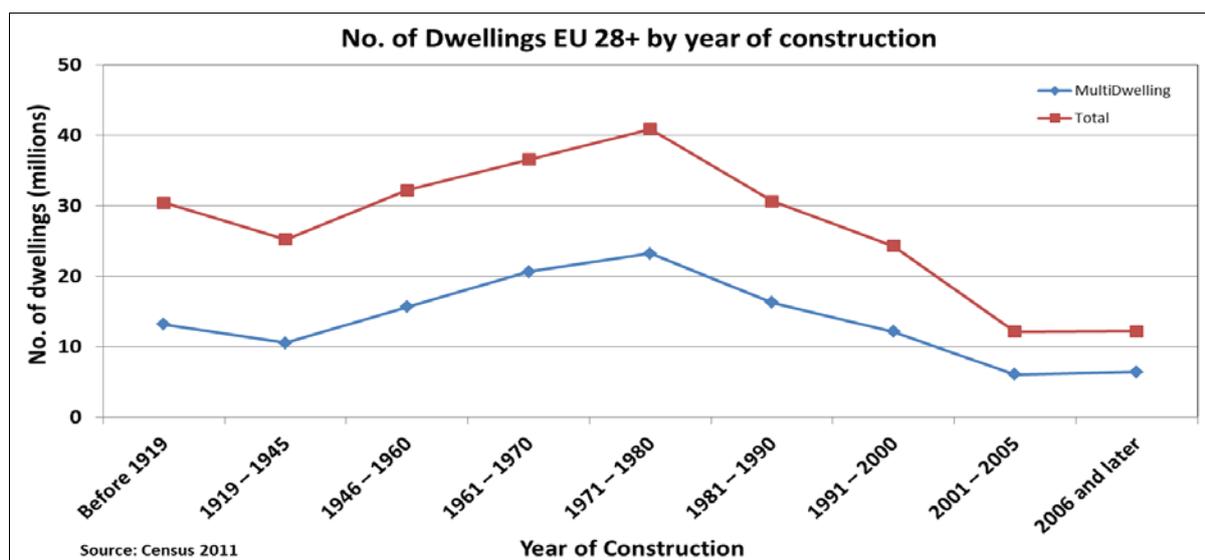


Figure 2 – Number of dwellings (in total and in multi-family housing) in EU-28+ by year of construction.

Note 1: Data from <https://ec.europa.eu/CensusHub2>. The database does not have the category “multi-family”, only dwellings in buildings with three or more dwellings, which is used here as a substitute, although it may be incorrect.

Note 2: Periods vary and are the same as appearing in the data source, i.e. unknown, 27, 15, 4 x 10, 5, approx. 5 years.

There exist many other publications with housing information, e.g. [8]. When comparing data from different countries (or data from different sources), it is important to know that data may not be directly comparable, e.g. in some countries, second homes, hotels, caravans, ships are included, in others not, see Ch.3 in [8].

### 3 Sound insulation requirements and acoustic classification for dwellings

Building regulations specify minimum requirements about acoustical conditions for new dwellings in most countries in Europe. When considering upgrade of sound insulation for older housing, the current regulations could be the goal - or as close as possible. Studies of regulatory requirements for sound insulation between dwellings in multi-storey housing - new-build - are described in detail in [9] and [10]. In Figures 3 and 4 (from [10]) are found diagrams illustrating the airborne and impact sound insulation requirements, respectively. Although some limit values may have changed slightly since the study, the overall picture remains the same. It is seen that especially the requirements for impact sound differ considerably across Europe. The reasons have not been investigated, but could be a mix of construction traditions and culture etc. For more details, see [9] and [10].

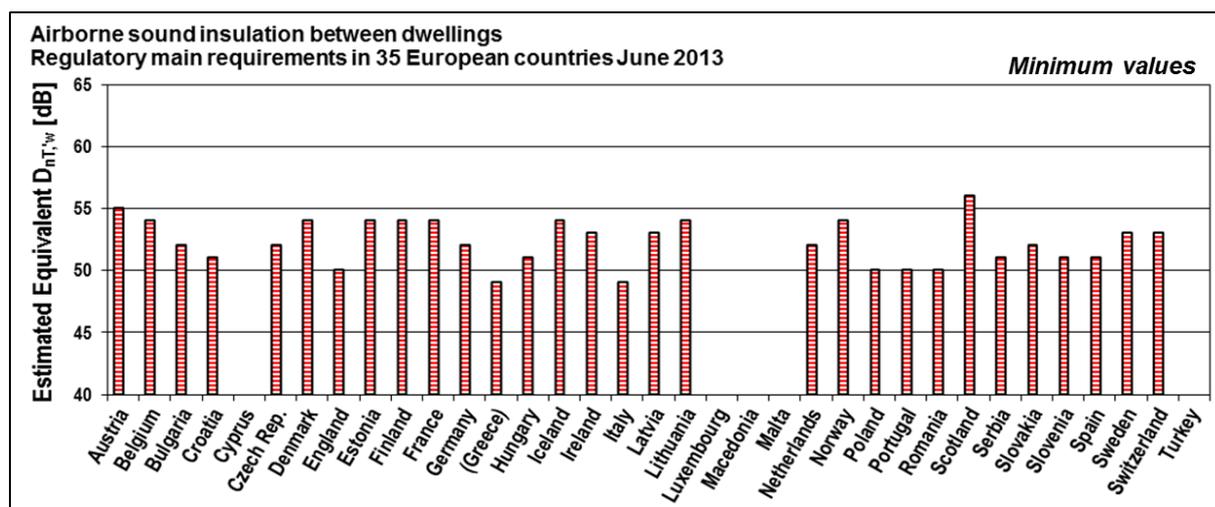


Figure 3 – Overview of airborne sound insulation requirements between dwellings. Status 2013. Graphical presentation of estimated equivalent values of  $D_{nT,w}$ . Note: The equivalent values are estimates only, as exact conversion is not possible. Figure from [10].

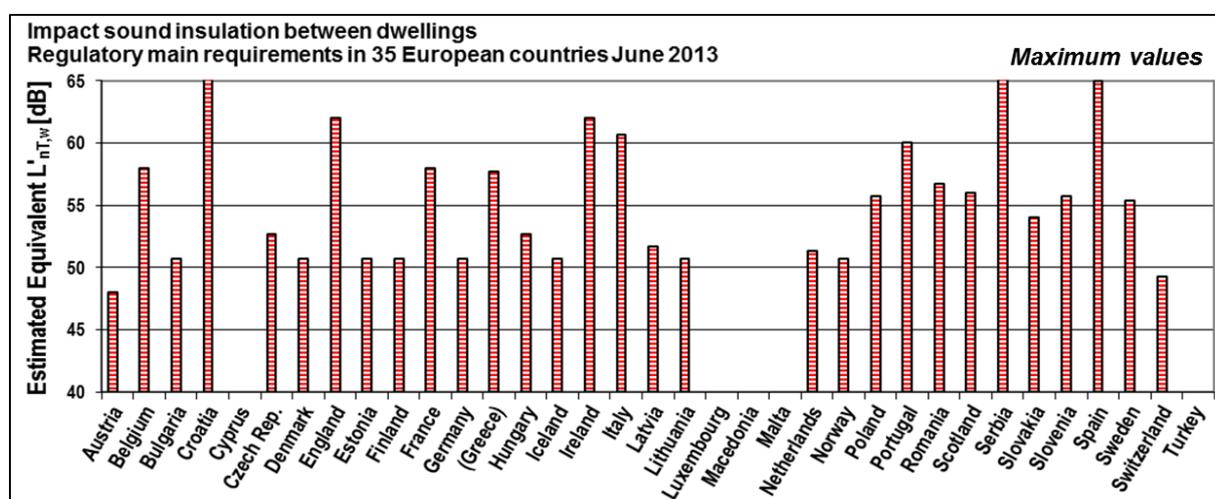


Figure 4 – Overview of impact sound insulation requirements between dwellings. Status 2013. Graphical presentation of estimated equivalent values of  $L'_{nT,w}$ . Note: The equivalent values are estimates only, as exact conversion is not possible. Figure from [10].

New housing is expected to fulfil current sound insulation requirements, but there is in general little knowledge about enforcement and the degree of compliance. In addition, complying with regulatory requirements does not guarantee satisfactory conditions for the occupants, and since the early 1990s, several countries have developed and introduced acoustic classification schemes with classes reflecting different levels of acoustical protection. The purpose is to make it easier for developers to specify and for users to require a standardized acoustic quality better than the quality defined by regulations. Acoustic classification schemes in Europe are national schemes. An overview of existing acoustic classification schemes for dwellings [11] to [20] is found in Table 1. For each scheme listed, the class denotations and the relation to the national building code are indicated. Information about an international proposal is found in [21] and [22]. Tables with specific main class criteria for airborne and impact sound insulation are found in [23].



Table 1 – European schemes for acoustic classification of dwellings and relation to building codes. A proposal prepared by COST TU0901 and now ISO/WI 19488 has been included for comparison. Status April 2016.

Country	Year of publication	CS Reference (latest version)	Class denotations <sup>(1)</sup>	BC link to CS	BC Reference to CS	Comment
DK [11]	2001/2007	DS 490 (2007)	A / B / C / D	+	Class C	
FI [12]	2004	SFS 5907 (2004)	A / B / C / D	-	N/A	BC = Class C
IS [13]	2003/2011/2016	IST 45 (2016)	A / B / C / D	+	Class C	
NO [14]	1997/2005/2008/2012	NS 8175 (2012)	A / B / C / D	+	Class C	
SE [15]	1996/1998/2004/2015	SS 25267 (2015)	A / B / C / D	-	N/A	See note (4)
LT [16]	2003	STR 2.01.07 (2003)	A / B / C / D / E	+	Class C	
IT [17]	2010	UNI 11367 (2010)	I / II / III / IV	-	N/A	BC ~ Class III
DE [18]	1994/2007/2012	VDI 4100 (2012) <sup>(2),(3)</sup>	III / II / I	-	N/A	
AT [19]	2012	ÖNORM B 8115-5 (2012)	A / B / C / D / E	-	N/A	BC = Class C
NL [20]	1999	NEN 1070 (1999)	I / II / III / IV / V	-	N/A	BC ~ Class III
ISO/WI	TU0901 (2013) ISO/WI since 2014	ISO/WI 19488 See [21], [22]	A/B/C/D/E/F and npd	N/A	N/A	See note (5)

Abbreviations: BC = Building Code (regulatory requirements); CS = Classification scheme

(1) Classes are indicated in descending order, i.e. the best class first.

(2) In addition to VDI 4100, the German Society of Acoustics (DEGA) has published a recommendation (DEGA-Empfehlung 103, "Schallschutz im Wohnungsbau – Schallschutzausweis", DEGA, March 2009) for acoustic labelling of dwellings. The system has seven classes A\*-F and a colour code.

(3) The revised version of VDI 4100 published in 2012 changed descriptors from  $R'_w$  and  $L'_{n,w}$  to  $D_{nT,w}$  and  $L'_{nT}$ , as had been discussed for years for the regulations. Also the class criteria were made stricter, and all classes are now stricter than regulations (before the lowest class corresponded to regulations).

(4) SS 25267 (2015) does not include class C criteria, but refers to values in the BC as class C.

(5) Proposal prepared by COST TU0901 in 2013. ISO/WI 19488 from 2014, see [22], ISO/CD expected in 2016.

It is obvious to think that acoustic classification could be applied for existing housing before renovation, if available with lower classes suitable for old housing. From Table 1 and [23] it is seen that the five Nordic countries and Italy have one quality class below regulations, Lithuania, Austria and the Netherlands have two classes. Germany (VDI4100) has none, thus following the original idea of acoustic classes to be only/mainly for specifying better acoustic conditions than regulations. To sum up briefly, the existing acoustic classification schemes do not in general include acoustic classes fitting major parts of the existing housing stock. In [24], which includes mapping of the Danish housing stock, i.e. number of dwellings according to construction year, constructions and estimated sound insulation, it is suggested to extend the present DS 490, see Table 1 and [11], with two lower classes E and F.

Another important issue is how building regulations deal with sound insulation, when renovating housing. Here, more sides are relevant, as both the actual contents of the regulations and how it is dealt with by the builders and building industry and enforced by the authorities. A small, simple survey was made by looking into the regulations in selected countries, in some cases by asking acoustic colleagues. Concerning policies for renovating or retrofitting, the most clear rules exist for change of use of a building (or parts of it), where requirements are the same as for new-build, e.g. when offices are converted to flats. Other general findings are that it is not (for the same use) allowed to degrade the sound insulation, and new partitions should fulfil current regulations. In some countries the rules are linked to whether a building permit is needed, and if so the current rules for new-build must be complied with. In general, technical possibilities are taken into account, and cultural heritage must be preserved. An initiative from Spain about preparing – before retrofitting old housing for public funds – an Existing Building Evaluation Report is interesting and might be considered, when updating procedures in other countries. Although the aim may already exist in most procedures, the detailing about acoustics and related guidelines in the building code seems worthwhile studying, see [25] - [27].



## 4 Neighbour noise annoyance in Europe

Before discussing initiatives aiming at improving sound insulation in existing housing, it is relevant to know the extent of the problem and the public interest in the issue. However, noise annoyance is included in many national health surveys aiming at providing a national overview of the health situation, and the results of health surveys are useful for planning and prioritizing public health services, disease prevention and health policy. Studies are also made at a more international level, cf. e.g. the WHO assessment report for Europe [28] addressing the environmental health inequalities in Europe and pointing out noise exposure at home as one of the environmental health inequality indicators. The WHO report includes compiled main data for 30 countries, based on Eurostat's EU-SILC data, [28]. There was only one noise question combining all types of noise in one question with answer options Yes and No: *“Do you have any of the following problems related to the place where you live?”*, including answer category *“Too much noise in your dwelling from neighbours or from outside (traffic, business, factory, etc.)”*. Different survey modes were applied for the interviews. The prevalence for EU (28 countries) was 19% for 2013, with country results in the range 10-30 %. Although providing an indication of the overall noise problem subjectively evaluated, such simplification lead to results that are insufficient as a basis for qualified decisions on relevant actions for improvements of housing, because the results don't reveal type of noise and whether the noise comes through the window, floor or wall.

Considering the ongoing and expected extensive renovation of housing all over Europe, much more attention to improvement of sound insulation between dwellings should be promoted, as it now appears to be a non-topic in spite of the importance to occupants of dwellings, evaluated from the prevalence of neighbour noise annoyance in several surveys, see e.g. results for Denmark in [29] with 33 % of occupants in multi-storey housing disturbed by neighbour noise and 16 % by traffic noise. Some main findings from German studies and references are included in [29].

## 5 Tools for promoting sound insulation improvements in housing

Based on findings described, the following tools could be recommended aiming at promoting and facilitating upgrading of sound insulation in multi-storey housing, when renovating:

- Assessment of acoustic performance should be a part of the building evaluation before renovation.
- Revise acoustic classification schemes to include lower classes appropriate for existing dwellings (like for energy labelling).
- Prepare a national catalogue of typical housing constructions and related sound insulation.
- Describe retrofitting cases in “Good Practice” publications.
- Revise building regulations to include more clear requirements or recommendations for improving sound insulation, when renovating housing.
- Information to builders, contractors and authorities about importance of sound insulation and solutions.
- Construction solutions to be developed further – innovation needed.
- Building authorities might pay more attention to the sound insulation issue and enforcement.

## 6 Conclusions

Most European countries have regulatory requirements for sound insulation between dwellings in multi-storey housing, mainly intended and applied for new housing and thus in many countries not describing rules for housing renovation. However, more than half of the European housing stock was built before acoustic regulations were implemented, and due to extensive renovation of the housing



stock in most countries and the seemingly very limited attention to upgrading of sound insulation, tools for promoting sound insulation improvement have been identified, hoping that joint efforts could lead to more focus on the issue and the recommended tools could prove useful.

## Acknowledgements

The author is grateful to those acoustic colleagues in Europe, who provided a first input on national policies for sound insulation of retrofitted housing. It is hoped that future cooperation could help develop and implement tools and practice, thus promoting improvement of sound insulation in existing housing.

## References

- [1] Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19 - 22 June 1946; signed on 22 July 1946 by the representatives of 61 states (official Records of the World Health Organization, No. 2, p. 100) and entered into force on 7 April 1948.
- [2] C. J. Grimwood (1993). *Effects of environmental noise on people at home*. BRE information paper IP 22/93. Building Research Establishment, UK.
- [3] Smith, S., *Profiling existing and new build housing stock*. Ch. 1 in COST Action TU0901 – Building acoustics throughout Europe. Volume 1: Towards a common framework in building acoustics throughout Europe. DiScript Preimpresion, S. L., 2014. p. 13-30. <http://www.costtu0901.eu/tu0901-e-books/volume-1.html>
- [4] Rasmussen, B., Machimbarrena, M., & Fausti, P. (red.) (2014). *COST Action TU0901 – Building acoustics throughout Europe. Volume 2: Housing and construction types country by country*. DiScript Preimpresion, S. L. <http://www.costtu0901.eu/tu0901-e-books.html>
- [5] <http://ec.europa.eu/eurostat/web/population-and-housing-census/overview>;  
<http://ec.europa.eu/eurostat/documents/4031688/6285607/KS-02-14-480-EN-N.pdf/05b4ca91-1f72-4dbb-ae2c-d3a07f56d795>; [http://ec.europa.eu/eurostat/statistics-explained/index.php/Housing\\_statistics](http://ec.europa.eu/eurostat/statistics-explained/index.php/Housing_statistics)
- [6] Eurostat. (2014). *Living conditions in Europe - 2014 Edition*. Eurostat Statistical books, European Union. Luxembourg: Publications Office of the European Union, 2014.  
<http://ec.europa.eu/eurostat/documents/3217494/6303711/KS-DZ-14-001-EN-N.pdf/d867b24b-da98-427d-bca2-d8bc212ff7a8>
- [7] Eurostat. (2015). *Key figures on Europe 2015 edition*. Eurostat Statistical books, European Union. Luxembourg: Publications Office of the European Union.  
<http://ec.europa.eu/eurostat/documents/3217494/7072644/KS-EI-15-001-EN-N.pdf/318ee884-50d6-48f0-b086-4410da85d6b6>
- [8] The Hague: Ministry of the Interior and Kingdom Relations. (2010). *Housing Statistics in the European Union 2010*. OTB Research Institute for the Built Environment, Delft University of Technology.
- [9] Rasmussen, B. (2010). *Sound insulation between dwellings - Requirements in building regulations in Europe*. Applied Acoustics. 71(4):373-385. Available from: [10.1016/j.apacoust.2009.08.011](http://dx.doi.org/10.1016/j.apacoust.2009.08.011)
- [10] Rasmussen, B., Machimbarrena, M., *Existing sound insulation performance requirements and classification schemes for housing across Europe*. Ch. 2 in COST Action TU0901 – Building acoustics throughout Europe. Volume 1: Towards a common framework in building acoustics throughout Europe. DiScript Preimpresion, S. L., 2014. p. 31-54. <http://www.costtu0901.eu/tu0901-e-books/volume-1.html>
- [11] DS 490:2007, *Lydklassifikation af boliger*. (Sound classification of dwellings), DK.
- [12] SFS 5907:2004, *Rakennusten Akustinen Luokitukset*, Finland. English version “Acoustic classification of spaces in buildings” published in July 2005.



- [13] IST 45:2016, *Hljóðvist - Flokkun íbúðar- og atvinnuhúsnæðis* (Acoustic conditions in buildings - Sound classification of various types of buildings), Icelandic Standards, Iceland.
- [14] NS 8175:2012, *Lydforhold i bygninger - Lydklasser for ulike bygningstyper* (Acoustic conditions in buildings - Sound classification of various types of building), Standards Norway.
- [15] SS 25267:2015, *Byggakustik – Ljudklassning av utrymmen i byggnader – Bostäder* (Acoustics – Sound classification of spaces in buildings – Dwellings). Swedish Standards Institute, Stockholm, Sweden.
- [16] STR 2.01.07:2003, *Dél Statybos Techninio Reglamento Str 2.01.07:2003, Pastatu Vidaus Ir Isores Aplinkos Apsauga Nuo Triuksmo* (Lithuanian building regulations. Protection against noise in buildings). Patvirtinimo, Lithuania.
- [17] UNI 11367:2010 *Acustica in edilizia – Classificazione acustica delle unità immobiliari – Procedura di valutazione e verifica in opera* (Building Acoustics - Acoustic classification of building units - Evaluation procedure and in-situ measurements)
- [18] VDI 4100:2012, *Schallschutz im Hochbau - Wohnungen - Beurteilung und Vorschläge für erhöhten Schallschutz* (Sound insulation between rooms in buildings - Dwellings - Assessment and proposals for enhanced sound insulation between rooms". VDI-Handbuch Lärminderung. Beuth, Germany.
- [19] ÖNORM B 8115-5:2012. *Schallschutz und Raumakustik im Hochbau - Teil 5: Klassifizierung*. (Sound insulation and room acoustics in buildings - Classification). ÖNORM, Austria.
- [20] NEN 1070:1999, *Geluidwering in gebouwen – Specificatie en beoordeling van de kwaliteit* (Noise control in buildings – Specification and rating of quality), Netherlands.
- [21] ISO/TC43/SC2 N1203 NWIP, Acoustics - Acoustic classification scheme for dwellings (Oct.2013); ISO/TC43/SC2 N1218 Annex to N1203 COST TU0901 Proposal Acoustic Classification (Nov.2013). ISO/TC43/SC2 N1244 Voting results ISO/NP 19488 (March 2014). ISO/TC43/SC2/WG29 established May 2014 to do the work.
- [22] Rasmussen, B. (2014). *International proposal for an acoustic classification scheme for dwellings: background and perspectives*. Proceedings of Inter-Noise 2014, Australian Acoustical Society.
- [23] Rasmussen, B. (2012). *Sound classification of dwellings - Quality class ranges and intervals in national schemes in Europe*. Proceedings of EuroNoise 2012. (s.1178-1183). European Acoustics Association - EAA. (Euronoise, Vol. 2012).
- [24] Rasmussen, B. & Hoffmeyer, D. (2015). *Lydisolation mellem boliger i etagebyggeri – Kortlægning og forbedringsmuligheder* (Sound insulation between dwellings in multi-storey housing - Mapping and possibilities for improvements). Copenhagen, SBI Report No. 2015:27.
- [25] Documento Básico HR (2009). *Protección frente al ruido* (Protection Against Noise). Ministerio de Fomento. <http://www.codigotecnico.org/images/stories/pdf/proteccionRuido/DBHR.pdf>.
- [26] Ministerio de Fomento. (2013). *IEE informe de Evaluación del Edificio* (Bygningvurderingsrapport). Gobierno de España. <https://iee.fomento.gob.es>.
- [27] Carrascal García, T., Romero Fernández, A., & Casla Herguedas, B. (2015). *Noise Requirements in Existing Buildings in Spain: New Proposals and the Existing Building Evaluation Report*. Proceedings of EuroNoise2015, p. 1889-1894. Maastricht.
- [28] WHO (2012). *Environmental health inequalities in Europe: Assessment report*. World Health Organization Regional Office for Europe, Copenhagen. [www.euro.who.int/\\_data/assets/pdf\\_file/0010/157969/e96194.pdf](http://www.euro.who.int/_data/assets/pdf_file/0010/157969/e96194.pdf).  
Note: The report includes SILC data ([http://ec.europa.eu/eurostat/web/products-datasets/-/ilc\\_mddw01](http://ec.europa.eu/eurostat/web/products-datasets/-/ilc_mddw01)).
- [29] Rasmussen, B. & Ekholm, O. (2015). *Neighbour and traffic noise annoyance at home - prevalence and trends among Danish adults*. Proceedings of EuroNoise 2015, p. 1895-1900. Maastricht.