Annex 51

Acoustic Signatures of Heat Pumps

Final Report – Part 4

1.2 Regulations - Countries overview

Editor:
Roberto Fumagalli, Politecnico di Milano
Philipp Wagner, Technischen Universität Graz, Institute für Wärmetechnik
Robert Pratter, Technischen Universität Graz, Institute für Wärmetechnik
René Rieberer, Technischen Universität Graz, Institute für Wärmetechnik François Bessac, CETIAT Centre Technique des Industries Aérauliques et Termiques Michèle Mondot, CETIAT Centre Technique des Industries Aérauliques et Termiques Henrik Hellgren, Chalmers University of Technology, Goteborg
Agostino Troll, Fraunhofer Institute for Building Physics IBP, Stuttgart
Pawel Lachman, PORTPC – Polish Heat Pump Association

November 2020

Report no. HPT-AN51-4

Published by

Heat Pump Centre
c/o RISE – Research Institutes of Sweden
Box 857, SE-501 15 Borås
Sweden
Phone +46 10 16 53 42

Website

https://heatpumpingtechnologies.org

Legal Notice

Neither the Heat Pump Centre nor any person acting on its behalf:
(a) makes any warranty or representation, express or implied, with respect to the information contained in this report; or
(b) assumes liabilities with respect to the use of, or damages, resulting from, the use of this information.
Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement recommendation or favoring.
The views and opinions of authors expressed herein do not necessarily state or reflect those of the Heat Pump Centre, or any of its employees. The information herein is presented in the authors' own words.

Production

Heat Pump Centre, Borås, Sweden

ISBN 978-91-89561-59-5
Report No. HPT-AN51-4

Preface

This project was carried out within the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP), which is a Technology Collaboration Programme within the International Energy Agency, IEA.

The IEA
The IEA was established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration, currently within the framework of nearly 40 Technology Collaboration Programmes.

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)
The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) forms the legal basis for the implementing agreement for a programme of research, development, demonstration, and promotion of heat pumping technologies. Signatories of the TCP are either governments or organizations designated by their respective governments to conduct programmes in the field of energy conservation.

Under the TCP, collaborative tasks, or “Annexes”, in the field of heat pumps are undertaken. These tasks are conducted on a cost-sharing and/or task-sharing basis by the participating countries. An Annex is in general coordinated by one country which acts as the Operating Agent (manager). Annexes have specific topics and work plans and operate for a specified period, usually several years. The objectives vary from information exchange to the development and implementation of technology. This report presents the results of one Annex.

The Programme is governed by an Executive Committee, which monitors existing projects and identifies new areas where collaborative effort may be beneficial.

Disclaimer
The HPT TCP is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes or TCPs. The TCPs are organized under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Views, findings and publications of the HPT TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

The Heat Pump Centre
A central role within the HPT TCP is played by the Heat Pump Centre (HPC).

Consistent with the overall objective of the HPT TCP, the HPC seeks to accelerate the implementation of heat pump technologies and thereby optimize the use of energy resources for the benefit of the environment. This is achieved by offering a worldwide information service to support all those who can play a part in the implementation of heat pumping technology including researchers, engineers, manufacturers, installers, equipment users, and energy policy makers in utilities, government offices and other organizations. Activities of the HPC include the production of a Magazine with an additional newsletter 3 times per year, the HPT TCP webpage, the organization of workshops, an inquiry service and a promotion programme. The HPC also publishes selected results from other Annexes, and this publication is one result of this activity.

For further information about the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) and for inquiries on heat pump issues in general contact the Heat Pump Centre at the following address:

Heat Pump Centre
c/o RISE - Research Institutes of Sweden
Box 857, SE-501 15 BORÅS, Sweden
Phone: +46 10 516 53 42
Website: https://heatpumpingtechnologies.org

Acoustic Signatures of Heat Pumps

IEA HPT Annex 51

1.2: Regulations - Countries overview

Roberto Fumagalli, Politecnico di Milano
Philipp Wagner, Technischen Universität Graz, Institute für Wärmetechnik
Robert Pratter, Technischen Universität Graz, Institute für Wärmetechnik
René Rieberer, Technischen Universität Graz, Institute für Wärmetechnik
François Bessac, CETIAT Centre Technique des Industries Aérauliques et Termiques
Michèle Mondot, CETIAT Centre Technique des Industries Aérauliques et Termiques
Henrik Hellgren, Chalmers University of Technology, Goteborg
Agostino Troll, Fraunhofer Institute for Building Physics IBP, Stuttgart
Pawel Lachman, PORTPC – Polish Heat Pump Association

Date: November 2020	Final Version, Review: 05

Index

1 Introduction 8
2 European Standards 9
2.1 Product standards 9
2.2 Generic standards on acoustics 9
2.3 Standards for sound power level determinations 10
2.3.1 EN ISO 3741 11
2.3.2 EN ISO 3744 12
2.4 Other useful standards and documents 12
2.5 EN 12102 contents 12
2.5.1 Scope 12
2.5.2 Generic acoustic standards and classes of measurement 13
2.5.3 Operating conditions 14
2.5.4 Installation and setting requirements 14
2.5.5 Some sound power measurements 15
2.6 EN 12102-2 15
2.7 EN 12102: an harmonized standard 17
3 European regulations on noise 19
3.1 Regulation n°206/2012 19
3.2 Regulation n°626/2011 20
3.3 Regulation n°813/2013 21
3.4 Regulation n°811/2013 21
3.5 Regulation n°814/2013 23
3.6 Regulation n°812/2013 24
3.7 Market surveillance 24
4 Ecolabel 25

5 European certification schemes....26
5.1 Eurovent Certified Programmes....26
5.2 Heat Pump Keymark....26
6 The French regulations....28
6.1 French regulation for building....28
6.2 Neighbourhood noise....29
6.3 NF PAC certification scheme....30
6.4 RGE qualification for installers....31
7 The regulations of the United Kingdom....32
7.1 General regulations requirements....32
7.2 Permitted Development Rights....32
7.3 MCS 020 Planning Standard....33
7.3.1 MCS007: Product Certification Scheme Requirements: Heat Pumps....33
7.3.2 MIS 3005....33
7.3.3 MCS 020 calculation procedure....34
7.4 Planning consent....37
7.4.1 BS 4142....37
8 The Austrian regulations....38
8.1 Introduction....38
8.2 Sold heat pumps....38
8.3 Legal basis....40
8.3.1 ÖNORM S 5021 (2017) (Austrian Standard)....40
8.3.2 Planning values for noise immission....40
8.3.3 Energy-equivalent sound pressure level Leq....42
8.3.4 Adjustment values Lz for different noise sources....43
8.3.5 Assessment level Lr....43
8.3.6 Assessment level for general noise pollution Lr,den....44

8.4 ÖAL Guideline No. 3 (Österreichischer Arbeitsring für Lärmbekämpfung, 2008).44

8.5 Information sheet of noise protection in the neighbourhood of heat pumps (Forum Schall, 2013).....46

8.6 ÖAL Guideline No. 6 (Österreichischer Arbeitsring für Lärmbekämpfung, 2011).47

8.7 Regulation and funding in the federal provinces.....48

8.8 Noise Calculator of the Austrian Heat Pump Association (Wärmepumpe Austria, 2018) 51

8.8.1 Sound propagation and evaluation 51

8.9 Implementation of Measurements (Wärmepumpe Austria, 2018) 53

8.10 Court decisions related to noise emissions of heat pumps 55

8.10.1 Court Case 10Ob25/11s (Rechtsinformationssystem des Bundes, 2011) 55

8.11 Summary.....56

8.12 References 57

8.13 Acknowledgement.....58

9 The Italian regulations.....59

9.1 Italian regulation for buildings 59

9.2 Environmental noise pollution 59

10 The Spanish regulations 64

10.1 Spain regulation for buildings 64

10.2 Environmental noise pollution 64

10.3 Regional or municipal limits. 67

11 The German Regulations.....72

11.1 Environmental Law 73

11.1.1 TA Lärm 74

11.1.2 Approval Procedure.....75

11.1.3 Verification Procedure.....76

11.1.4 Differentiation from other legal fields.....76

11.2 Neighbor law 76

11.3 Public building law 77
11.3.1 Verification procedure 79
11.3.2 Additional information 80
11.4 Private building law 81
11.5 Tenancy law 82
11.6 Literature 82
12 The Polish regulations 84
12.1 Sound emissions 84
12.1.1 Transferring sound in the building 84
12.1.2 Moving sound in the open space 85
12.1.3 Determination of the sound pressure level 86
12.2 Literature 89
13 The Denish regulations 90
14 The Swedish regulations 91
14.1 Environmental regulations 91
14.1.1 External industrial noise 91
14.1.2 Noise from roads and railways 92
14.2 Building regulations 92
14.2.1 New buildings 92
14.2.2 Existing buildings 93
14.3 Safety regulation 94
15 The Finnish regulations 95
16 The Norwegian regulations 96
17 The Swiss regulations 97
17.1 Preface 97
17.2 Introduction 97
17.3 Sold heat pumps 97

17.4Legal basis 98
17.4.1 The Federal Act on the Protection of the Environment (EPA)....98
17.4.2 Principles 98
17.4.3 Emission limitations 99
17.4.4 Noise Abatement Ordinance (NAO) 99
17.4.5 Emission limitation for new installed systems 99
17.4.6 Exposure Limit Values for Industrial and Commercial Noise 100
17.4.7 Soundproofing of new buildings 103
17.4.8 Regulation in the canton Basel 103
17.4.9 Conclusion 104
17.5Cercle Bruit 105
17.6Implementation of Measurements 105
17.7Noise protection measures....106
17.7.1 Measures for indoor installed heat pumps 107
17.7.2 Measures for outdoor installed heat pumps 107
17.7.3 Measures for structure-borne sound 108
17.8Court decisions related to noise emissions of heat pumps 108
17.8.1 Federal Supreme Court Decision 1C_506_2008 108
17.8.2 Comment to Article 11 of the Federal Act on the Protection of the Environment 109
17.8.3 Canton court case 7H 15 138....109
17.8.4 Federal Court decision about the noise emission of a heat pump system ..109
17.9References 110
17.10 Acknowledgement....111
18 The Korean Regulations....112
18.1Ecolabel for Air conditioners 112
18.2Ecolabel for multi air conditioners 112
18.3The KS mark....112

19 The Japanese regulations....114

20 Appendix - List of standards....115

21 FIGURES INDEX....117

22 TABLES INDEX....118

1 Introduction

This document consists of three parts. In the first part the reference standards and the main certification and labeling schemes used in Europe for heat pumps were described.

In a second part, the national laws of some member states participating in the present research project are reviewed. Where possible, in addition to the general laws that regulate the noise emissions on the various national territories, also eventual specific laws for the series of products covered by this study have been described. In some cases there are also cases of jurisprudence with the pronouncement of some national courts. As you can see, the situation in Europe is very uneven: some nations have a tradition of a few decades, while other nations have specific laws only in recent years. Moreover, in some states there is not even a single law valid for the entire national soil, but the problem of noise has been regulated differently by the various local authorities (Municipalities or Provinces). As you can see in detail there are not even unique ways to determine the environmental noise: in some countries the noise should be determined on an annual basis, in many others on a daily basis (with the day divided into periods like day, evening, night) and in other countries noise can also be determined by measuring shorter periods. Although all member states have transposed Directive 2002/49/EC, only for some it forms the basis for environmental noise regulation, others (especially those already provided with specific national laws) have made use of the national descriptors previously adopted. In the latter cases, the 2002/49/EC is used only for epidemiological investigation purposes, and does not set specific limits (this is not the purpose of that directive), but is used only for the determination of the environmental noise caused by large road infrastructures (roads, railways and airports) and industrial noise.

Finally in a third part, as data already available, the legal situations of other non-member states were reported, both near and far Europe, but judged nevertheless countries of interesting catchment areas for the heat pump market.

2 European Standards

2.1 Product standards

European product standards are developed for testing and rating acoustic performance of electrically driven heat pumps.

These standards are relying on generic standards for acoustic measurements describing methods such as the reverberant room or the intensity technique.

The product standards aim at defining the installation and the operating conditions in which any generic acoustic measurement method can be used accurately.

The standard EN 12102 is dedicated to the sound power level measurement of heat pumps, air conditioners, liquid chilling packages when used for space hating and/or space cooling.

The current version is dated 2017 and entitled: “Air conditioners, liquid chilling packages, heat pumps, process chillers and dehumidifiers with electrically driven compressors – Determination of the sound power level – Part 1: Air conditioners, liquid chilling packages, heat pumps for space heating and cooling, dehumidifiers and process chillers”.

This standard was developed by CEN TC113 WG9 “Acoustics” chaired by François Bessac (CETIAT, FR).

Today this standard is under revision and will be split in two parts:

- The first part (to become EN 12102-1) will mainly reproduce the existing EN 12102 as its scope will be the same, i.e. heat pumps for space heating and/or cooling, and some minor corrections,
- The second part (to become EN 12102-2) will be a new part and will cover acoustic measurement for heat pump water heaters.

2.2 Generic standards on acoustics

Most of the generic standards on acoustic measurement techniques have been developed at the international standardization level (ISO TC43/SC1/WG 28) and adopted at the CEN level.

There are two series of "basic" standards, which can be used directly or to produce test codes dedicated to a specific range of products:

- ISO 1120X to measure sound pressure levels
- ISO 374X + ISO 9614 to determine sound power levels.

ISO 1120X will produce a sound pressure level at a given point under specific environmental conditions. Measurements are rather easy and the result can be produced directly by a measurement device (sonometer).

ISO 374X + ISO 9614 + ISO/TS 7849 will produce a sound power level. It is an intrinsic characteristic of the machine and this quantity is then the most representative of its acoustic emission. Unfortunately the measurement is not direct and requires post-processing pressure or intensity obtained at several measurement points. We will focus on these standards in this document.

2.3 Standards for sound power level determinations

ISO 3740 is a guide to help choosing the most adapted standard regarding grades (1: Precision method, 2: Engineering method, 3: Survey method), environmental (free field/reverberant field) situation and measured quantity (pressure/intensity/vibration).

The standards using **acoustic pressure** are :

ISO 3741:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms*

ISO 3743-1:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for small movable sources in reverberant fields – Part 1: Comparison method for a hard-walled test room*

ISO 3743-2:1994[1], *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering methods for small, movable sources in reverberant fields — Part 2: Methods for special reverberation test rooms*

ISO 3744:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

ISO 3745:2012, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for anechoic test rooms and hemi-anechoic test rooms*

ISO 3746:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

ISO 3747:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering/survey methods for use in situ in a reverberant environment*

They can be summarized by Table 2-1:

Parameter	Grade of Accuracy	Test Environment
ISO 3741	Precision	Reverberation room
ISO 3743-1	Engineering	Hard-walled room
ISO 3743-2	Engineering	Special reverberation room
ISO 3744	Engineering	Essentially free-field over a reflecting plane
ISO 3745	Precision	Anechoic or hemi-anechoic room
ISO 3746	Survey	In situ over a reflecting plane
ISO 3747	Engineering or Survey	Essentially reverberant field in situ

Table 2-1: ISO 374X family standard for sound power level determination

The standards using **acoustic intensity** are:

ISO 9614-1:1993, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points*

ISO 9614-2:1996, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning*

ISO 9614-3:2002, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 3: Precision method for measurement by scanning*

The grade of accuracy of the three parts can be: precision, engineering and survey depending on specialized ancillary tests and measurement can be performed in any test environment satisfying specified requirements in relation to the instrumentation used.

The standards using **vibration** are:

ISO/TS 7849-1:2009, *Acoustics — Determination of airborne sound power levels emitted by machinery using vibration measurement — Part 1: Survey method using a fixed radiation factor*

ISO/TS 7849-2:2009, *Acoustics — Determination of airborne sound power levels emitted by machinery using vibration measurement — Part 2: Engineering method including determination of the adequate radiation factor*

2.3.1 EN ISO 3741

This standard describes the determination of the sound power of a sound source by measuring the sound pressure in the diffuse field of a reverberation room.

During the measurements the source is to be put into a state, that is representative for its loudest mode of operation. Note, that this can be considered a contradiction to EN 12102-1 (see section 2.5) where measurement during the defrosting phase of a heat pump is not

intended. Apart from that, the ISO 3741 also demands constant conditions of operation during the measurements.

The sound power level can then be determined by using either of two methods:

- Calculation through the use of the equivalent absorption area of the reverberation room.
- Repeating the measurements with a well-known sound source in the same reverberation room.

The standard demands a certain number of microphone positions (up to 30) depending on the acoustic properties of the reverberation room. Furthermore climate and geometry of the room must fulfill certain conditions. The ambient noise level must also not exceed certain values.

2.3.2 EN ISO 3744

This standard describes a measurement technique that can be used outdoors or in an anechoic chamber. The ground should not have an absorption coefficient above 0.1. This condition is satisfied by asphalt or concrete grounds. The shape of the sound propagation (hemisphere, quarter cylinder, …) is assumed according to the installation site. By measuring the sound pressure at points of equal assumed sound intensity (points on the same hemisphere/quarter cylinder, …) the sound power of the source can be calculated.

2.4 Other useful standards and documents

Other useful standards to declare noise measurements or to draft noise test codes are given below:

ISO 4871, *Acoustics — Declaration and verification of noise emission values of machinery and equipment*

ISO 12001:1996, *Acoustics — Noise emitted by machinery and equipment — Rules for the drafting and presentation of a noise test code*

Through the task force Nomad, the EC issued a guide for manufacturers on how to report noise emission in instruction manuals and other literature in accordance with Machinery Directive 2006/42/EC and Outdoor Noise Directive 2000/14/EC. The document entitled “Guide for manufacturers noise emission machinery” can be freely downloaded from the website of the Commission in several languages (search for “Guide ADCO Nomad”).

2.5 EN 12102 contents

2.5.1 Scope

EN 12102-1 establishes requirements for determining the sound power level emitted into the surrounding air by air conditioners, heat pumps, and liquid chilling packages with electrically driven compressors when used for space heating and/or cooling, including water cooled multisplit systems.

It includes:

- Air-to-air heat pumps and air conditioners
- Air-to-water heat pumps and chillers
- Water(brine)-to air heat pumps and air conditioners
- Water(brine)-to water(brine) heat pumps and chillers

These units can be either ducted on non-ducted on the air side.

For the scope and some common definitions, EN 12102-1 refers to EN 14551-1 “Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling — Part 1: Terms, definitions and classification”.

Note: direct expansion-to-water heat pumps covered by EN 15879-1 are not included in the scope of EN 12102-1.

2.5.2 Generic acoustic standards and classes of measurement

The EN 12102-1 gives two classes of measurements and results, according to the test environment:

- Class A measurements correspond to controlled operating conditions, for which tolerances shall be fulfilled
- Class B measurements correspond to the case where the tolerances defined in the standard cannot be fulfilled.

In both classes, precision or engineering class acoustic methods should be applied. The choice of the acoustic measurement method is done in accordance with EN ISO 3740 and EN ISO 9614 depending on the type of surrounding acoustic fields (diffuse or free field, enclosed or open space), and the available instrumentation.

. The standard does not recommend the use of EN ISO 3746 or EN ISO 3747 as survey grade methods due to the high level of uncertainties. Their use is only allowed for non-controlled environments or the use of engineering or laboratory grade methods.

Three methods for determining the sound power levels are specified in order to avoid unduly restricting existing facilities and experience:

- the first methodology is based on reverberation room measurement (EN ISO 3741, EN ISO 3743 and EN ISO 3747 in some favourable cases when the engineering grade can be fulfilled);
- the second method is based on measurements in an essentially free field over a reflecting plane (EN ISO 3744 and EN ISO 3745);
- the third method is based on sound intensity measurement (see EN ISO 9614) in preferably free field environment.

2.5.3 Operating conditions

The standard can be used for determining the sound power level of heat pumps with any set of operating conditions (temperatures, humidity, air/water flow rate, …). However, for comparison purposes - generally according to regulation requirements or certification scheme - the standard refers to the test conditions which are proved in EN 14511-2 and used for determining energy efficiency performance.

Due to the design constraints of acoustic rooms or the use of free field measurements the allowable deviations on operating conditions are slightly larger for the acoustic measurement than those in EN 14511-3 for the capacity measurement.

Therefore in the same test conditions (or very close), a manufacturer can both declare the capacity and COP of a heat pump and the "corresponding" sound power level.

Note: At 7(6)°C outdoor air temperature, an air-to-water or and air-to-air heat pump may undergo frosting /defrosting cycles that makes not always possible to measure a sound power level in steady-state conditions.

In the case of heat pumps with air as the heat transfer medium, the evaporator shall be free of ice during the measurement. However, sound measurements are sometimes not possible due to coil frosting and stationary time running requirement.

2.5.4 Installation and setting requirements

EN 12102 provides detailed requirements on how to install the unit depending on the shape of the unit (wall-mounted, ceiling-suspended, floor-standing, single duct, window, …) such as:

- distance from walls or ceiling
- length and material for air ducts, bends
- settings for pressure and flow rates
- settings for inverter type units

Some other requirements are linked to the acoustic method used as illustrated on Figure 2-1:

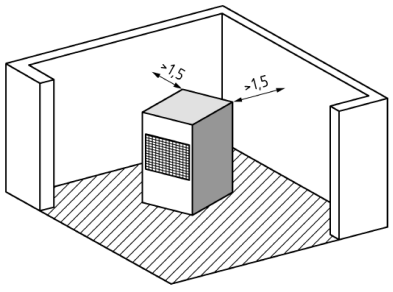
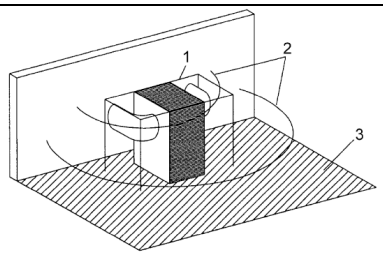


Figure 1 — Measurement of L_W in reverberation room



Key

1 reference surface
2 measurement surface
3 reflecting surface

Figure 4 — Measurement of L_W using the free field over a reflecting plane method

Figure 2-1: EN 12102 – Device under test positioning

2.5.5 Some sound power measurements

Depending of the shape of the unit, one or several acoustic indicators provide the relevant information on the acoustic behaviour of the unit:

- Noise radiated by the casing
- Noise radiated by the openings (inlets and/or outlets)

In that respect the standard EN 12102-1 includes an Annex illustrating typical configurations of heat pumps and the acoustic measurements to be reported according to the standard;

An example for air-to-water heat pumps is given in Figure 2-2.

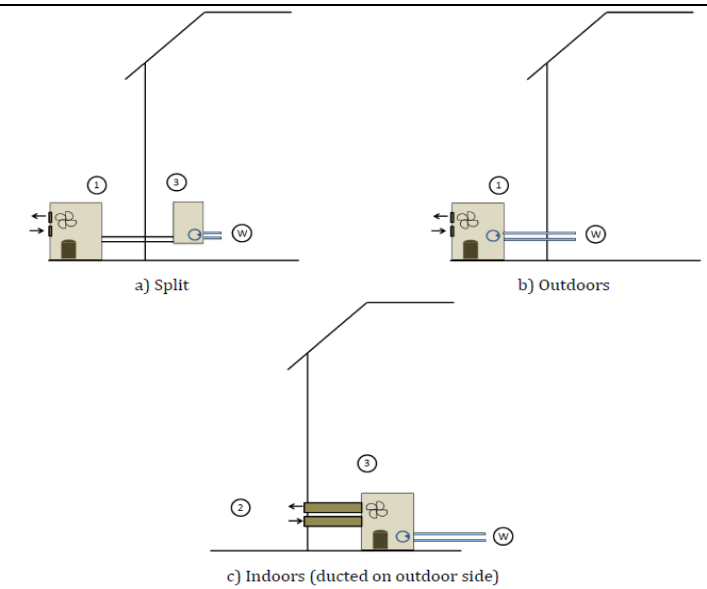


Figure B.2 — Air-to-water(brine) units

Figure 2-2: EN 12102 – Device under test, examples of positioning

2.6 EN 12102-2

In addition to the EN 12102-1, a Part 2 concerns the determination of the sound power level of heat pump water heaters.

The particularity of heat pump water heaters is their non-steady operation as they can either:

- recharge the water tank, because the water temperature is below the set point (e.g. 55°C),
- not operate because the set point is reached,
- operate or not during tapping of hot water.

All the different stages of operation are described in EN 16147 for rating the energy performance of the heat pump water heater, the COP being determined during a 24h-tapping cycle.

For sound power level measurements, the tapping cycle is not relevant as:

- the unit is not necessarily ON
- the unit may cycle ON and OFF, i.e. non-steady state operation
- the duration of the test is 24 hours

Therefore, the draft standard under development is proposing to measure the sound power level during the heating up period with two consideration, according to the VPD of the unit, with VPD = Declared power (W) / Tank volume (l)

- With VPD < 10, the heating period is long and the acoustic measurement is done when the water temperature in the tank is around 45 °C, measured by small tappings.
- With VPD > 10, the heating can be short and the acoustic measurement is done continuously. The sound power level to give is the one when water tank temperature is presumed to be 45 °C (according to speed of heating up and time).

For compliance with Ecodesign and Energy labelling, the measurements will be done at three target hot water temperatures:

- 25 °C;
- (Tset + 25)/2 °C;
- (Tset − 5) °C.

The sound power level of the appliance is the arithmetic mean value of the three sound power levels.

As in EN 12102-1, the standard provides examples of typical configurations of heat pump water heaters with the acoustic measurements to be reported according to this standard.

An example for air-to-water heat pumps is given in Figure 2-3 and in Figure 2-4.

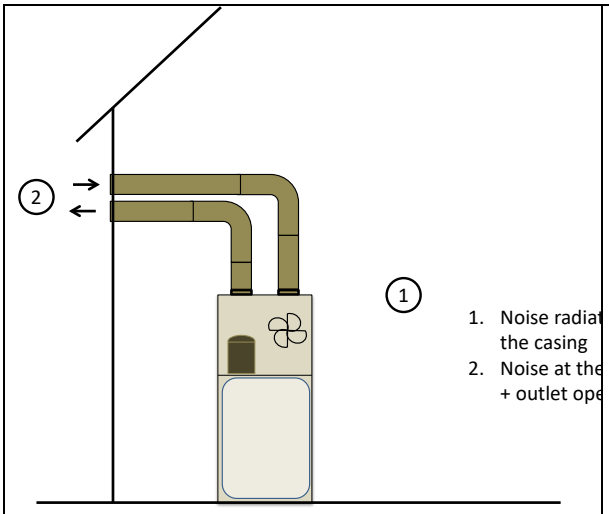


Figure 2-3. EN 12102 – Oudoor air unit ducted inlet/outlet

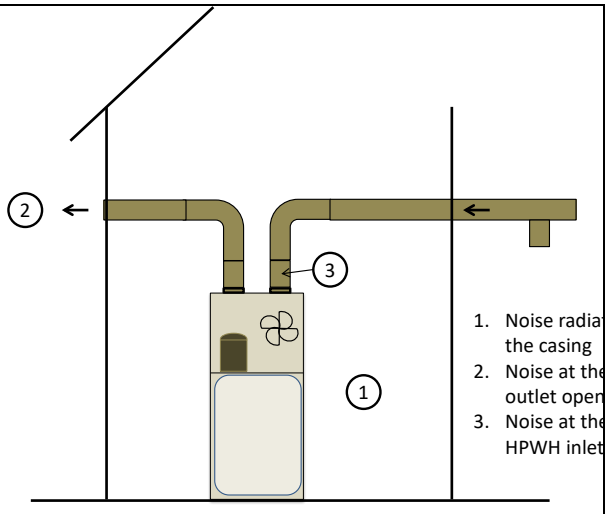


Figure 2-4: EN 12102 – Individual exhaust air unit

2.7 EN 12102: an harmonized standard

The recently implemented regulations in the framework of Ecodesign and Energy Labelling Directives applicable to heat pumps require the measurement, declaration and labelling of the sound power level for most types of heat pumps.

The European Commission requested CEN to develop so called harmonized standards that can be used to demonstrate that the products comply with the requirements of the relevant EU regulations.

Therefore EN 12102 is today a harmonized standard for electrically driven heat pumps as covered by:

- Commission Regulation (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for air conditioners and comfort fans
- Commission Delegated Regulation (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners.

And the future EN 12102 Parts 1 and 2 will be a harmonized standard for heat pumps covered by:

- Commission Regulation (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for air conditioners and comfort fans
- Commission Delegated Regulation (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners.

- Commission Regulation (EC) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for space heaters and combination heaters.
- Commission Regulation (EC) No 811/2013 of 18 February 2013 implementing Directive 2010/30/UE of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device.

The standards include Annexes that specify the relationship between the requirements of the regulation and the clauses of the standard to apply.

All relevant regulations are described in Chapter 3: European regulation on noise.

3 European regulations on noise

The concern of noise disturbance is tackled at the European level within the Ecodesign and Energy Labelling Directives.

The implementing regulations of these two Directives for heat pumps which have requirements on sound power level are as follows:

- Commission Regulation (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for air conditioners and comfort fans
- Commission Delegated Regulation (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners.
- Commission Regulation (EC) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for space heaters and combination heaters.
- Commission Regulation (EC) No 811/2013 of 18 February 2013 implementing Directive 2010/30/UE of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device.

3.1 Regulation n°206/2012

Regulation n°206/2012 applies to air conditioners below 12 kW rated capacity (and to heating only heat pumps).

From January 2013, the units shall correspond to the maximum sound power level requirements as stated in Table 3-1.

Table 5

Requirements for maximum sound power level

Rated capacity ≤ 6 kW		6 < Rated capacity ≤12 kW	
Indoor sound power level in dB(A)	Outdoor sound power level in dB(A)	Indoor sound power level in dB(A)	Outdoor sound power level in dB(A)
60	65	65	70

Table 3-1: 206/2011 – maximum power level requirements

The sound power level shall be measured according to EN 12102 in the temperature conditions (corresponding to EN 14511-2) reported in Table 3-2:

Temperatures Dry bulb (wet bulb)	Air-to-air unit cooling only	Ai-to-air unit reverse cycle	Air-to-air unit Heating only
Outdoor air	35 (24)°C	35 (24)°C	7(6)°C
Indoor air	27(19)°C	27(19)°C	20 (max. 15)°C

Table 3-2: EN 12102 – test conditions

Note: For a heating only unit, frosting /defrosting cycles may occur at 7(6)°C which are not steady-state conditions for noise measurements, which makes the declaration and the fulfilment of the requirement quite difficult.

3.2 Regulation n°626/2011

Regulation n° 626/2011 is the supplementing regulation for energy labelling of products covered by regulation n° 206/2012.

The regulation requires the sound power level(s) – indoor and/or outdoor where relevant – to be stated on the energy label to be provided with the product to the customer.

The figure below is an example of the energy label for a reverse cycle air-to-air unit showing on the left bottom side the sound power level information

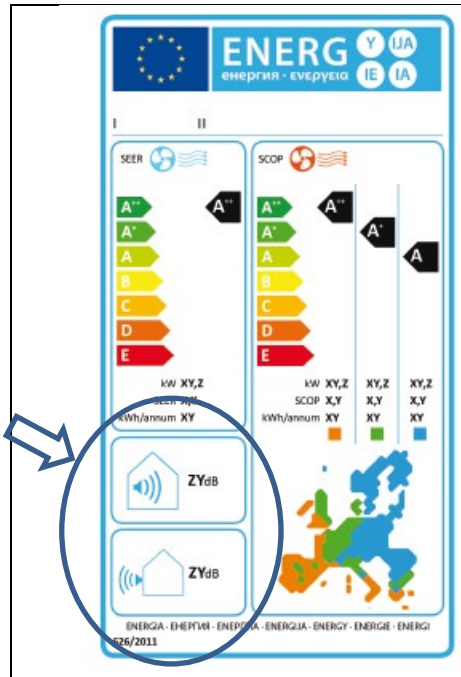


Figure 3-1: 626/2011 – label

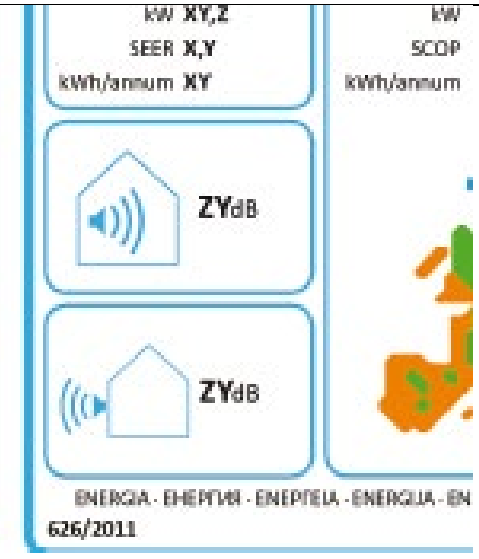


Figure 3-2: 626/2011 – label, acoustic detail

3.3 Regulation n°813/2013

Regulation n° 813/2013 applies to air-to-water and water(brine)-to- water heat pumps for space heating (so-called heat pump space heater) or for space heating and hot water production (so-called heat pump combination heater) with capacity not greater than 400 kW.

From September 2015, the sound power level of these heat pumps shall not exceed the following values:

Rated heat output ≤ 6 kW		Rated heat output > 6 kW and ≤ 12 kW		Rated heat output > 12 kW and ≤ 30 kW		Rated heat output > 30 kW and ≤ 70 kW	
Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors	Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors	Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors	Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors
60 dB	65 dB	65 dB	70 dB	70 dB	78 dB	80 dB	88 dB

Table 3-3: 813/2013 – maximum sound power levels

The sound power level shall be measured according to EN 12102 for the space heating application and in the following temperature conditions (corresponding to EN 14511-2):

Dry bulb (wet bulb) air temperatures Or inlet-outlet water(brine) temperatures	Air-to-water heat pump	Exhaust air-to-water heat pump	Water-to-water heat pump	Brine-to-water heat pump
Outdoor heat exchanger	7(6)°C	20 (12)°C	10-7°C	0-(-3)°C
Indoor heat exchanger (low temperature application)	30-35°C			
Indoor heat exchanger (except low temperature application)	47-55°C			

Table 3-4: EN 12102 – test conditions

3.4 Regulation n°811/2013

Regulation n° 811/2013 is the supplementing regulation for energy labelling of products covered by regulation n° 813/2013 but limited to 70 kW rated capacity.

The regulation requires the sound power level(s) – indoor and/or outdoor where relevant – to be stated on the energy label to be provided with the product to the customer.

The figures below give examples of the energy label for a heat pump space heater and a heat pump combination heater showing on the left bottom side the sound power level information.

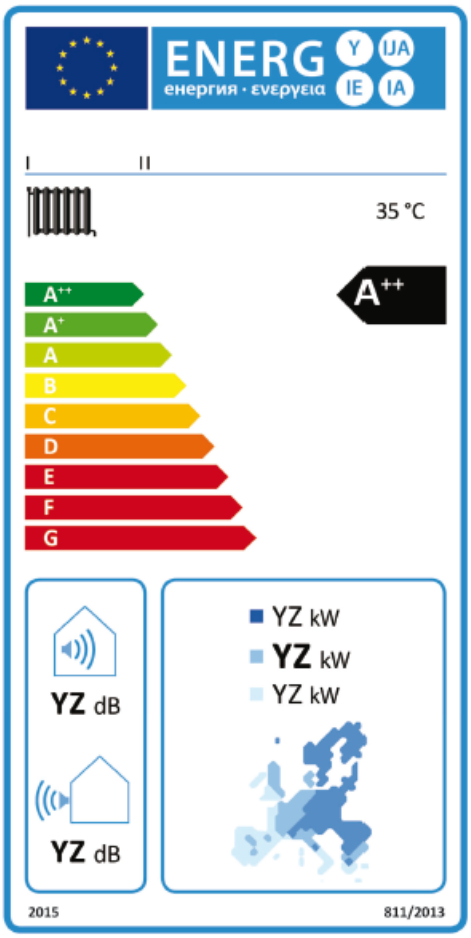


Figure 3-3: 811/2013 – Low-temperature heat pump space heater

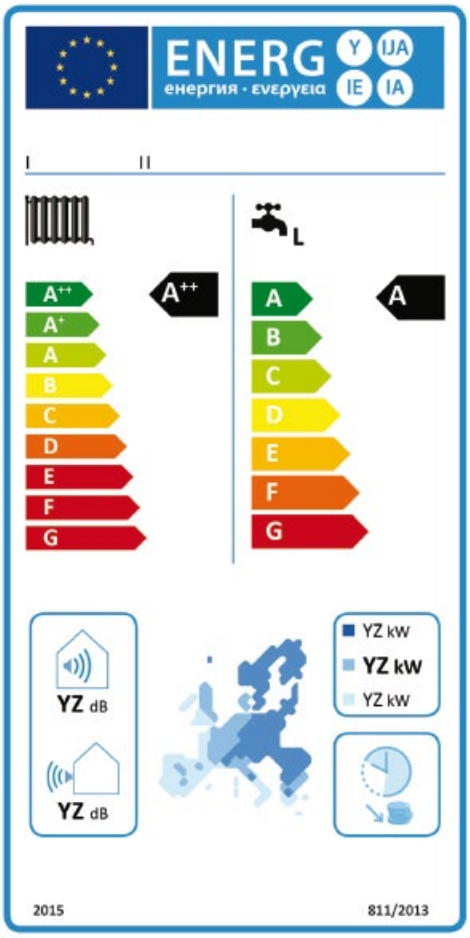


Figure 3-4: 811/2013 – Heat pump combination heater

3.5 Regulation n°814/2013

Regulation n° 814/2013 applies to air-to-water and water(brine)-to-water heat pump water heaters with a capacity not greater than 400 kW.

From September 2015, the sound power level of the heat pump water heaters shall not exceed the following values:

Rated heat output ≤ 6 kW		Rated heat output > 6 kW and ≤ 12 kW		Rated heat output > 12 kW and ≤ 30 kW		Rated heat output > 30 kW and ≤ 70 kW	
Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors	Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors	Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors	Sound power level (L_{WA}), indoors	Sound power level (L_{WA}), outdoors
60 dB	65 dB	65 dB	70 dB	70 dB	78 dB	80 dB	88 dB

Table 3-5: 814/2013 – maximum sound power levels

The test procedure is today described in a Commission Communication (2014/C 207/03) which originally makes reference to EN 12102:2013 (today updated by EN 12102:2018) and specifies adjustments and particular settings for measurements as follows:

The unit is kept at ambient conditions of operation for at least 12 h; The temp. at the top of the tank of the water heater is monitored; The electric consumption of the compressor, the fan (if present), the circulation pump (if present), are monitored (to know the period of defrosting).

The product is filled with cold water at 10 °C ± 5 °C.

Clause 5: Replace the 4th paragraph 'The noise measurement …' by: The measurement points shall be performed in steady state conditions at the following water temperatures at the top of the tank: 1st point at 25 ± 3 °C, 2nd point at (Tset+25)/2 ± 3 °C, 3rd point at Tset +0/- 6 °C (Tset is water temperature in 'out of the box-mode').

During the measurement of noise: the water temp. at the top of the tank should be included in the tolerance range (e.g. included between 25 °C ± 3 °C for the first measurement);

the periods of defrosting are excluded (zero electric consumption of the compressor, the fan or the circulation's pump)

This provisional method is not sufficiently described to ensure repeatability of the method especially in case of market surveillance. For example, it does not take into account that heat pump water heaters are not in steady working conditions and that their water tank temperature can not be easily measured without tapping. It is the reason why Part 2 of EN 12102 is under development to overcome possible discrepancies in testing.

3.6 Regulation n°812/2013

Regulation n° 812/2013 is the supplementing regulation for energy labelling of products covered by regulation n° 814/2013 but limited to 70 kW rated capacity.

The regulation requires the sound power level(s) – indoor and/or outdoor where relevant – to be stated on the energy label to be provided with the product to the customer.

The figure below gives an example of the energy label for a heat pump water heater showing on the left bottom side the sound power level information.

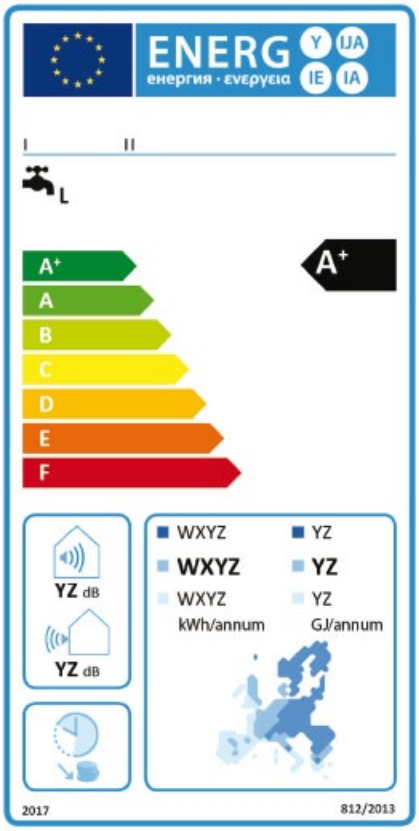


Figure 3-5: 812/2013 – Labelling of a heat pump water heater

3.7 Market surveillance

For the purpose of market surveillance by the Member States authorities, the measured values shall not be more than 2 dB higher than the rated value declared by the manufacturer.

This requirement applies to all above described Ecodesign and Energy Labelling regulations.

4 Ecolabel

The Commission Decision of 28 May 2014 establishes the criteria for the award of the EU Ecolabel for water-based heaters.

The criteria for the Ecolabel include noise emission limits and apply to all fuel driven or electrically driven heat pumps.

The document makes reference to the following standards to be used:

- EN ISO 3744
- EN ISO 3746
- EN 12102

The noise emissions shall not exceed the limit values indicated in Table 15. Noise emissions shall be measured at standard rating conditions and rated heat output. The unit of measurement shall be given in dB(A) or dB(C), as appropriate.

Heat generator technology	Measurement	Noise emission limit
Heat pump heaters equipped with external combustion and electrically-driven heat pumps	A-weighted sound power level limit value ($L_{WAd,\ lim}$)	$17 + 36 \times \log(P_N + 10)$ dB(A)
Heat pump heaters equipped with internal combustion engine	A-weighted sound pressure level limit value ($L_{PAd,\ lim}$)	$30 + 20 \times \log\ (0{,}4 \times P_N + 15)$ dB(A)
	C-weighted sound pressure level limit value ($L_{PCd,\ lim}$)	$L_{PAd,\ lim} + 20$ dB(C)
Cogeneration space heaters equipped with internal combustion engine	A-weighted sound pressure level limit value ($L_{PAd,\ lim}$)	$30 + 20 \times \log\ (P_E + 15)$ dB(A)
	C-weighted sound pressure level limit value ($L_{PCd,\ lim}$)	$L_{PAd,\ lim} + 20$ dB(C)

Note: P_N means the nominal (full load) or declared heat output; P_E means the electricity output.

Table 4-1: Ecolabel table 15 – noise emission limits by heat generator technology

For assessment and verification, a certificate signed by the manufacturer declaring compliance with this citerion shall be submitted to the awarding competent body together with the relevant documentation.

5 European certification schemes

5.1 Eurovent Certified Programmes

Eurovent Certification certifies the performance ratings of air-conditioning and refrigeration products according to European and international standards.
The objective is to build up customer confidence by levelling the competitive playing field for all manufacturers and by increasing the integrity and accuracy of the industrial performance ratings.

The Eurovent Certified Programs (ECP) aim at guarantee the performances declared by the manufacturers without any minimum performance requirement.

The certification scheme is based on periodic testing of products without factory control.

It is why most of the ECPs are “certify-all” type, which means that the applicant shall declare and certify all products within the ECP.

Certified products and their certified performances are listed in the Eurovent Directory under http://www.eurovent-certification.com/

In the technology of heat pumps, products covered by ECP include:

- Air-to-air conditioners
  - AC1: air conditioners, reverse cycle or not ≤ 12 kW
  - AC2: air conditioners, reverse cycle or not between 12 and 45 kW
  - AC3: air conditioners, reverse cycle or not between 45 and 100 kW
  - CC: close control air conditioners
- Chillers and heat pumps heating only (LCP-HP)
- Roof-top units (RT)
- Variable refrigerant flow units (VRF)

For all categories, the sound power level (indoors / outdoors where applicable) of the unit is part of the certified characteristics. Measurements are made according EN 12102.

5.2 Heat Pump Keymark

The heat pump Keymark[1] was recently developed and is effective since 2016 for the certification of heat pumps for heating, cooling and/or hot water production.

The certification scheme relies on annual factory control, selection of products for periodical sampling testing by ISO 17025 testing labs.

[1] www.heatpumpkeymark.com

The aim is to certify all data required for compliance to related Ecodesign and Energy Labelling regulations.

In the scope of the HP Keymark, one will find:

- Air–to-air air heat pumps and air conditioners < 12 kW
- Air-to-water, water(brine)-to–water and DX-to-water heat pump space heaters and combination heaters, up to 400 kW
- Air-to-water, water(brine)-to–water and DX-to-water heat pump water heaters up to 400 kW

The sound power level (indoors / outdoors where applicable) of the units is part of the certified performance within the HP Keymark.

Measurements are made according EN 12102.

6 The French regulations

6.1 French regulation for building

The French regulation defines the "acoustic characteristics of housing building" and is called "new acoustic regulation" (NRA) since its publication in 1994. It replaces the former first acoustic regulation published in 1969. It has been updated on June 30rd 1999 ("Arrêté du 30 juin 1999").

The main characteristics of this regulation are:

- Standardised sound insulations
  - inside the building $D_{nT,A}$ between the rooms (neighborhood, common spaces, commercial rooms, garage, etc.),
  - and on with respect to external noise (road, railway, etc.)
- Requirement considering the noise due to shock on the floor
- Set a maximum sound pressure level L_{nAT} in the domestic rooms due to individual heating or air-conditioning equipment, with 35 dB(A) in the main rooms (living room, bedroom), and 50 dB(A) in the kitchen.
  For American kitchen configurations (kitchen in the same volume than the living room), the 35 dB(A) value is replaced by 40 dB(A).

L_{nAT} is the sound pressure level for a standardised reverberation time T_{r0}.

$$L_{nAT} = L_p' + 10 \log (T_r/T_{r0}) \qquad \textit{Eq. 6-1}$$

With L_p' : sound pressure level corrected from background noise;

T_{r0} : 0.5 s. Reference reverberation time;

T_r : measured reverberation time.

A document, with no regulatory value (published by the French Building Scientific and Technical Center – CSTB), gives solutions that have demonstrated their effectiveness, even if their use does not guarantee the regulatory result. This document., entitled "exemples de solutions acoustiques" translates the regulatory requirements expressed in Lp in Lw values for these equipement.

For individual units for heating (boilers) or air-conditioning, the requirements are:

	Tests from certification process	Tests done in accredited laboratory
Kitchen	$45 < L_w \leq 51$	$43 < L_w \leq 49$
Kitchen open on living room or studio	$40 < L_w \leq 45$	$38 < L_w \leq 43$
Living room	$L_w \leq 40$	$L_w \leq 38$

Table 6-1: French Regulation – requirements for heating (boilers) or air-conditioning

6.2 Neighbourhood noise

By the decree 2006-1099, dated August 31, 2006, regulatory provisions relating to the violation of the tranquillity of the neighbourhood or the health of the man by the noise were introduced in the public health code. It defines that "*No particular noise shall, by its duration, repetition or intensity, affect the tranquillity of the neighbourhood or the health of man, in a public or private place, whether a person is himself origin or through the intermediary of a person, of a thing of which it has custody or of an animal placed under its responsibility*".

The neighbourhood noise is not clearly defined as itself, but for heat pumps, it is mostly covered by the category "Sounds of things that a person has custody of" or "behaviour noise" for non professional use. The heat pumps of professional activities is covered as well, but in the first case, the offense can be ascertained without making a measurement, whereas for professional context, a sound meter is required.

On the subject of sanctions, Article R. 1337-7 specifies that the fact of being at the origin of such an offense is punishable by a fine for third-class offenses. (maximum amount: 450 €)… and of course, the disturbance shall be stopped.

Anyway, the disturbance to the tranquillity of the neighbourhood or the health of man is characterized if the global emergence of this noise perceived by others is greater than 5 dB(A) for daytime (7:00 am to 10:00 pm), and 3 dB(A) at night-time (10:00 pm to 7:00 am). A correction term in dB(A) is added, which is a function of the cumulative duration of noise occurrence (the allowed noise is higher if it is of short time duration).

≤ 1 min	> 1 min ≤ 5 min	> 5 min ≤ 20 min	> 20 min ≤ 2 h	> 2h ≤ 4 h	> 4h ≤ 8 h	> 8h
+ 6 dB(A)	+ 5 dB(A)	+ 4 dB(A)	+ 3 dB(A)	+ 2 dB(A)	+ 1 dB(A)	0

Table 6-2: French Regulation – correction terms for short time duration of noise

However, the global emergence concept is implemented only when the measured ambient noise level, including the particular noise, is greater than 25 dB(A) if the measurement is carried out inside the rooms housing, open or closed windows, or 30 dB (A) in other cases.

In addition, a spectral component can be taken into account, defined by a spectral emergence limit in octave band, with + 7 dB(A) for 125 and 250 Hz, and 5 dB(A) for 500 to 4000 Hz.

https://www.service-public.fr/particuliers/vosdroits/F612

https://www.legifrance.gouv.fr/affichCode.do?idSectionTA=LEGISCTA000035425901&cidTexte=LEGITEXT000006072665

6.3 NF PAC certification scheme

NF PAC[2] is a French certification scheme managed by Eurovent Certita Certification (ECC) on behalf of AFNOR since 2008.

The certification scheme is based of factory control and periodic sampling testing of products.

NF PAC applies to all types of heat pumps: fuel/gas or electrically driven and using air, water, brine or ground as heat source and/or heat sink for the following applications:

- Space heating
- Space heating and cooling
- Space heating and hot water production
- Water heating for swimming pools

The scheme defines minimum requirements for the certification to be granted, both minimum energy performance and maximum sound power level.

For the sound power level, the requirement only apply to the heating function of the heat pump and its measurement based on EN 12102 with an allowable tolerance of +2dB(A).

The sound power level shall be declared as for the ErP application (47/55 °C or 30/35 °C) at rated point +7 °C, necessarily in average climate and for the other climates if applicable.

[2] http://www.certita.fr/marque-certita/nf-pompe-chaleur

The sound power level outside the building, must comply with the following thresholds:

Heating capacity P [kW]	Sound power at Prated Lw [dB(A)]
0 < P ≤ 6	≤ 70
6 < P ≤ 10	
10 < P ≤ 12	≤ 73
12 < P ≤ 20	
20 < P ≤ 30	≤ 78
30 < P ≤ 50	
50 < P ≤ 70	No threshold defined
70 < P ≤ 100	

Table 6-3: French Regulation – threshold values for outdoor side sound power level of heat pumps (source: NF PAC scheme rules July 2017)

6.4 RGE qualification for installers

The qualification RGE (Reconnu Garant de l'Environnement) is a qualification for installers that ensure the quality of the heat pump installation and may allow the end users to benefit from specific incentives.

An installer having the qualification QualiPac has access to the RGE status for installing heat pumps.

The QualiPac training includes some fundamentals on acoustics for heat pumps.

7 The regulations of the United Kingdom

7.1 General regulations requirements

Installing certain renewable energy technologies, such as solar thermal, photovoltaic and biomass boilers, has now been made a lot simpler thanks to Permitted Development Rights introduced on 6th April 2008 in England, and 12th March 2009 in Scotland. These were further extended to cover the noise limits in England for air source heat pumps and wind turbines on December 6th 2011.

For heat pumps, the requirements are as follows:

1. Heat pumps shall be in compliance with the ErP regulations.
2. Permitted development rights. if a single heat pump is being installed and the predicted sound pressure level at the nearest sensitive receptor is less than 42 dB(A) then the heat pump qualifies for permitted development rights and no further planning consent in relation to acoustics is required.
3. Planning consent. For heat pumps that don't achieve permitted development rights or when more than one heat pump is being installed then planning permission, including in relation to noise, is required. A site-specific assessment would be carried out for the heat pump(s) to determine predicted noise levels at the nearest sensitive receptor(s). The noise criteria are set by local planning authorities around the UK and quite often the noise criteria will refer to a noise assessment in accordance with BS 4142. This assesses the predicted noise level of the heat pump(s) against site specific background noise levels.

7.2 Permitted Development Rights

In England and Scotland, changes to permitted development rights for renewable technologies have lifted the requirements for planning permission for most domestic microgeneration technologies.

The General Permitted Development Order (GPDO), or the Town and Country Planning (General Permitted Development) (Domestic Microgeneration) (Scotland) Amendment Order 2009 grants rights to carry out certain limited forms of development on the home, without the need to apply for planning permission. The scope of the GPDO in England and the TCP (GPD) in Scotland now extends to the following technologies:

- Solar Photovoltaic
- Solar Thermal
- **Ground Source Heat Pumps**
- Biomass

The following technologies are covered under The General Permitted Development Order (GPDO) for noise levels under 42dB (please refer to MCS 020 Planning Standard):

- **Air Source Heat Pumps**
- Wind Turbines

7.3 MCS 020 Planning Standard

The MCS 020 is part of the Microgeneration Scheme and sets out the MCS Planning Standard which must be complied with for domestic installations of air source heat pumps on domestic premises to be "permitted development".

It is designed to allow installation companies to establish clearly whether an installation will comply with the MCS Planning Standard and includes a calculation procedure designed to confirm whether the permitted development noise limit of 42 dB LAeq,5 mins (at the assessment position – ignoring the effect of that façade).

would be met. The Standard, and the notes and calculations carried out by installation companies, will also be used by local planning authorities and the MCS to verify compliance.

The MCS Planning Standard for air source heat pumps is as follows:

(a) The air source heat pump product shall be certificated in accordance with MCS 007;

(b) The air source heat pump shall be installed by an installation company certificated in accordance with MIS 3005;

(c) The installation shall be carried out in compliance with the calculation procedure contained in Table 2. Installers must complete the "results/notes" column in Table 2 for each step of the calculation procedure to show how it has been followed.

7.3.1 MCS007: Product Certification Scheme Requirements: Heat Pumps

Heat pump space heaters shall meet the requirements of the COMMISSION REGULATION (EU) No 813/2013, Annex II, Section 3, "Requirements for sound power level".

7.3.2 MIS 3005

The Microgeneration Installation Standard MIS 3005 (issue 3.0 dated 2011) sets out requirements for the approval and listing of contractors undertaking the supply, design, installation, set to work, commissioning and handover of microgeneration heat pump systems for building space heating and/or hot water system.

The contractor shall be assessed under one or more of the following three categories of heat pump installation work:

- Ground source heat pump (GSHP) systems
- Air source heat pump (ASHP) systems
- Exhaust air heat pump systems

Under clause 4 "Design and installation requirements" the document describes site specific issues and recommendations regarding sound emission such as:

- Heat Pumps should not be located adjacent to sleeping areas or on floors that can transmit vibration
- Anti-vibration pads/mats/mounts and flexible hose connections should be installed according to the manufacturer's instructions to reduce the effects of vibration on the building structure
- The location of external fans and heat pump compressors should be chosen to avoid nuisance to neighbours and comply with planning requirements
- Internal fans and ducts should be fitted with sound attenuation devices

The contractor shall have competences related to:

- environmental considerations such as noise and vibration pollution,
- Understanding of noise, vibration and insulation requirements.

These competences are not specifically emphasized for air source heat pumps.

7.3.3 MCS 020 calculation procedure

The air source heat pump calculation procedure is set out in Table 2. MCS installation companies must complete one table for each assessment position that could potentially be affected by noise from the air source heat pump.

Installation companies must insert their results in the „results/notes" column for each step of the calculation procedure to show how it has been followed. Installation companies must retain one copy of the completed table for their records and provide another copy to the client.

The different steps of the procedure, with an example of a typical application, are given in the following Table. Terms, definitions and explanations for the different steps are provided in addition to the described procedure. The final result is the sound power level to be compared to 42 dB(A) for permitted development or not of the heat pump.

STEP	INSTRUCTIONS	INSTALLER RESULTS / NOTES
1.	**From manufacturer's data, obtain the A-weighted sound power level of the heat pump. See 'Note 1: Sound power level'. The highest sound power level specified should be used (the power in "low noise mode" should not be used).** *Example: Manufacturer's data states the sound power level of the heat pump is 55 dB(A).*	STEP 1 RESULT =
2.	**Use 'Note 2: Sound pressure level' and 'Note 3: Determination of directivity' below to establish the directivity 'Q' of the heat pump noise.** *Example: The heat pump is to be installed on the ground and against a single wall hence the directivity (Q) of the heat pump noise is Q4.*	STEP 2 RESULT =
3.	**Measure the distance from the heat pump to the assessment position in metres.** *Example: Distance between heat pump and assessment position is 4 metres.*	STEP 3 RESULT =
4.	**Use table in 'Note 4: dB distance reduction' below to obtain a dB reduction.** *Example: 4metres @ Q4 = -17 dB.*	STEP 4 RESULT =
5.	**Establish whether there is a solid barrier between the heat pump and the assessment position using 'Note 5: Barriers between the heat pump and the assessment position' and note any dB reduction.** *Example: There is a brick wall between the heat pump and the assessment position. Moving less than 25cm enables the assessment position to be seen. dB reduction = -5 dB.*	STEP 5 RESULT =
6.	**Calculate the sound pressure level (see 'Note 2: Sound pressure level') from the heat pump at the assessment position using the following calculation:** **(STEP 1) + (STEP 4) + (STEP 5)** *Example (55) + (-17) + (-5)=55 – 17 – 5 =33 dB(A) Lp*	STEP 6 RESULT =

Table 7-1: United Kingdom regulation – MCS020 calculation procedure

7.	**Background noise level. For the purposes of the MCS Planning Standard for air source heat pumps the background noise level is assumed to be 40 dB(A) Lp. For information see 'Note 6: MCS Planning Standard for air source heat pumps background noise level'.** *Example: Background noise level is 40 dB(A).*	STEP 7 RESULT = 40 dB(A)
8.	**Determine the difference between STEP 7 background noise level and the heat pump noise level using the following calculation:** (STEP 7) – (STEP 6) *Example: 40 dB(A) (background) – 33 dB(A) (heat pump) = 7dB(A).*	STEP 8 RESULT =
9.	**Using the table in 'Note 7: Decibel correction' obtain an adjustment figure and then add this to whichever is the higher dB figure from STEP 6 and STEP 7. Round this number up to the nearest whole number.** *Example: Adjustment figure is 0.8 dB and the higher figure is 40 dB(A).* *40 + 0.8 = 40.8 dB(A).* *Rounded up to 41 dB(A)* *Final result at this assessment position is 41 dB(A).*	FINAL RESULT=
10.	**Is the FINAL RESULT in STEP 9 lower than the permitted development noise limit of 42 dB(A)?** **If YES - the air source heat pump will comply with the permitted development noise limit for this assessment position and may be permitted development (subject to compliance with other permitted development limitations/conditions and parts of this standard). NOTE - Other assessment positions may also need to be tested.** **If NO – the air source heat pump will not be permitted development. This installation may still go ahead if planning permission is granted by the local planning authority.** *Example: 41 dB(A) is lower than 42 dB(A).*	Final result is lower than 42 dB(A) YES / NO (delete as appropriate)

Table 7-2: United Kingdom regulation – MCS020 calculation procedure

7.4 Planning consent

For heat pumps that don't fulfil the requirements of 42 dB(A) for development rights or when more than one heat pump is being installed then planning permission, including in relation to noise, is required.

A site-specific assessment is carried out for the heat pump(s) to determine predicted noise levels at the nearest sensitive receptor(s). The noise criteria are set by local planning authorities around the UK and quite often the noise criteria will refer to a noise assessment in accordance with BS 4142. This assesses the predicted noise level of the heat pump(s) against site specific background noise levels.

7.4.1 BS 4142

BS4142: 2014 " Method for rating industrial and commercial sound" is used to assess the outdoor sound levels for likely effects of sound on people in residential dwellings, and in particular at proposed new dwellings or premises used for residential purposes.

The principles basis of the standard are:

- Determine specific sound level
- If specific sound levels vary take necessary measurements
- Measure residual sound level in absence of specific noise
- Take away effect of residual sound on specific sound
- Measure background sound level of residual sound

For assessing the noise level which will be compared to the noise criteria as defined by local authorities.

8 The Austrian regulations

8.1 Introduction

Heat pumps are more and more used for domestic heating and hot water production. Heat pumps are seen as one of the key technologies against climate change. Using heat pumps for heating and hot water production is one major measure to reduce the CO_2 emissions and to reach the ambitious climate targets of the European Union. In the last couple of years especially heat pumps with ambient air as heat source are getting more and more popular. Energy on a low temperature level is brought by means of a heat pump process to a higher temperature level which can be used for heating purposes. Basically, the energy on the low temperature level can be either from the air, from ground water or from surface collectors. These different types have their advantages and disadvantages. Actually most of the heat pumps use the ambient air as heat source, because it is easy to access and cheap. Regarding noise emissions, an approval from the building authority is sometimes necessary, which is based on a calculation procedure. The main disadvantage and the biggest challenge of air-water heat pumps is the emission of noise.

As it is one of the biggest barrier for the market diffusion the emission of noise has to be reduced and clear rules concerning noise emission and immission limits are needed. Especially in Austria there is no nationwide legal regulation. There are different regulations even at the municipal level and it's difficult to overlook all these regulations. This report will give an overview about the regulations and the current situation in Austria. A detailed explanation of the influence of the heat pump installation and the effects on the surrounding environment can be found in the Task 5 report.

8.2 Sold heat pumps

The development of the heat pump market in Austria is a success story over the last 20 years. Different effects are responsible for the increasing number of sold heat pump units. A significant contribution was made by an increased energy efficiency of new buildings, which were qualified for the energy-efficient use of heat pumps due to the low specific heat demand and low temperature heating systems, e.g. floor heating systems (Benke et al., 2015). Additionally, there was an incentive-oriented energy policy by the Austrian government and the government of the provinces.

According to Benke et al. (2015) Figure-8-1 gives an overview of the distribution of installed heating systems in Austria in the year 2013. The most important heating system was a gas-fired boiler. Heat pumps (HP) had a share of around 16.5 % of installed heating systems.

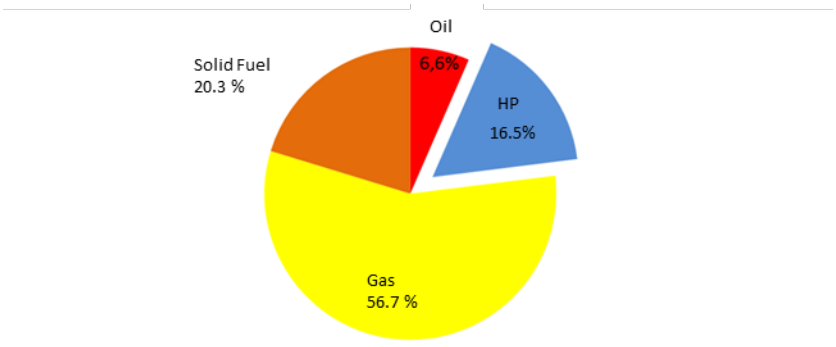


Figure-8-1: Austrian regulation – Installed heating systems in Austria in 2013 (Benke et al., 2015)

Figure-8-2 shows a detailed course of sold heat pump units from 1993 to 2016 in Austria. Figure-8-2 (left) shows the absolute values of sold heat pump units for different energy sources, Figure-8-2 (right) shows relative values. From 1993 to 2008 there was a significant increase in sold heat pump units. Until 2011 there was a slight decrease which was followed by another increase of the amount of sold heat pump units until 2015. In 2015 the number of sold heat pump units reached its maximum at around 17800 sold units. From 2010 to 2016 there was a strong rise of sold air-water heat pump units which resulted in around 12000 sold air-water heat pump units in 2016. From 2003 to 2010 brine-water heat pump units were the dominating ones. Thus, the share of air-water heat pump units increased from 2008 from 20 % to 70 % in 2016, whereas the share of brine-water heat pump units decreased from 2008 from 50 % to around 20 % in 2016 (see Figure-8-2 (right)). Due to technological improvements and costs of air-water heat pumps the share of direct expansion ground-coupled heat pump units decreased from around 65 % in 1997 to 5 % in 2016.

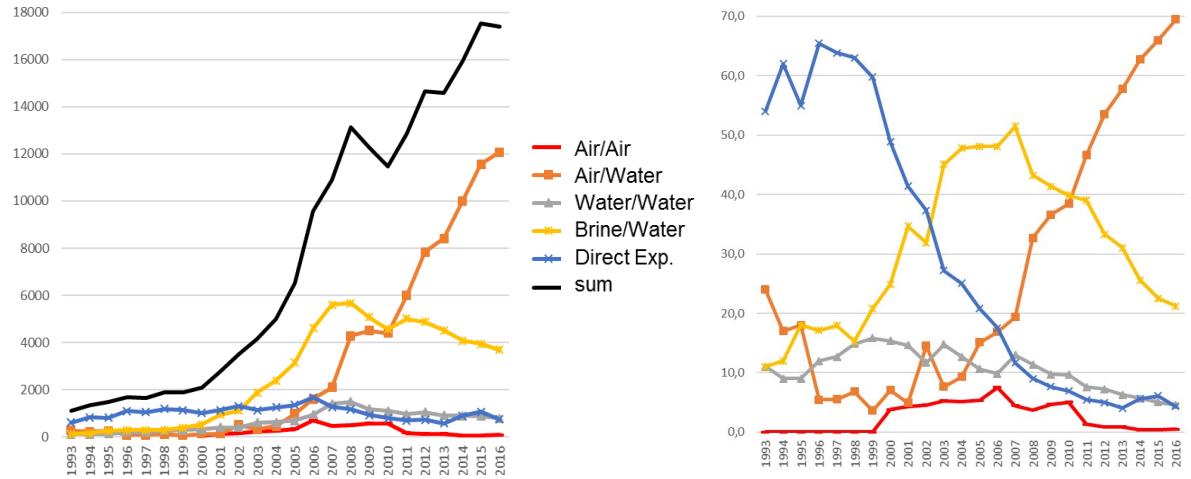


Figure-8-2: Austrian regulation – Absolute (left) and relative (right) values of sold heat pump units in Austria (Biermayr et al., 2017)

8.3 Legal basis

For the inside or outside installation of an air-water heat pump, there is no approval from the local government necessary if the building laws don't include any regulations for heat pumps. In the case of a suspicion of a possible health hazard of persons (e. g. neighbours, employees, …) the building authority can arrange an expert opinion or an evaluation out of a medical point of view on a case-by-case basis. The worst case is that the building authority can prohibit the operation of the plant (heat pump). Usually the end-customer is responsible for the heat pump system. However, installers and producers have to inform the customer of possible noise generation and the disturbance of the neighbours. This is an unfavourable situation for the customers. Customers always have to fear to get sued by the neighbours.

In Austria there are some important documents which are regulating the immission of noises, but there is no nationwide law for the regulation of noise emission/immission of heat pumps.

The available and important documents regarding noise emissions are:

- ÖNORM S 5021 (2017) (main document)
- ÖAL Guideline No. 3: Evaluation of noise immissions in the neighbourhood, (Österreichischer Arbeitsring für Lärmbekämpfung, 2008)
- Information sheet of noise protection (Forum Schall, 2013)
- ÖAL Guideline No. 6: The effects of noise on the humans – Assistance for the medical experts (Österreichischer Arbeitsring für Lärmbekämpfung, 2011)
- Regulations / Information sheets of the federal provinces

For the estimation of the noise, there is a Noise Calculator of "Wärmepumpe Austria" (Wärmepumpe Austria, 2018).

The following subchapters contain abstracts of the available documents. It has to be noted, that this report should only give an overview of the situation in Austria regarding noise immission and has therefore no legal relevance.

8.3.1 ÖNORM S 5021 (2017) (Austrian Standard)

The ÖNORM S 5021 (2017) is used for the regulation of noise immissions from road traffic, trains and plants. There is no explicit regulation for heat pumps, but it is obvious that heat pumps can be handled as plants.

The ÖNORM S 5021 (2017) is mainly used for the land use designation and the regional planning. This standard shall not be used for the evaluation of disputes regarding noise immissions. For this, the ÖAL Guideline No. 3 (Österreichischer Arbeitsring für Lärmbekämpfung, 2008) has to be used.

8.3.2 Planning values for noise immission

Table 8-1 shows the planning values for the noise immission dependent on the area and the location. The land use designation and the regional planning has to consider that the immission of noise does not cause any disturbance of the residents and the neighbours. Therefore the areas are divided into two different types, the building areas and the grassland. The building area is subdivided into six different location types and the grassland is subdivided into three different location types. Each location is allocated to a certain noise immission value depended on the different noise emitters and the claim to rest. The locations of the building area are subdivided

between the resting areas (zone with higher noise prevention requirements) and the industrial areas (operation emitting a high level of noise is permitted). There are no noise immission limits for the industrial area, because there is no claim to rest. The grassland is mainly used for agriculture, but with a special grant it can also be used as a cure or a local recreation area. The cure area is a zone with higher noise abatement requirements and the local recreation area is a zone with lower noise abatement requirements. There are no noise immission limits for the third one, the agricultural area due to the unnecessity to rest.

Category	Area	Location	Assessment level			$L_{r,den}$
			dB			dB
			Day	Evening	Night	
1	Building area (Bauland)	Resting area	45	40	35	45
2		Residential area (rural)	50	45	40	50
3		Residential area (urban)	55	50	45	55
4		Central area	60	55	50	60
5		Residential & industrial a.	65	60	55	65
6		Industrial area	-	-	-	-
1	Grassland (Grün-land)	Cure area	45	40	35	45
2		Local recreation area	50	45	40	50
3		Agricultural area	-	-	-	-

Table 8-1: Austrian regulation – Planning Values for noise immission (ÖNORM S 5021, 2017)

In addition to the division of the areas with different location types there are also different noise emission levels (assessment level L_r) for different times of the day. The day time is defined as the time between 6 a.m. and 7 p.m. (13 hours), the evening as the time between 7 p.m. and 10 p.m. (3 hours) and the night is defined as the time between 10 p.m. and 6 a.m. (8 hours). The assessment level for the general noise pollution ($L_{r,den}$) is an averaged value with different weights for the different times of the day (day, evening and night). The calculation of the assessment level for the general noise pollution ($L_{r,den}$) is described in chapter 8.3.6.

Usually the noise emissions of plants with a continuous operation is limited to the basis value. According to ÖNROM S 5021 (2017) it can be assumed that the basis value for the spatial planning (basis sound pressure level) is 10 dB lower than the allowed assessment level depending on the location and the period of time (day, evening, night). The real basis sound pressure level ($L_{A,95}$) can only be determined by an on-site measurement and is defined as the value which is exceeded during 95 % of the measurement time. Simplified the basis sound pressure level can be seen as the ambient noise at which it is subjectively silent. This means, the sound pressure level hardly falls below this value. According to Wärmepumpe Austria (2014) the noise immission of a plant is not annoying if it is below the basis level. It has to be noted, that the actual local basis level is dependend on the geographical location (roads, air traffic, rivers, …) and the time of the day. One measurement has to be done for at least one hour. Operating conditions with a higher noise emission (e.g. defrosting, …) are averaged within one hour. Out of an empirical point of view and according to (Wärmepumpe Austria, 2014) a heat pump unit, which fulfils the noise immission limit during the night, also fulfils the limit during the day and the evening.

This means that the values given in Table 8-1 have to be reduced by 10 dB as the heat pump unit is classified as a continuous noise source and therefore the maximum allowed value is limited to the basis sound pressure level. If the real on-site basis sound pressure level (measured value) is lower than the assumed basis sound pressure level according to ÖNORM S 5021 (2017) (Assessment level L_r – 10 dB) the lower one is relevant for the evaluation. Otherwise if the real on-site basis sound pressure level (measured value) is higher than the assumed basis sound pressure level according to ÖNORM S 5021 (2017) (Assessment level L_r – 10 dB) the higher one is relevant for the evaluation. Special operating conditions such as defrosting have to fulfilled the limits given in Table 8-1, as it is only for a short period of time. Normally the given immission levels have to be observed at the property line.

If the noise immission of the plant exceeds the basis sound pressure level (ambient sound pressure level) an individual analysis according to Österreichischer Arbeitsring für Lärmbekämpfung (2008) is necessary whether the immission is still in an acceptable range or not. In Österreichischer Arbeitsring für Lärmbekämpfung (2011) the absolute upper limit is defined from a medical point of view where hazards to the health of humans can not be excluded. From an empirical point of view the noise immission of a plant (heat pump) is critical, if the sound pressure level exceeds the basis sound pressure level by 10 dB or more (Wärmepumpe Austria, 2014).

8.3.3 Energy-equivalent sound pressure level Leq

For the calculation of the assessment level for general noise pollution in Table 8-1 (right) the energy-equivalent sound pressure level is needed. The energy-equivalent continuous sound level is calculated as the sound pressure level that is energy-equivalent in case of a permanent exposure of any desired sound. The energy-equivalent sound pressure level can be calculated according to Eq. 8-1.

$$L_{eq} = 10 \cdot log \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} dt \; in \; dB \qquad \textit{Eq. 8-1}$$

$t_2 - t_1$ ..... measuring time in h

p ..... sound pressure in Pa

p_0 ..... reference sound pressure, $p_0 = 2 \cdot 10^{-5}$ Pa (equivalent to the humans hearing threshold)

The A-rated Energy-equivalent sound power level $L_{A,eq}$ has to be determinded according to OVE/ÖNORM EN 61672-1 (2015).

8.3.4 Adjustment values Lz for different noise sources

The adjustment value has to be specified according to the state-of-the art. The adjustment value for different noise types is added to the assessment level L_r (see chapter 8.3.5). For the different noise types there are three typical adjustment values:

- Train - 5 dB
- Road traffic 0 dB
- Plants + 5 dB

This classification means, that the train is privileged against the road traffic and the plants. From the point of the noise exposure this means, that intermittent noises are privileged. In the ÖNORM S 5021 (2017) there is neither an adjustment value for heat pumps nor an explanation if heat pumps have to be qualified as plants. But it can be assumed that heat pumps are classified as plants. There is also no declaration if there is a difference between industrial or private use. If special noise characteristics should be taken into account, a different adjustment may be specified.

8.3.5 Assessment level Lr

The assessment level can be calculated according to Eq. 8-2. It is necessary to indicate the period of time the assessment level is referred to. To account for the sensitivity of the ear, the energy-equivalent sound pressure level (L_{eq}) in Eq. 8-2 is A-rated (indicated by the index A).

$$L_r = L_{A,eq} + 10 \bullet \log\left(\frac{T}{T_{Bez}}\right) + L_Z \; in \; dB \qquad \textit{Eq. 8-2}$$

L_r ..... Assessment level in dB

T ..... Duration of the noise within the reference time in h

T_{Bez} ..... Reference time in h

L_z ..... adjustment value in dB

8.3.6 Assessment level for general noise pollution Lr,den

The Assessment level for general noise pollution is determined with Eq. 8-3. The subscript "den" stands for day, evening and night and indicates the three different times of the day (see chapter 8.3.2). Each noise source is considered separately (road, train, air traffic and plants) with its adjustment value (see chapter 8.3.5). This means that the overall noise has to be split up into the different noise types. This value also considers the classification of the different periods of a day. The assessment level for general noise pollution is an averaged value for a day with different weights for the different times of the day. The numbers in front of the sigma sign accounts for the hours of each period of the day. The assessment level of the evening is weighted with + 5 dB and the assessment value of the night is weighted with + 10 dB.

$$L_{r,den} = 10 \bullet \log \frac{1}{24}\left(13 \bullet \sum_{k=1}^{4} 10^{\frac{L_{r,day,k}}{10}} + 3 \bullet \sum_{k=1}^{4} 10^{\frac{L_{r,evening,k}+5}{10}} + 8 \bullet \sum_{k=1}^{4} 10^{\frac{L_{r,night,k}+10}{10}}\right) in\ dB \qquad \text{Eq. 8-3}$$

$L_{r,day,k}$ ..... Assessment level for the noise source typ k during day in dB

$L_{r,evening,k}$ ..... Assessment level for the noise source typ k during evening in dB

$L_{r,night,k}$ ..... Assessment level for the noise source typ k during night in dB

k = 1 ..... Noise source type for the road traffic

k = 2 ..... Noise source type for the train

k = 3 ..... Noise source type for the air traffic

k = 4 ..... Noise source type for plants

8.4 ÖAL Guideline No. 3 (Österreichischer Arbeitsring für Lärmbekämpfung, 2008)

The main task of the Austrian Task Force for Noise Prevention ("Österreichischer Arbeitsring für Lärmbekämpfung – ÖAL") is to develop guidelines for the evaluation of noise disturbance since more than 40 years. The ÖAL Guideline No. 3 is used for the evaluation of noise immissions in the neighbourhood and has proven to be a standard reference. The guideline is also recommended from the Federal Ministry for Health and Environmental Protection.

In order to give appraisers assistance from a medical point of view in individual cases limits to avoid health hazards are defined. Therefore an assessment scheme was developed. Figure 8-3 shows the general three step assessment scheme which. For the evaluation of the different noise types (plants, road traffic, train, air traffic and construction sites) this scheme is adapted and extended within the ÖAL Guideline No. 3 (Österreichischer Arbeitsring für Lärmbekämpfung, 2008).

The first step is to check whether the assessment value of the specific noise immission is below the limit of expected health hazards or not. The assessment level is defined according to ÖNORM S 5021 (2017). The assessment level for the day can either be the average of 13 hours (between 6 a.m. and 7 p.m.) or if the average of an entire hour within these 13 hours is 5 dB higher than the 13 hours average, this maximum hourly value less 5 dB is taken as the assessment value. The assessment level for the evening is defined as the average between 7 p.m. and 10 p.m. (3 hours). For the night the average of an hour with the highest assessment value between 10 p.m. and 6 a.m. is taken. If the assessment value of the specific noise immission is above the limit of health hazards measures are required to reduce the noise emission.

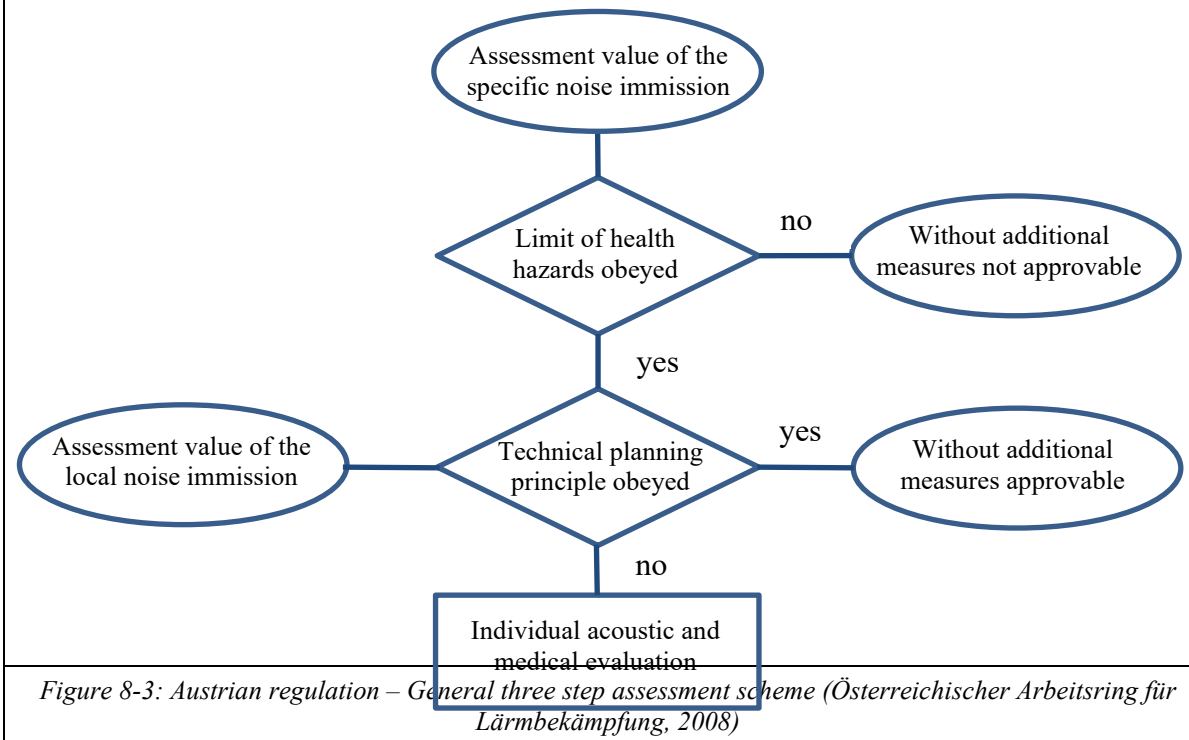


Figure 8-3: Austrian regulation – General three step assessment scheme (Österreichischer Arbeitsring für Lärmbekämpfung, 2008)

The next step is to check whether the noise immissions have relevant effects on the surroundings or not (technical planning principle). The assessment level of the local noise immission can either be determined from a measurement or by a calculation. It has to be separated into the different times of the day (day, evening, night) with average hourly values. The measurement has to be carried out in a representative period of time. If it is done by a calculation the emission value of adjoining and approved plants have to be taken, without considering random noise emissions. If the technical planning principle is not obeyed an individual acoustic and medical evaluation considering acoustic and non-acoustic parameters is required, otherwise it is approvable without additional measures. A detailed flow chart of the evaluation of the technical planning principle can be found in (Österreichischer Arbeitsring für Lärmbekämpfung, 2008) for plants, road traffic, train, air traffic and construction sites.

The aim of this guideline is to protect people in the vicinity of sound sources. The compliance with the upper limits of this guideline ensures to avoid health hazards and therefore the compliance with the technical planning principle is irrelevant with regard to the criterion of unacceptable noise emission. However, the upper limit of acceptable noise emission cannot be determined directly from the ÖAL Guidline No. 3. It has to be derived by means of an individual acoustic and medical evaluation by the authority. Out of the ÖAL Guidline No. 3 the medical experts are the last to decide if health hazards are expected or not

In the ÖAL Guideline No. 3 there is also a precautionary principle defined. If a noise source (e.g. a plant) has to be approved, the assessment level out of the land use designation (ÖNORM S 5021, 2017) cannot be fully utilized, if it can be expected that other noise sources will be installed in the future. This basically means that an area is subdivided into sub-areas with lower allowed noise immission values. As a consequence of this, additional noise sources can be installed without exceeding the noise immission values of the overall area.

Normally the given immission levels have to be observed at the property line. In Österreichischer Arbeitsring für Lärmbekämpfung (2008) there is one special definition for the night time. Due to the lack of outside presence of humans during the night the values have to be observed at the nearest window of the bedroom as a medical point of view. The neighbours also have the privilege to keep their window open.

The ÖAL Guideline No. 3 also gives some detailed examples about how to proceed in single cases. Although it is recommended by the Federal Ministry for Health and Environmental Protection, but it has no direct legal relevance. In some cases the ÖAL Guideline No. 3 can be in a concurrence with other regulations and guidelines (Austrian Standard – ÖNORM, psychoacoustic methods, …). Based on the decision of the Austrian administrative court, the regulation or guideline which is linked to the law has to be used and if there is no connection to the law – as it is in the case of the evaluation of noise emissions – the regulation or guideline which suits best to the premises and assessment criteria has to be used. That under certain circumstances several different guidelines or regulations are available does not harm the judgement, as long as the appraiser selects an adequate one. Currently the ÖAL Guideline No. 3 is under revision and will be updated in the near future.

8.5 Information sheet of noise protection in the neighbourhood of heat pumps (Forum Schall, 2013)

The “Forum Schall” is a group of experts (appraisers, …) which is supported by the Austrian Federal Environment Agency. A summary about the regulation of noise emission can be found in the “Information Sheet of Noise Protection” of Forum Schall (2013). The information sheet mainly combines the regulations from the ÖNORM S 5021 (2017) and the ÖAL guidelines. The “Forum Schall” also pointed out, that there are no statutory limits regarding noise immissions. In principle the basis level of the local noise immission should be used for continuous noise sources. Based on experience it can be assumed that the base level in a silent residential area is between 20 and 25 dB during the night (10 p.m. to 6 a.m.) (Forum Schall, 2013). In order to avoid any disturbances due to noise immissions and especially low-frequency noise immissions from air-water heat pumps continuous noises should be below the basis level, from a medical point of view (Österreichischer Arbeitsring für Lärmbekämpfung, 2008). For this reason a target value of 25 dB during the night should be achieved. Higher values are only justified if measurements show that the base level is actually significantly higher.

Neither in the ÖNORM S 5021 (2017) nor in the ÖAL Guideline No. 3 it is described which limit has to be fulfilled, if two areas with a different deduction (e.g. residential area and industrial area) adjoin each other. According to “Forum Schall” the lower value has to be fulfilled at the border of the property. For the residential area (rural) an A-rated sound pressure level of 30 dB at the property line has to be obeyed during night as it is seen as a continuous noise source. Forum Schall (2013) also prefers that the basis level is added to the noise immission of the heat pump unit without a noticeable increase (Sudy, 2018). This means if the basis level is close to the limit of 30 dB the noise immission of the heat pump unit at the property

line has to be around 23 to 25 dB to not exceed the limit of 30 dB at the property line. According to Sudy (2018) this is not considered for the approval of heat pump units in Graz.

To fulfil the target value of $L_{A,eq}$ = 25 dB during the night the heat pump can not be installed at the property line. A distance to the neighbour is necessary. The distance has to be increased if the sound pressure level of the heat pump is higher.

In Forum Schall (2013) there are also possible measures described to reduce the noise immission. This can be an averted position of the neighbour, a speed reduction of the compressor or a complete shutdown during the night. For a complete shutdown during the night a storage may become necessary

8.6 ÖAL Guideline No. 6 (Österreichischer Arbeitsring für Lärmbekämpfung, 2011)

The ÖAL Guideline No. 6 was also published by the Austrian Task Force for noise prevention (Österreichischer Arbeitsring für Lärmbekämpfung, 2011). The ÖAL Guideline No. 6 is used to describe the effects of noise on humans. It should be seen as a guideline for medical experts to assist them during the medical evaluation of noise pollution. The guideline was created with the actual scientific knowledge regarding the effects of noise immissions. It is also described which information is necessary in an experts opinion which is written for an authority procedure.

The relationship between the level of sound immission and the observed impact on the humans in this guideline is mainly based on the “Night Noise Guidelines for Europe” from the World Health Organization (WHO). The description of the effects of noise immissions on the humans health are differentiated between an outside and inside sound pressure level. Table 8-2 shows an overview of the effects on the humans health for different sound pressure levels during the night at the outside.

%

Up to 30 dB(A)	No effects recognizable (No Observed Effect Level [NOEL]).
30 to 42 dB(A)	Effects such as increased body movements, sleep disorders and EEG arousals are observed. It cannot be assumed that only sensitive groups are affected. However, the occurrence of these effects depend strongly on the noise characteristics and the frequency of the occurrence.
42 to 55 dB(A)	Strong increase in negative health effects as well as increased wake-up reactions. A large number of the human population has to arrange their lives differently in order to cope with the noise. Sensitive groups are significantly affected at this level of sound immission.
Above 55 dB(A)	The situation is dangerous for the health of the human population and the risk for cardiovascular disease increases.

Table 8-2: Austrian regulation – Overview of effects of different sound pressure levels during night at the outside (Österreichischer Arbeitsring für Lärmbekämpfung, 2011)

Sleep disorders caused by noise immissions are dependent on the sound level and the frequency of their occurrence. Table 8-3 shows an overview of the effects on the humans' health for different sound pressure levels during the night if it occurs inside the building.

Up to 35 dB(A)	Effects such as increased body movements, sleep disorders and EEG arousals are observed.
35 to 42 dB(A)	Extended time to fall asleep, increased waking-up reactions and a shorter sleeping time can be observed.

Table 8-3: Austrian regulation – Overview of effects of different sound pressure levels during night at the inside (Österreichischer Arbeitsring für Lärmbekämpfung, 2011)

For an "air-hygienic" reason and thermal comfort during the summer, these values should not be exceeded with an open window.

8.7 Regulation and funding in the federal provinces

The technical requirements concerning the acoustics of an air-water heat pump differ in the federal provinces widely due to different buildings laws. An overview of noise immission limits in the federal provinces is shown in Table 8-4. This noise immission limits ($L_{r,zul}$) shown in Table 8-4 are mainly derived from the planning values according to ÖNORM S 5021 (2017) for residential areas (rural) (see chapter 8.3.5). Due to the classification of a heat pump as a continuous noise source in most of the federal provinces the A-rated energy-equivalent sound pressure level depending on the land use designation has to be 10 dB lower than the planning values according to ÖNORM S 5021 (2017).

Federal Province	$L_{r,zul}$ [dB]	$L_{r,zul}$ [dB]	$L_{r,zul}$ [dB]
Tyrol	40	35	30
Salzburg	40	35	30
Carinthia	40 (35)	35 (30)	30 (25)
Vorarlberg	40 (35)	35 (30)	30 (25)
Upper Austria	40	35	30
Vienna	30 with a distance of 1 m to the unit		
Lower Austria	-	-	-
Styria	-	-	30 (25)
Burgenland	-	-	(25)
Environment Agency Austria	-	-	(25)

Values at property line; (…) Measurement at the window (closest sleeping room) or 3 m from the property line

Table 8-4: Austrian regulation – Overview of noise immission limits in the federal provinces (Doppler, 2015) (IG Umwelt und Technik, 2007)

Generally this limits have to be fulfilled at the property line. The approval in the federal provinces is mainly based on a mathematical estimation of the sound pressure level at the property line $L_{r,calc}$ (Eq. 8-4).

$$L_{r,calc} = L_{w,A} + L_Z + K_0 - 20 \cdot \log(Distance) - C\ in\ dB \leq L_{r,zul} \qquad \textit{Eq. 8-4}$$

$L_{w,A}$ ..... Sound power level of the heat pump unit in dB

L_z ..... Adjustment value for continuous low-frequency noise

0 dB if it is verified (certificate, manufacturer) that the heat pump unit has no low frequency noise otherwise it is +5 dB

K_0 ..... Adjustment value for the position of the heat pump unit / the directivity

0 dB for a freestanding heat pump unit, +3 dB if it is places at the facade or +6 dB if it is placed at an internal corner

C ..... Constant connecting sound pressure and sound power level

11 dB for a spherical sound propagation or 8 dB for a hemispherical sound propagation

The estimation uses the sound power level given by the manufacturer, adjustment values for the position of the heat pump unit (K_0) and for the consideration of continuous low-frequency noise (L_z) as well as the distance between the heat pump unit and the property line. Not every federal province considers all factors during the approval process. In Styria for example the adjustment value for low-frequency noise is not considered.

Vienna and Burgenland have different limits and in Lower Austria there are no limits if the heat pump is used for heating purposes. In Vienna the maximum allowed A-rated energy-equivalent sound pressure level is 30 dB with a distance of 1 m to the heat pump unit. Burgenland complies

with the suggestion of Forum Schall (2013) which recommends a value of 25 dB during night. Tyrol is the only federal provinces with an own law which includes noise emission limits (Tiroler Gas-, Heizungs- und Klimaanlagenverordnung, 2014). This means Tyrol is the only federal province with noise immission limits which have a direct legal validity.

In some federal provinces (e.g. Vienna, Styria) an approval from the building authority is necessary. According to Sudy (2018) in Styria there is also a difference if a heat pump unit has to be evaluated within the industrial (industrial area) or the building (residential area) regulations. If a heat pump unit has to be evaluated according to the Steiermärkische Baugesetz (2017) (building regulation) the noise immission limits have to be observed at the property line but if it has to be evaluated after the Gewerbeordnung (2018) the closest sleeping room window and therefore the values in brackets in Table 8-4 are relevant. As a heat pump is not seen as a building structure it can also be closer than 3 m to the property line in Styria. If it is closer than 3 m to the property line the distance to the closest sleeping room windows is relevant and the values in brackets in Table 8-4 are taken. It has to be noted that if a heat pump is surrounded by a wall, as a noise absorption measure, the wall is seen as a building and must have a distance of 3 m to the property line.

In most of the federal provinces the compliance with the noise immission limits shown in Table 8-4 is necessary to receive a funding. In Upper Austria for example the adjustment value for continuous low-frequency noise is considered whereas the noise immission limit is increased to 35 dB to receive a funding (Land Oberösterreich, 2017). There is not only a funding from the national government; it is also possible to receive a funding from the energy providers. Furthermore the customer is responsible to observe the guidelines regarding noise immissions.

Normally there are no on-site measurements of the real basis sound pressure level or the noise immission of a heat pump unit taken due to high costs of acoustic appraisals. If an on-site measurement is taken, the values shown in Table 8-4 have to be fulfilled as A-rated energy-equivalent sound pressure level.

8.8 Noise Calculator of the Austrian Heat Pump Association (Wärmepumpe Austria, 2018)

On the website of the Austrian Heat Pump Association, a "sound propagation calculator" can be found (Wärmepumpe Austria, 2018). With this calculator an estimation of the sound pressure level in a certain distance can be determined.

8.8.1 Sound propagation and evaluation

With an increasing distance from the sound source, the sound power level is distributed within an increased area. Subsequently the sound pressure level is reduced with an increased distance. The following parameters have an essential influence on the sound propagation (Wärmepumpe Austria, 2014):

- Directivity of the sound (orientation of the heat pump unit)
- Shielding with obstacles (buildings, walls, …)
- Reflection of the sound (ground, buildings, …)
- Reduction of the sound with absorbing surfaces

Figure 8-4 shows the interface of the Noise Calculator. In the first step, the calculation method ("Berechnungsverfahren") has to be chosen, between the hemispheric and the enveloping surfaces method (see chapter 8.9). This program includes a huge database of noise emission values of different heat pumps. In the second step the manufacturer ("Hersteller") and the model ("Modell / Typ") as well as the installation typ (inside/outside) can be chosen and the maximum sound pressure level is filled in automatically. Additional measures to reduce the noise emission can also be considered. Annoying background noises, such as knocking, squeezing or continuous low-frequency noises, can also be considered with the tonality ("Tonhaltigkeit/Tonalität"). According to Wärmepumpe Austria (2018) a noise can be classified as low-frequency noise if the C-rated sound pressure level is 20 dB higher than the A-rated sound pressure level. The classification has to be done by the manufacturer. If there is no proof provided by the manufacturer a surcharge of 5 dB is added to the sound pressure level to account for the possibility of a perceptible low-frequency noise emission share.

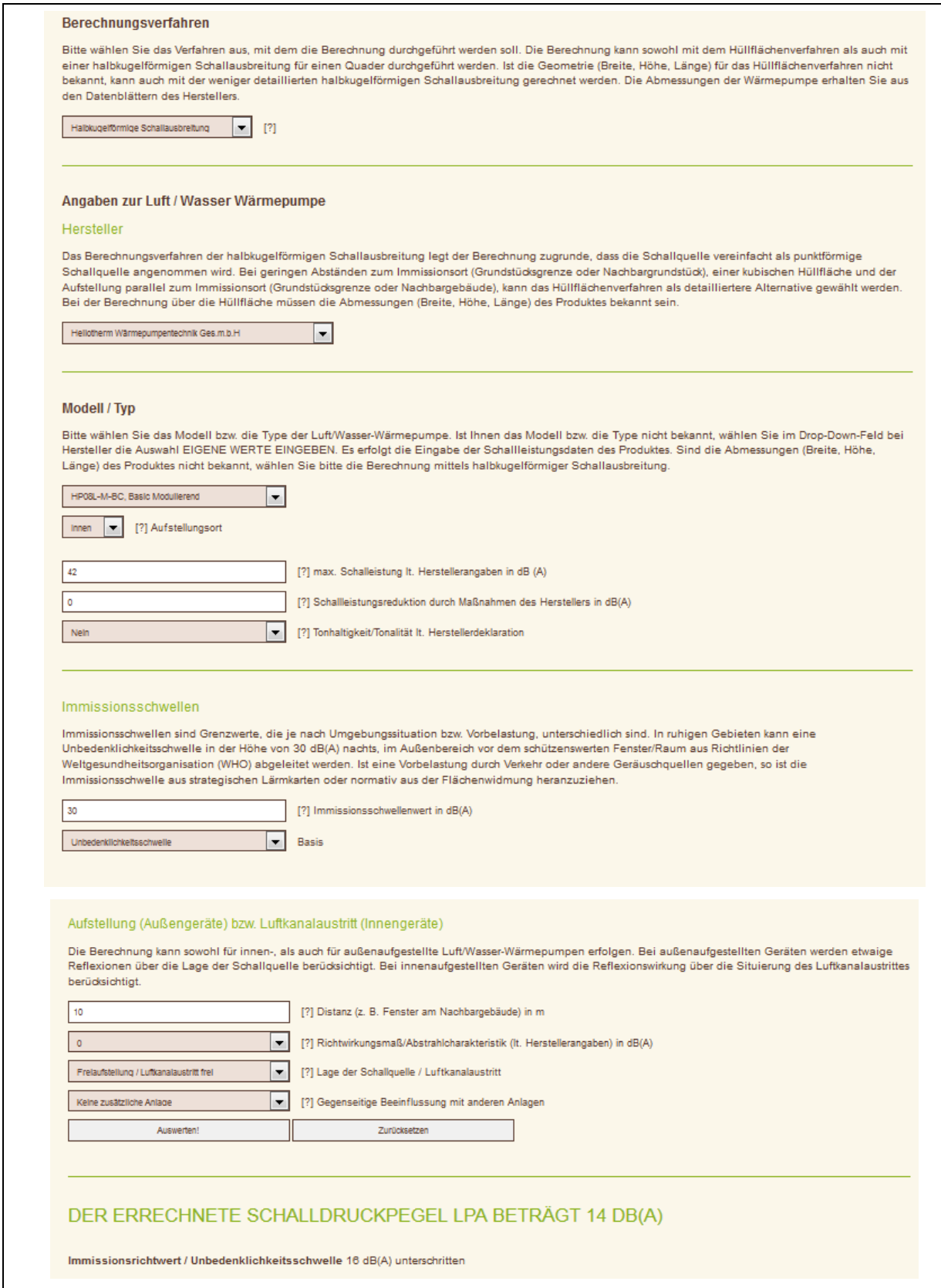


Figure 8-4: Austrian regulation – Noise calculator of the Austria Heat Pump Association (Wärmepumpe Austria, 2018)

After finalizing the heat pump setup, the assessment level (“Immissionsschwellen”) which describes the noise immission limit has to be defined. This value can be taken out of the strategic noise map, the land use designation and the regional planning or no observed effect level (NOEL) can be set.

The influence of the installation can also be taken into account. A distance to the property line or to the next window (“Distanz”), the directivity (“Richtwirkungsmaß”), the position of the sound source (“Lage der Schallquelle”) and the interference with other plants can be set.

With the given input parameters, the program estimates the sound pressure level in the defined distance. The program also informs whether the noise immission limit is obeyed or exceeded. This program is dedicated to from planners and installers to estimate the sound immission at a given distance. The values are only on an informal basis and don’t have any legal relevance.

8.9 Implementation of Measurements (Wärmepumpe Austria, 2018)

If it is necessary to determine the sound pressure level a sound-level measuring device according to ÖN EN 61672 (2015) is necessary. For precise measurements the device has to fulfil a measurement inaccuracy of ± 0,7 dB and has to be calibrated from the bureau of standards every two years.

Measurements can be taken before or after the installation of an air-water heat pump. If the measurements are taken before, the basis sound pressure level can be determined, if the measurements are taken after the installation the emissions / immissions of the air-water heat pump can be checked and whether the assessment values are not exceeded.

According to Wärmepumpe Austria (2014) the followings tips should be fulfilled during the measurement:

- The operation mode of the air-water heat pump has to be observed.
- The measurements should be taken close to the air-water heat pump unit and the distance between the air-water heat pump and the microphone has to be documented.
- The measurement should also be unaffected by background noise (e.g. construction noise, conversations, …).
- The measurement should not be affected by a shield or by reflections.

The reason why the measurement should be taken close to the air-water heat pump is that in a greater distance (e.g. at the property line) the noise immission should not be distinguished from the ambient noise (excluding defrosting) and therefore it should not be possible to see any changes in the measurements.

Out of the measurement the plant-related sound pressure level can be derived. If the unit has compact dimensions (e.g. a point source) a hemispheric sound propagation (Figure 8-5) can be assumed.

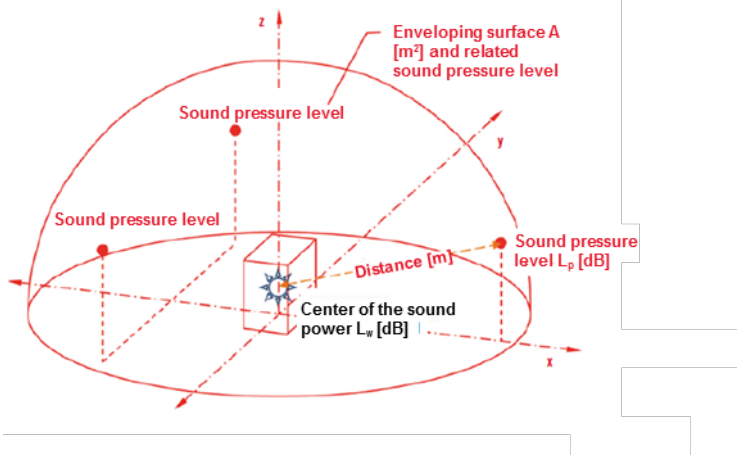


Figure 8-5: Austrian regulation – Hemispherical enveloping surface (Wärmepumpe Austria, 2014)

According to Wärmepumpe Austria (2014) the sound power level ($L_{W,A}$) can be calculated from the sound pressure level ($L_{p,A}$) dependent on the distance according to Eq.8-5. The distance has to be given in meters.

$$L_{W,A} = L_{p,A} + 20 \cdot \lg(Distance) + 8 \qquad \textit{Eq.8-5}$$

In case of a huge unit or a measurement distance lower than three meters the assumption of a hemispheric sound propagation would underestimate the sound pressure level. Therefore the enveloping surface method is used. Instead of the hemispherical enveloping surface a cubic enveloping surface is determined dependent on the dimensions of the unit. This method needs more measurements and is therefore more time-consuming.

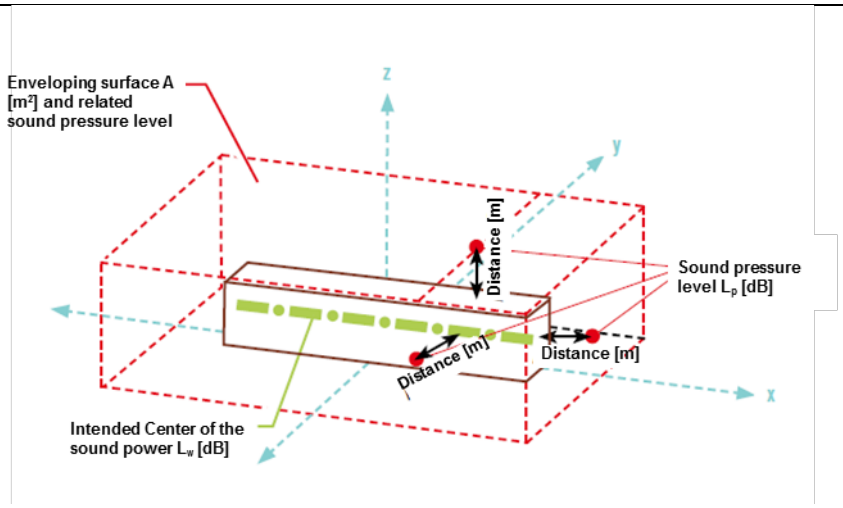


Figure 8-6: Austrian regulation – Cubic enveloping surface (Wärmepumpe Austria, 2014)

The sound power level ($L_{W,A}$) can be calculated from the sound pressure level ($L_{p,A}$) dependent on the enveloping surface according to Eq.8-6 (Wärmepumpe Austria, 2014). The enveloping surface has to be given in square meters.

$$L_{W,A} = L_{p,A} + 10 \cdot \lg(Enveloping\ surface) \qquad \textit{Eq.8-6}$$

With the measurement methods shown, the sound power level of an air-water heat pump unit can be determined. If the sound pressure level in a desired distance has to be determined within a calculation ÖNORM ISO 9613-2 (2008) can be used to consider sound absorption effects (e.g. ground, forest, …).

8.10 Court decisions related to noise emissions of heat pumps

Due to the unclear legal situation regarding noise immission of air-water heat pumps in Austria there are lots of complaints and also some court proceedings. Here one example of a court proceeding is shown.

8.10.1 Court Case 10Ob25/11s (Rechtsinformationssystem des Bundes, 2011)

In general in Austria are only court decisions from the supreme court online available. In 2006 a owner of a property installed an air-water heat pump around five to six meters away from the property of the neighbours. The neighbours felt disturbed and sued the owner of the heat pump at the regional court in 2010. The neighbours requested an immediate injunctive relief of any noise and vibrations caused by the heat pump. They thought that the vibrations and the noise immissions are exceeding the usual level. In contrast to this opinion, the defendant argued that the heat pump complies with all technical regulations and guidelines. The regional court finally dismissed the claim. They argued that the heat pump complies with all technical regulations. They also found out, that the heat pump causes noise and vibrations in the neighbourhood, but in the same order of magnitude such as the spinning of a washing machine or a tumble dryer. The sound pressure level in the house of the neighbours increased around 8 dB to 24 dB. This value is below the values given in ÖNORM S 5021 and below the value of the WHO. This means that there is no health risk.

The plaintiffs were not satisfied with the decision and filed an appeal. The court of appeal granted the complaint because so far there was no supreme court decision on vibrations and noise caused by heat pumps. The question was whether a bad condition of the neighbours house would allow an injunctive relief. In summary, the court of appeal assumed that a heat pump which complies with the relevant standards does not preclude the right for an injunctive relief even if the limits are fulfilled. However, the defendant had not provided the evidence that the symptoms would not occur in the case of averagely sensitive users of the property (and not only by very sensitive persons). The defendant's objection that the health impairments are due to construction defects in the plaintiff's house is not relevant because health is a legally protected right.

The appeal court came to a completely different decision than the regional court. The defendants were not happy with this decision and filed an appeal. The decision was now up to the supreme court. The supreme court deferred the decision back to the appeal court because they made some procedural mistakes. They did not do a repetition of evidence, made their decision on a particular sensitivity of a person and not on an averaged inhabitant (established jurisprudence) and they judged – without an expert opinion of the state of the house - that construction defects cannot impede an injunctive relief.

After three decisions the dispute was back to the appeal court. The final decision of the appeal court is not available online and therefore it can not be reported here how this dispute ended up. But it should show how difficult and ambiguous the situation in Austria is.

8.11 Summary

In Austria no laws regarding the noise immission of heat pumps exist, but there are some regulations and guidelines. The most important one is the Austrian Standard ÖNORM S 5021 (2017) with its assessment level dependent on the land use designation. The ÖNORM S 5021 (2017) also shows a calculation method of the assessment level for the general noise pollution.

For the evaluation of the noise immissions in the neighbourhood, the ÖAL Guideline No. 3 can be used (Österreichischer Arbeitsring für Lärmbekämpfung, 2008). This guideline is recommended from the Federal Ministry for Health and Environmental Protection, but doesn't have direct legal relevance. There are detailed explanations how to proceed in single cases. There is also a recommendation how to proceed in an individual acoustic and medical investigation.

From the Austrian Heat Pump Association an online sound propagation calculator is available (Wärmepumpe Austria, 2018). This calculator calculates the noise immission value/sound pressure level in a defined distance for a given heat pump. The calculated value can only be used for an estimation and doesn't have any legal relevance.

There are also local documents in the federal provinces regarding noise immission limits. These limits also have to be fulfilled to not have any troubles with the local building authority and to gather funding from the government.

The investigation of regulations regarding noise immissions of air-water heat pumps pointed out, that there are no laws to regulate noise emission limits. There are also different guidelines which can be taken into account. Based on the decision of the Austrian administrative court, if there is no regulation connected to the law – as it is in the case of the evaluation of noise emissions – the regulation or guideline which suits best to the premises and assessment criteria has to be used. This means that there is no legal certainty for the customer/end-user because he is responsible to comply with the noise immission limits. It is also not defined which operating point has to be taken for the verification of the compliance with the noise immission limits. As an outcome of this report a clear regulation regarding noise emissions of air-water heat pumps in Austria would be beneficial.

8.12 References

Benke, G., Amann, C., S. Amann, S., 2015. Expertise zum Einsatz von Luftwärmepumpen in Österreich. Energie Markt Analyse GmbH, Wien.

Biermayr P., Dißauer, C., Eberl, M., Enigl, M., Fechner, H., Leonhartsberger, K., Maringer, F., Moidl, S., Schmidl, C., Strasser, C., Weiss, W., Wonisch, P., Wopienka, E., 2017. Innovative Energietechnologien in Österreich Marktentwicklung 2016. Bundesministerium für Verkehr, Innovation und Technologie, Wien.

Doppler, A., 2015. Vortrag zur Akustik von Luft-Wasser-Wärmepumpen und vergleichbaren Anlagen. Linz.

Forum Schall, 2013. Informationsblatt zum Lärmschutz im Nachbarschaftsbereich von Luftwärmepumpen. Umweltbundesamt / Lebensministerium, Wien.

Gewerbeordnung, 2018. https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10007517 (2018/04/09)

IG Umwelt und Technik, 2007. Umgebungslärm. Bundesministerium für Land- und Forstwirtschaft, Umwelt- und Wasserwirtschaft, Wien

Land Oberösterreich, 2017. Berechnung der Schallemissionen bei Luftwärmepumpen. Online: https://www.google.at/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjdn7rSzbHaAhWCmbQKHb_ZChoQFggqMAA&url=https%3A%2F%2Fwww.land-oberoesterreich.gv.at%2FMediendateien%2FFormulare%2Fform_umwelt%2FUWD_US_E_73d_Schallemmissionen_Luftwaermepumpen_Datenblatt.pdf&usg=AOvVaw1rSDJr5iJWlqpnZ4i2qABw (2018/02/05)

Rechtsinformationssystem des Bundes, 2011. Gerichtsurteil Geschäftszahl 10Ob25/11s. Online: https://www.ris.bka.gv.at/Dokument.wxe?Abfrage=Justiz&Dokumentnummer=JJT_20110503_OGH0002_0100OB00025_11S0000_000 (2018/01/20)

ÖNORM ISO 9613-2, 2008. Akustik - Dämpfung des Schalls bei der Ausbreitung im Freien – Teil 2: Allgemeines Berechnungsverfahren. Österreichisches Normungsinstitut, Wien.

ÖNORM S 5021, 2017. Schalltechnische Grundlagen für die örtliche und überörtliche Raumplanung und –ordnung. Österreichisches Normungsinstitut, Wien.

Österreichischer Arbeitsring für Lärmbekämpfung, 2008. ÖAL-Richtlinie Nr. 3: Beurteilung von Schallimmissionen im Nachbarschaftsbereich. Österreichisches Normungsinstitut, Wien.

Österreichischer Arbeitsring für Lärmbekämpfung, 2011. ÖAL-Richtlinie Nr. 6: Die Wirkungen des Lärms auf den Menschen. Österreichisches Normungsinstitut, Wien.

OVE/ÖNORM EN 61672-1, 2015. Elektroakustik - Schallpegelmesser - Teil 1: Anforderungen. Österreichisches Normungsinstitut, Wien.

Sudy, 2018. Personal information. Bau- und Anlagenbehörde – Technische Anlagen, Graz

Steiermärkisches Baugesetz, 2017. Online: https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10007517 (2018/04/09)

Wärmepumpe Austria, 2014. Leitfaden zur Akustik von Luft-Wasser-Wärmepumpen. Wärmepumpe Austria, Linz.

Wärmepumpe Austria, 2018. Schallrechner. Online: https://www.waermepumpe-austria.at/schallrechner-v2 (2018/01/10)

WHO Europe, 2009. Night Noise Guidelines for Europe. WHO Europe, Bonn.

8.13 Acknowledgement

The work on "IEA HPP Annex 51" is financially supported within the framework of the "IEA Research Cooperation" on behalf of the "Austrian Federal Ministry for Transport, Innovation and Technology" (bmvit) (FFG project number: 864146).

9 The Italian regulations

9.1 Italian regulation for buildings

The Italian regulation defines the "passive acoustic requirements of buildings" in the law DPCM 05-12-1997, published in 20-02-1998. It concerns the minimum requirements in terms of acoustics insulation. Recalls many standards among which EN ISO 10140 series and EN ISO 12354 series, and is applied for different kind of building divided by intended use as in Table 9-1:

category A:	buildings used as residences or similar
category B:	buildings used as offices and similar
category C:	buildings used for hotels, pensions and similar activities
category D:	buildings used as hospitals, clinics. nursing homes and similar
category E:	buildings used for school activities at all levels and similar
category F:	buildings used for recreational or cult activities or similar
category G:	buildings used for commercial or similar activities

Table 9-1: Italian regulation – different kind of building divided by intended use

In particular (in the point of view of HP or others cooling or heating systems) this law define limits for noise installations (continuous and discontinuous). Noise of continuous services is evaluated with LAeq (in dB(A)) Acoustic descriptor, while the one generated by discontinuous services uses L_{ASMax} as synthetic descriptor.

This seven category are grouped together in 4 groups as shown in Table 9-2:

Group	Category	L_{ASMax}	L_{Aeq}
1	D	35 dB(A)	25 dB(A)
2	A, C	35 dB(A)	35 dB(A)
3	E	35 dB(A)	25 dB(A)
4	B, F, G	35 dB(A)	35 dB(A)

Table 9-2: Italian regulation – groups of categories with omogeneous limits

9.2 Environmental noise pollution

The Italian statutory law on noise pollution, “Legge 447/95” issued by the Parliament on 26th October 1995 and in force since 1st January 1996, assesses and controls the noise in order to assign specific competences to the municipalities, to the local authorities, to the regions and to the central administration.

The main definitions of this law are:

1. emission limit values: the greatest noise value given out by a source, measured near the source;
2. immission limit values: the greatest noise value introduced by one or more sources, measured near exposed people;
3. attention values: noise values potentially dangerous to human health;
4. quality values: noise values to be achieved for reduction of harmful effects on human health.

Only emission (1) and immission (2) limit are cogent.

A government decree has been issued on 1st December 1997 regarding noise emission values by individual sources, territory classification from the noise level point of view and noise limit values for urban areas. Every municipality has to classify its territory according to the Table 9-3:

Class I	in this class are all the protected areas where quiet is the main element. Pertain to this class hospitals, schools, parks, country residential areas.
Class II	in this class are all the areas are devoted to residential settling, with low inhabitant's density. In these areas there is only local traffic, no industries and only few commercial activities.
Class III	in this class the areas are called mixed. These areas are characterized both by local and passing traffic, with mean inhabitant's density, commercial activities, and offices but with no industries.
Class IV	in this class are the areas with high human activity, high inhabitants density, high road traffic, many commercial activities; these areas are near main roads, main railways or ports; in these areas may be as well few small industries
Class V	in this class are mainly industrial areas. In these areas are industries and very low inhabitants density.
Class VI	in this class are only industrial areas. In these areas are industries only; no dwellings are in these areas.

Table 9-3: Italian regulation – definitions of different areas

Every territory class has its own noise emission limit by any source but roads, railways and airports. These sources are covered by specific laws, with specific limits to respect.

The emission limit values are in Table 9-4:

Territory classes	Reference periods	
	Day-period (06.00-22.00)	Night-period (22.00-06.00)
Class I	45 dB(A) L_{Aeq}	35 dB(A) L_{Aeq}
Class II	50 dB(A) L_{Aeq}	40 dB(A) L_{Aeq}
Class III	55 dB(A) L_{Aeq}	45 dB(A) L_{Aeq}
Class IV	60 dB(A) L_{Aeq}	50 dB(A) L_{Aeq}
Class V	65 dB(A) L_{eq}	55 dB(A) L_{Aeq}
Class VI	65 dB(A) L_{Aeq}	65 dB(A) L_{Aeq}

Table 9-4: Italian regulation – emission limits for every kind of zone

The noise emission values reported in the table are to be respected by any not mobile source and are to be measured within the area where the source is, nearby buildings, dwellings or places where people usually stay. Besides the noise emission limit values there are for any area as well noise immission values no to be exceeded altogether by all the noise sources acting in the area in every point of the same area. The emission limit values are in Table 9-5:

Territory classes	Reference periods	
	Day-period (06.00-22.00)	Night-period (22.00-06.00)
Class I	50 dB(A) L_{Aeq}	40 dB(A) L_{Aeq}
Class II	55 dB(A) L_{Aeq}	45 dB(A) L_{Aeq}
Class III	60 dB(A) L_{Aeq}	50 dB(A) L_{Aeq}
Class IV	65 dB(A) L_{Aeq}	55 dB(A) L_{Aeq}
Class V	70 dB(A) L_{Aeq}	60 dB(A) L_{Aeq}
Class VI	70 dB(A) L_{Aeq}	70 dB(A) L_{Aeq}

Table 9-5: Italian regulation – immission limits for every kind of zone

The noise immission values of table are not for roads, railways and airport within their pertaining areas, where these transport infrastructures have their own limits to respect. Outside their pertaining areas roads, railways and airport have to respect the noise limits fixed for every area according to the table 4, altogether with any other not mobile source of noise acting there. The decree issued on 1st December 1997 provides also noise limit values, called attention values, namely values no to be exceeded for long term. The attention values are those of table when referred to the canonical period or the same increased by 10 dB for the day-period and by 5 dB for the night-period when referred to one hour. Long term observation could mean a

seasonal period or a year period. In case of excess of the attention values action plans have to set up.

This is actually adopted for almost the whole urbanized territory. Only few peripheral or rural municipalities haven't adopted yet a plan to divide their area into zones as described above. In these cases are valid an older law: "D.P.C.M. 01/03/1991" that establish simplified limits as reported in Table 9-6:

Territory classes	Day-period (06.00-22.00)	Night-period (22.00-06.00)
Whole national territory	70 dB(A) L_{Aeq}	60 dB(A) L_{Aeq}
A areas (defined in "decreto ministeriale n.1444/88")	65 dB(A) L_{Aeq}	55 dB(A) L_{Aeq}
B areas (defined in "decreto ministeriale n.1444/88")	60 dB(A) L_{Aeq}	50 dB(A) L_{Aeq}
Only industrial areas	70 dB(A) L_{Aeq}	70 dB(A) L_{Aeq}

Table 9-6: Italian regulation – limits valid for all non-zoned national soil

Moreover, a "differential immission level" is defined as the difference between noise immission noise and background noise. Usually is the most critical criterion. It is also defined in the law "D.P.C.M. 01/03/1991" and asserts that the limits are: 5 dB(A) for day-period and 3 dB(A) for night-period. Measurements have to make only inside the buildings. This criterion does not apply:

1. in the areas classified as Only industrial areas of municipal noise zoning;
2. if the noise measured at open windows is less than 50 dB(A) during the day-period and 40 dB(A) during the night-period;
3. if the noise measured at closed windows is less than 35 dB(A) during the day-period and 25 dB(A) during the night-period;
4. to the noise produced by:
    - road, rail, airport and sea infrastructure;
    - activities and behaviors not related to production, commercial and professional needs;
    - services and fixed installations of the building used for common use, limited to the disturbance caused inside it.

The focus of this regulation is usually on activities related to production, commercial and professional needs.

All the laws showed until now was written to revise an old law adopted for private citizens: "normal tolerability" exposed in "art. 844 codice civile":

"The owner of a fund can not prevent the emission of smoke or heat, fumes, noises, shaking and similar propagations from the fund of the neighbor, if they do not exceed normal tolerability, if also regarding the condition of the places. In applying this rule, the judicial authority must balance the needs of production with the reasons for ownership. It can take into account the priority of a particular use".

First judges traduced this “normal tolerability” as overcoming of 3 dB (Not expressed in Leq, but it must be intended as an instant value!!) the background noise present in the area. The background noise must also be cleansed from road noise!! For doing so is used 95% percentile L_{95} to evaluate background noise. To reach this criterion is very very difficult in many cases.

The problem in Italy seems that many judges even now refer to this older law, for causes between private citizens and not only!!

10 The Spanish regulations

10.1 Spain regulation for buildings

It seems there is no regulations based on ISO 16283, ISO 10140, ISO 12354, specific for noise insulation or particular requirements for plants and installation noise. The limits valid for plants and installations are those ones reported in the follow section.

10.2 Environmental noise pollution

The Spanish legislation on noise pollution is relatively recent, despite the fact that there were already local regulations or ordinances that tried to bring order, each in its own way. Thus, it was not until 2003 when Law 37/2003, of Noise, was published. This text, with its importance for being the first to address this problem in a harmonized manner throughout the state, actually meant more a declaration of intent than an applicable regulation.

This law is the reception of 2002/49 CE, and do not define limits, but introduce only: describers as L_{den}; definition of day, evening, night reference period; strategic noise mapping; major transport source (roads, railways, aircraft noise, industrial complexes); and so on.

Currently there is Royal Decree 1367/2007, which develops the Law of Noise by defining basic criteria to which local regulations must be adapted - they may be more restrictive, but not less. It is a text for technician text since it is based in part on the UNE-ISO 1996-2: 2009 standard, as many others national laws, and shows how evaluate the noise.

This regulation introduce:

- day level L_d;
- evening L_e;
- night level L_n;
- equivalent continuous A-weighted noise level $L_{Aeq,T}$ (over the period T);
- corrected level $L_{K,x}$ with corrections for: tonal component noise (K_t), impulsive noise (K_i), tonal component noise for low frequencies (K_f);
- equivalent continuous correct noise level $L_{Keq,T}$ (over the period T);

$$L_{Keq,T} = L_{Aeq,T} + K_t + K_f + K_i \qquad \textit{Eq. 10-1}$$

- long-term noise index $L_{K,x}$, defined as the long-term average sound level, given by the expression that follows, determined as throughout one-year evaluation periods "x" using the formula:

$$L_{K,x} = 10\lg\left(\frac{1}{n}\sum_{i=1}^{n} 10^{0.1(L_{Keq,x})_i}\right) \qquad \textit{Eq. 10-2}$$

  Where:

  - n is the number of samples from the evaluation period "x", in one year;
  - $(L_{Keq,x})_i$ is the corrected sound level, determined in the evaluation period "x" of the i-th sample.
- acoustic zoning;

- action plans.

Reference national period are defined as:

- 07:00-19:00 for day period;
- 19:00-23:00 for evening period;
- 23:00-07:00 for night period.

For the acoustic zoning a noise pollution, this law define many quality objective values. There are also Limit values or noise immission applicable to road, railway infrastructures and airports as reported in table A1 for new realizations (annex III), or the limit for maximum noise level applicable to infrastructures expressed in terms of L_{Amax} as shown in table A2.

Most important values are the ones reported in Table 10-1.

Type of acoustic area		Noise index		
		$L_{K,d}$	$L_{K,e}$	$L_{K,n}$
e	Areas with predominance of land for sanitary, educational and cultural use that requires special protection against noise pollution	50	50	40
a	Areas with predominance of land for residential use.	55	55	45
d	Areas with predominance of tertiary use land other than that contemplated in c.	60	60	50
c	Areas with predominance of land for recreational use and entertainment.	63	63	53
b	Areas with predominance of land for industrial use	65	65	55

Table 10-1: Spanish regulation – table B1 of royal decree 1367/2007 "Limit values for noise imission applicable to port infrastructures and activities"

See also Table 10-2 ("values of limit noise transmitted to adjoining room by activities") is important for indoor limits:

Use of the adjoining room	Type of use:	Noise index		
		$L_{K,d}$	$L_{K,e}$	$L_{K,n}$
residential	others	40	40	30
	bedroom	35	35	25
tertiary	professional office	35	35	35
	officinas	40	40	40
medical	stay zones	40	40	30
	rooms	35	25	25
school	rooms	35	35	35
	reading rooms	30	30	30

Table 10-2: Spanish regulation – table B2 of royal decree 1367/2007 "values of limit noise transmitted to adjoining room by activities"

These limit values are intended to be yearly! (due to "K" subscript).

Therefore, when activities are inspected, article 25 is applied:

Article 25. Compliance with noise limit values applicable to acoustic emitters.

1. In the case of measurements or the application of other appropriate evaluation procedures, it shall be considered that the noise immission limit values set out in Articles 23 and 24 are complied with, when the values of the acoustic indices evaluated in accordance with the procedures established in Annex IV, comply, for the period of one year, that:

a) Road, rail and airport infrastructures, of article 23.

i) No average value of the year exceeds the values set in Table A1, of Annex III.
ii) No daily value exceeds by 3 dB the values set in Table A1 of Annex III.
iii) 97% of all daily values (Note of writer: L_{97}) do not exceed the values set in Table A2 of Annex III.

b) Port infrastructures and activities, of article 24.

i) No average value of the year exceeds the values set in the corresponding table B1 or B2, of Annex III.
ii) No daily value exceeds by 3 dB the values set in the corresponding table B1 or B2 of Annex III.
iii) No measured value of the $L_{Keq,Ti}$ index exceeds by 5 dB the values set in the corresponding table B1 or B2, of Annex III.

Value for corrections for: tonal component noise (K_t), impulsive noise (K_i), tonal component noise for low frequencies (K_f) could be 0, 3 o 6 dB, but the total correction $K_t+K_i+K_f$ can't be greater than 9 dB(A).

10.3 Regional or municipal limits.

The following tables show the requirements of different autonomous communities that have independent laws to control environmental noise

Autonomous community	Immission limit values		
Andalusia	area of acoustic sensitivity	L_{Aeqd} Day (07:00-23:00)	L_{Aeqd} Night (23:00-07:00)
	Type I (silent areas)	55 dB(A)	40 dB(A)
	Type II (quite noise areas)	55 dB(A)	45 dB(A)
	Type III (tolerable noise areas)	65 dB(A)	55 dB(A)
	Type IV (noisy areas)	70 dB(A)	60 dB(A)
	Type V (most noisy areas)	75 dB(A)	65 dB(A)

Table 10-3: Spanish regulation – Noise limits in Andalusia

Autonomous community	Max sound pressure level				
Balearic Islands	area of acoustic sensitivity	Maximum sound pressure level outdoor		Maximum sound pressure level indoor	
		Day	Night	Day	Night
	All areas except industrial or tourist	55 dB(A)	45 dB(A)	35 dB(A) (30 dB(A)in bedroom)	30 dB(A) (25 dB(A)in bedroom)
	Industrial or tourist areas	65 dB(A)	60 dB(A)	40 dB(A)	35 dB(A)

Table 10-4: Spanish regulation – Noise limits in Balearic Islands

Autonomous community	target limit to achieve of environmental sound pressure level			
Castilla – La Mancha	area of acoustic sensitivity	Urban zones		Developable zones	
		L_{Aeq} Day weekly	L_{Aeq} Night weekly	L_{Aeq} Day weekly	L_{Aeq} Night weekly
	silent areas	60 dB(A)	50 dB(A)	50 dB(A)	40 dB(A)
	quite noise areas	65 dB(A)	65 dB(A)	55 dB(A)	45 dB(A)
	tolerable noise areas	70 dB(A)	60 dB(A)	65 dB(A)	55 dB(A)
	noisy areas	75 dB(A)	70 dB(A)	70 dB(A)	60 dB(A)
	most noisy areas	No limits	No limits	No limits	No limits

Table 10-5: Spanish regulation – Noise limits in Castilla – La Mancha

Autonomous community	Immission limit values		
Castilla y Leon	area of acoustic sensitivity	Max SPL Day	Max SPLNight
	A. Sanitary areas	45 dB(A)	35 dB(A)
	B. area destined for production and tertiary residence. no commercial areas	55 dB(A)	45 dB(A)
	C. Commercial areas	65 dB(A)	55 dB(A)
	D. Industrial areas and intended for warehouses areas	70 dB(A)	55 dB(A)

Table 10-6: Spanish regulation – Noise limits in Castilla y Leon

Autonomous community	Immission levels of environmental noise produced by transports			
Cataluña	area of acoustic sensitivity	Immission limit values		Attention limit svalue	
		L_{Ar} Day	L_{Ar} Night	L_{Ar} Day	L_{Ar} Night
	A. High sensivity	60 dB(A)	50 dB(A)	65 dB(A)	60 dB(A)
	B. Moderate sensivity	65 dB(A)	55 dB(A)	68 dB(A)	63 dB(A)
	C. Low sensivity	70 dB(A)	60 dB(A)	75 dB(A)	70 dB(A)
	Immission levels of environmental noise produced by aircraft transport				
	area of acoustic sensitivity	Immission limit values		Attention limit svalue	
		L_{Ar} Day	L_{Ar} Night	L_{Ar} Day	L_{Ar} Night
	A. High sensivity	60 dB(A)	50 dB(A)	65 dB(A)	60 dB(A)
	B. Moderate sensivity	65 dB(A)	55 dB(A)	68 dB(A)	63 dB(A)
	C. Low sensivity	70 dB(A)	60 dB(A)	75 dB(A)	70 dB(A)
	Maximum Immission levels of environmental noise produced by aircraft transport				
	area of acoustic sensitivity	Immission limit values		Attention limit svalue	
		L_{Ar}		L_{Ar}	
	A. High sensivity	80 dB(A)		85 dB(A)	
	B. Moderate sensivity	85 dB(A)		88 dB(A)	
	C. Low sensivity	90 dB(A)		93 dB(A)	

Table 10-7: Spanish regulation – Noise limits in Cataluña

Autonomous community	Maximum external sound pressure level		
Extremadura	area of acoustic sensitivity	Max SPL Day	Max SPLNight
	A. Sanitary areas	35 dB(A)	35 dB(A)
	B. residential and commercial areas	60 dB(A)	45 dB(A)
	C. industrial areas	70 dB(A)	55 dB(A)

Table 10-8: Spanish regulation – Noise limits in Extremadura

Autonomous community	Maximum immission sound pressure level L_{pAeq}		
Galicia	area of acoustic sensitivity	Day (08:00-22:00)	Night (22:00-08:00)
	High sensivity	60 dB(A)	50 dB(A)
	Moderate sensivity	65 dB(A)	55 dB(A)
	Low sensivity	70 dB(A)	60 dB(A)
	Service and other specific areas	75 dB(A)	75 dB(A)

Table 10-9: Spanish regulation – Noise limits in Galicia

Autonomous community	Areas in which urban development is expected. Limit values expressed in L_{Aeq}		
Madrid Community	area of acoustic sensitivity	Day	Night
	Type I: silent areas	50 dB(A)	40 dB(A)
	Type II: quite noise areas	55 dB(A)	45 dB(A)
	Type III: tolerable noise areas	65 dB(A)	55 dB(A)
	Type IV: noisy areas	70 dB(A)	60 dB(A)
	Type V: most noisy areas	75 dB(A)	65 dB(A)

Table 10-10: Spanish regulation – Noise limits in Madrid Community

11 The German Regulations

This section describes the main German regulations and their noise protection contexts. The overview is limited to the impact of noise immissions and the associated regulations, and to the approval and verification procedures. The machine-specific regulations for the supply of goods (here: heat pumps) in the European single market are explained in the preceding sections and also apply without restriction to the German market.

In Germany, noise protection regulations arise from various legal areas. Therefore, noise immissions from the operation of heat pumps are assessed differently depending on the application (e.g. private or commercial). Figure 11-1 shows the essential interrelationships between the fields of law and the resulting noise protection regulations.

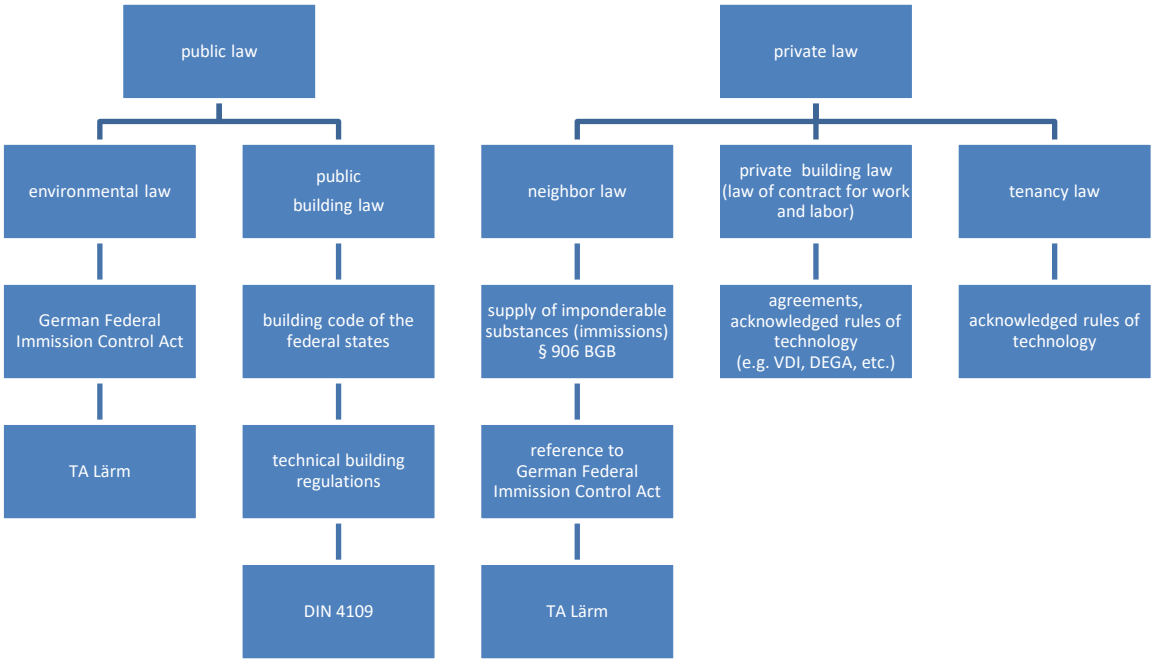


Figure 11-1: Fields of law and the resulting noise protection regulations.

Figure 11-2 shows the interrelationships of the regulations from a practical perspective, thus allowing for a better understanding of the assessment depending on the application.

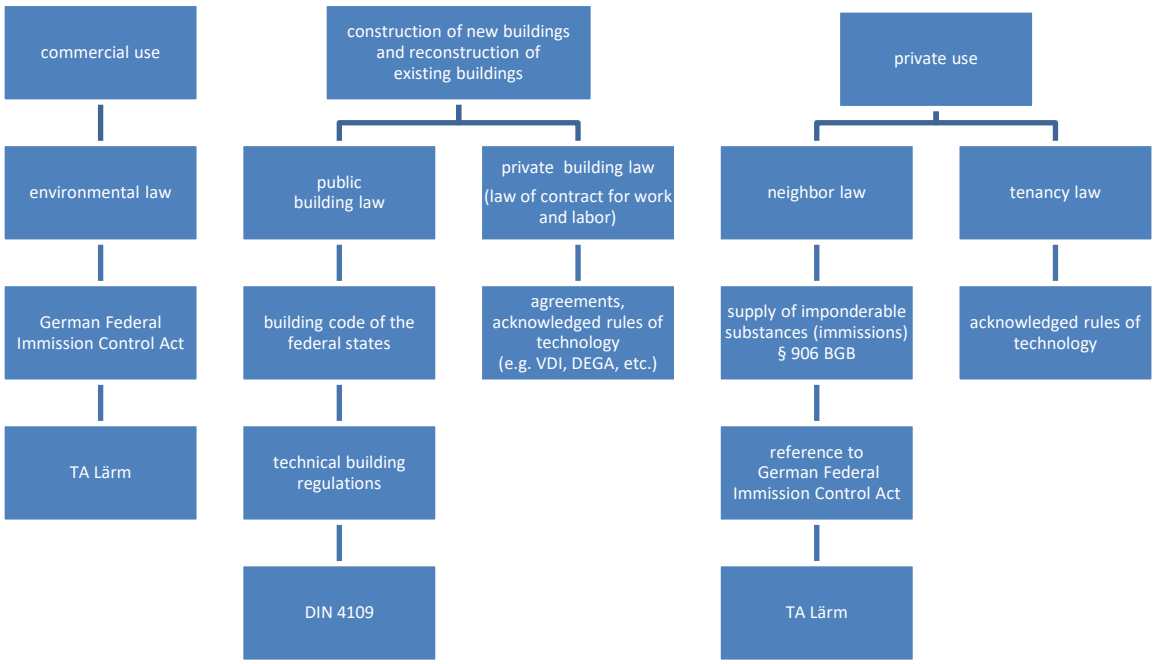


Figure 11-2: Regulations for noise protection depending on the application of heat pumps.

11.1 Environmental Law

The German Federal Immission Control Act (BImSchG) [1] regulates the protection against harmful environmental impacts. This act applies primarily to the construction and operation of facilities for commercial purposes. An exception to this is, for example, introducing imponderable substances (immissions) from one property to another. The neighboring law, in this case, refers with § 906 of the German Civil Code (BGB) to the BImSchG. Heat pumps, being privately operated non-commercial systems, are therefore subject to the immission control requirements [2] regarding noise effects.

According to § 1 BImSchG, the purpose of the law is to protect humans, animals and plants, soil, water, the atmosphere, and cultural and other material assets from harmful environmental impacts, and to prevent such harmful environmental impacts. According to § 3 (1), harmful environmental impacts as used in the Act shall be immissions which, according to their nature, extent or duration, are liable to cause hazards, considerable disadvantages or considerable nuisance to the public or the neighborhood. Section 3 (2) and (3) specify the harmful effects on the environment, including noise and vibrations.

Heat pumps are not subject to licensing within the meaning of the BImSchG and are therefore subject to the requirements of §§ 22 to 25 a. According to § 22 BImSchG, the operator must construct and operate the plant in such a way that harmful effects on the environment which are avoidable according to the state-of-the-art or to minimize unavoidable harmful effects on the environment according to the state-of-the-art. This implies that the immission guide values of the general administrative regulation TA Lärm [3], issued according to § 48 BImSchG, must not be exceeded.

If the operator does not comply with his obligations, the competent authority may prohibit the construction and operation of the plant in whole or in part in accordance with § 25 paragraph 1 BImSchG until the requirements have been fulfilled.

11.1.1 TA Lärm

The German Technical Instructions on Noise Protection (TA Lärm) define immission guide values for various uses of areas and rating periods, which must be observed at the relevant place of immission.

The location of this relevant place of immission is determined in accordance with Annex A.1.3 of the TA Lärm. It is the place within the plant's area of influence where the immission guide values are most likely to be exceeded. According to Annex A.1.3 of TA Lärm, the relevant place of immission for built-up areas is 0.5 m outside the center of the open window of the room most affected by the noise and requiring noise protection according to DIN 4109 [4]. With undeveloped or built-up areas which do not contain buildings with rooms requiring noise protection, the relevant point of immission is at the most severely affected edge of the area where buildings with rooms requiring protection may be constructed in accordance with building and planning law (generally 3 m from the edge of the property at a height of 4 m [5]). Within buildings, the relevant point of immission is located in the most severely affected non-operational room in need of protection according to DIN 4109. The immission guide values apply to the rating level L_r, which is calculated in accordance with DIN 45645-1 [6] and according to section 3.4.1 of the TA Lärm and which specifies

$$L_r = 10 \lg \left[\frac{1}{T_r} \sum_{j=1}^{N} T_j \cdot 10^{0{,}1\left(L_{Aeq,j} - C_{met} + K_{T,j} + K_{I,j} + K_{R,j}\right)} \right] \quad \text{[dB]} \qquad \textit{Eq. 11-1}$$

with

L_r	rating level for the rating periods by day and at night
T_r	16 h by day, 1 h or 8 h at night in accordance with No. 6.4
T_j	part-time j
N	number of selected part-times
$L_{Aeq,j}$	equivalent continuous sound pressure level during part-times T_j
C_{met}	meteorological correction terms acc. to DIN ISO 9613-2, draft September 1997 version [7], equation 6
$K_{T,j}$	adjustment for tonality and information component acc. to no. A.2.5.2 (prognosis) or A.3.3.5 (measurement) during part-time T_j
$K_{I,j}$	adjustment for pulse strength acc. to no. A.2.5.3 (prognosis) or A.3.3.6 (measurement) during part-time T_j
$K_{R,j}$	adjustment for daytimes with increased sensitivity acc. to no. 6.5 during part-time T_j

In addition, there are requirements for individual short-term noise peaks described by the maximum A-weighted sound pressure level L_{AFmax}.

The immission guide values for the rating level L_r for immission locations outside buildings are

a)	in industrial areas		70 dB(A)
b)	in commercial areas	day	65 dB(A)
		night	50 dB(A)
c)	in urban areas	day	63 dB(A)
		night	45 dB(A)
d)	in central areas, village areas and mixed areas	day	60 dB(A)
		night	45 dB(A)
e)	in residential areas and small residential estate areas	day	55 dB(A)
		night	40 dB(A)
f)	in exclusively residential areas	day	50 dB(A)
		night	35 dB(A)
g)	in spa areas, for hospitals and care facilities	day	45 dB(A)
		night	35 dB(A)

Individual short-term noise peaks may not exceed the immission guide values by more than 30 dB(A) during the day and by more than 20 dB(A) at night. For the assessment of the night values, the full night hour with the highest rating level is relevant.

For noise transmission inside buildings, the immission guide values for the rating level for rooms requiring external protection according to DIN 4109 are 35 dB(A) during the day and 25 dB(A) at night. Individual short-term noise peaks may not exceed the immission guide values by more than 10 dB(A).

For low-frequency noises (predominant energy components below 90 Hz), separate regulations apply in accordance with section 7.3 of TA Lärm. If harmful environmental effects are to be expected from low-frequency noises as per DIN 45680 [8], suitable noise control measures shall be considered.

An assessment according to TA Lärm considers the total load at the relevant immission site. Therefore, it may also be necessary to consider the preload. The approval of a plant, however, may not be prohibited because of its preload, if the plant under consideration does not contribute relevantly to the total load. According to TA Lärm section 3.2.1, this applies if the additional load of the assessed plant is 6 dB(A) below the immission guide value.

11.1.2 Approval Procedure

Since heat pumps are not subject to licensing in terms of the BImSchG, there is no approval procedure that is applicable generally. The operator himself must comply with the requirements of TA Lärm. An obligation to provide proof only arises if the competent authority requires proof, which is depending on the individual case and can be the case, for example, before or after commissioning, but also only in case of complaints.

11.1.3 Verification Procedure

Noise immissions according to TA Lärm can be determined either by prognosis (TA Lärm Annex A.2) or by measurement (TA Lärm Annex A.3).

For the prognosis of noise immissions, a rough and a detailed procedure are provided. The rough procedure is intended for preliminary planning and when no exceedance is to be expected. In practice, the prognosis is usually computer-aided with a software calculating the sound propagation according to DIN ISO 9613 [7]. The prognosis takes into account the sound power levels of the sources, including the exposure times, the directivity corrections, the local conditions (location, surrounding buildings, vegetation), an unfavorable weather situation, an adjustment for tonality and information component, an adjustment for impulsiveness and for daytimes with increased sensitivity. The adjustments for tonality, information component and impulsiveness shall be determined at the discretion of an expert based on experience, and shall be 0, 3 or 6 dB(A).

The measurement-based determination of noise immissions according to TA Lärm takes place at the relevant place of immission. Depending on the task, the existing load, the additional load or the total load are to be determined. If a measurement at the relevant place of immission is not possible, e.g. due to external noise influences, the competent authority may determine substitute measurements carried out at another location. In contrast to the prognosis, the adjustment for the impulsiveness is derived from the measured values, whereas the adjustment for tonality and information component may be determined at the discretion of an expert. The tonality of a noise may also be determined by measurement according to DIN 45681 [9].

11.1.4 Differentiation from other legal fields

If the places of emission and immission are located on different properties, the assessment is always carried out according to TA Lärm. However, if the immission site is constructionally connected with the heat pump, the assessment according to TA Lärm is only intended for commercial use. If a heat pump is used privately and classified as a building service equipment, other assessment criteria may be relevant, depending on the application.

11.2 Neighbor law

In Germany, private neighbor law (part of private law) is governed by the German Civil Code [10]. The supply of imponderable substances, such as noise and vibrations, is regulated in § 906 of the German Civil Code (BGB):

(1)The owner of a property may not prohibit the supply of gases, vapours, smells, smoke, soot, heat, noise, shocks and similar effects emanating from another property if these impacts do not, or only insignificantly, affect the use of his property. Usually, an insignificant impact shall be deemed to exist if the limit or guide values specified in laws or legal decrees are not exceeded by the effects determined and assessed in accordance with these regulations. The same applies to values specified in general administrative regulations that have been issued in accordance with § 48 of the Federal Immission Control Act and that are reflecting the current state-of-the-art.

(2) The same shall apply if an essential impairment is caused by a use of the other property in accordance with local custom, and if it cannot be prevented by measures which are economically reasonable for this type of users. If the owner has to tolerate an impact, he can

demand from the user of the other property an adequate compensation in money, if the impact impairs a customary use of his property or its yield beyond the reasonable measure.

(3) Feeding through a special line is not permitted.

Thus, regarding noise effects, heat pumps are subject to the immission control requirements of the BImSchG and TA Lärm as non-commercial but privately operated systems.

11.3 Public building law

In Germany, building law is the responsibility of the federal states. There are 16 state building codes which are based on a common standard, the Model Building Code (MBO) [11]. According to § 15 (2) MBO, buildings must have sound insulation corresponding to their use. Noise emanating from installations fixed within buildings or on building plots have to be insulated in a way that hazards or unacceptable nuisances will not arise. The requirements pursuant to § 15 (2) MBO shall be deemed to be met if the technical building regulations are complied with during the construction of new buildings and reconstruction of existing buildings. The technical building regulations are also a matter for the federal states, and are based on a common model, the Model Administrative Regulation for Technical Building Regulations [12]. The technical building regulations refer to standards and are partly supplemented by further regulations. DIN 4109 (Sound insulation in buildings) has currently been introduced by the building authorities for sound insulation, however in different versions and with different additional requirements, depending on the federal state.

DIN 4109 [13] specifies the minimum requirements for the sound insulation of building components of rooms requiring sound protection, and the permissible sound levels in rooms requiring sound protection in residential and non-residential buildings. Although different versions of DIN 4109 apply depending on the federal state, the requirements for sound immissions from building service equipment are uniform in all 16 federal states.

The maximum permissible A-weighted sound pressure levels of noise from building service equipment impacting on external rooms requiring sound protection are shown in Table 11-1. For technical sound sources that are permanently installed in the occupants' own living and working areas, and that are not operated or put into operation by the occupants themselves (when used for their intended purpose), the requirements specified in Table 11-2 shall be met.

sound sources		maximum permissible A-weighted sound pressure levels [dB]	
		living rooms and bedrooms	**classrooms and workspaces**
Sanitary and water installations (water supply and sewage systems together)		$L_{AF,max,n} \leq 30^{a,b,c}$	$L_{AF,max,n} \leq 35^{a,b,c}$
Other internal, permanently installed technical sound sources of the technical equipment, supply and disposal as well as garage facilities		$L_{AF,max,n} \leq 30^{c}$	$L_{AF,max,n} \leq 35^{c}$
restaurants, including kitchens, shops, businesses, etc.	during the day 6.00a.m–10.00p.m.	$L_r \leq 35$ $L_{AF,max} \leq 45^{c}$	$L_r \leq 35$ $L_{AF,max} \leq 45^{c}$
	at night acc. to TA Lärm	$L_r \leq 25$ $L_{AF,max} \leq 35^{c}$	$L_r \leq 35$ $L_{AF,max} \leq 45^{c}$

a Individual short-term noise peaks occuring when valves and equipment are operated acc. to Table 11 (opening, closing, adjusting, interrupting) are currently not to be taken into account.

b Prerequisites for meeting the permissible sound pressure level:

- The design documents must take into account the requirements of sound insulation, i.e. the required sound insulation proofs must be available for the components.

- In addition, the responsible site management must be specified and consulted for a partial acceptance before closing or cladding the installation.

c - Deviating from DIN EN ISO 10052:2010-10, 6.3.3, the measurement carried out in the loudest corner of the room is omitted (see also DIN 4109-4)

Table 11-1: Maximum permissible A-weighted sound pressure levels in external rooms requiring sound protection, generated by building service equipment. Table 9 in DIN 4109.

sound sources	maximum permissible A-weighted sound pressure levels [dB]	
	living rooms and bedrooms	**kitchens**
permanently installed technical sound sources of the air conditioning systems in one's own living and working area	$L_{AF,max,n} \leq 30^{a,b,c,d}$	$L_{AF,max,n} \leq 33^{a,b,c,d}$

a Individual, short-term noise peaks occuring when the systems are switched on and off must not exceed a maximum of 5 dB.

b Prerequisites for meeting the permissible sound pressure level:

- The design documents must take into account the requirements of sound insulation, i.e. the required sound insulation proofs must be available for the components;

- In addition, the responsible site management must be specified and consulted for a partial acceptance before closing or cladding the installation.

c Deviating from DIN EN ISO 10052:2010-10, 6.3.3, the measurement carried out in the loudest corner of the room is omitted (see also DIN 4109-4)

d Values of up to 5 dB higher are permissible, provided that it is continuous noise without noticeable individual tones.

Table 11-2: Requirements for maximum permissible A-weighted sound pressure levels in rooms requiring sound protection in one's own home, generated by air conditioning systems in one's own living area. Table 10 in DIN 4109.

11.3.1 Verification procedure

The building regulations of the federal states require proof of sound insulation in the building permit procedure. The sound insulation certificate is submitted with the building application. In most cases, however, the proof of sound insulation can also be submitted later during the building application. The sound insulation certificate is typically prepared in performance phase 3 of the HOAI (Federal Honorarium Code for Architects and Engineers) [14], the draft planning. Somtimes, however, the noise protection certificate is not produced in practice and the competent authority does not demand it until the construction project has been completed. This failure may lead to planning errors.

The sound insulation proof is calculated according to DIN 4109-2 [15]. However, there is no normatively introduced calculation method for the sound transmission of building service equipment and businesses connected with the building. DIN EN 12354-5 [16] provides a basis on which the future calculation methods are to be developed according to DIN 4109. The prognosis models mentioned in DIN EN 12354-5 can be used as an orientation for the acquisition of data and for the basic procedure for the prognosis of sound levels.

Since there is no calculation method for the normative proof, the verification for building service equipment can be done by measurements, and carried out either by a quality inspection of a concrete building situation on site according to DIN 4109-4 [17], or by testing a reference solution in a sample building. According to DIN 4109-4, the maximum normalized A-weighted sound pressure level of building service equipment $L_{AF,max,n}$ is determined according to DIN EN ISO 10052 [18]. However, the additional specifications and deviations according to DIN 4109-4 must be observed.

$$L_{AF,max,n} = L_{AF,max} - k - 10\,\lg\frac{A_0 T_0}{0{,}16\,V} \quad \text{[dB]} \qquad \textit{Eq. 11-2}$$

with

$L_{AF,max,n}$ maximum normalized A-weighted sound pressure level of building service equipment;

$L_{AF,max}$ maximum A-weighted sound pressure level of building service equipment corrected for background noise, calculated from three measurements at three positions in three different operating cycles in the reverberant field of the room

$$L_{AF,max} = 10\,\lg\left(\frac{1}{3}\sum_{i=1}^{3} 10^{L_{AF,max,i}/10}\right);$$

k reverberation index, calculated from the arithmetic average value of the measured reverberation time according to [19] in the octave bands 500 Hz, 1 kHz and 2 kHz

$$k = 10\,\lg\left[\frac{1}{3\,T_0}\left(T_{500} + T_{1000} + T_{2000}\right)\right];$$

A_0 reference absorption area (10 m²);

T_0 reference reverberation time (0,5 s);

V volume of receiving room (m³).

According to the technical building regulations, the proof of sound insulation during the noise transmission of businesses must be carried out on the basis of measurements in compliance with TA Lärm. These measurements must be performed in accordance with DIN 4109-4 by building acoustics test laboratories which are either recognized according to the relevant building code of the federal states (LBO), or specified in a list of "recognized sound insulation test laboratories" at the Association of Material Testing Institutes (VMPA).

11.3.2 Additional information

The component catalogue for building service equipment of DIN 4109-36 [20] section A.2.2. contains useful information especially for heat pumps which are listed below:

Description of component group

Heat pumps include the following equipment:

- brine-to-water heat pumps for indoor and outdoor installation;
- air-to-water heat pumps for indoor and outdoor installation;
- water-to-water heat pumps for indoor and outdoor installation;
- air-to-air heat pumps for indoor and outdoor installation.

Significant factors affecting the sound insulation

Noises from heat pumps can lead to a nuisance in rooms requiring sound insulation, in recreation rooms and in the neighborhood. Since heat pumps can be installed both inside and outside buildings, the products are to be distinguished according to their type of installation.

Usually, heat pumps are not installed in the living area but in separate rooms. If heat pumps are installed in one’s own living area, special protective measures are necessary (i.e. the planner must provide appropriate protective measures).

For heat pumps installed outdoors, the requirements of TA-Lärm must be taken into account. Adequate distance from neighboring buildings must be provided to comply with the immission guide values. Regardless of the type of installation, there are the following influencing parameters for heat pumps:

- supply and exhaust air equipment and ducts
- fan
- heat pump compressor
- electric motor
- or internal combustion engine
- burner for gas engine heat pumps
- solvent pump.

Planning and installation information

The installation of the heat pump must be planned according to the local conditions. For outdoor installation, the living rooms and bedrooms of the building to be heated, the adjacent buildings, and the reflections from sound-reflecting building components are to be taken into account.

For indoor installation, the supply and exhaust air ducts have to be planned according to the local conditions. Appropriate measures must be taken to avoid structure-borne noise transmission via the supply and exhaust vents, the floor fixing of the heat pump and the pipe connections to the heating system.

Data for calculation-based verification

The calculation-based determination of the airborne sound radiation of heat pumps is carried out according to DIN EN 12102. The data are determined in continuous operation.

Origin of the data

Published data are not available, they have to be provided by the manufacturer.

11.4 Private building law

The private building law regulates the legal relations between the private parties involved in the building project. The focus is on the relationship between the party commissioning the construction (client) (the term ‘client’ comes from the public building law) and the parties planning and carrying out the construction (such as architects, engineers, construction companies and craftsmen) (building contract law). Private building law also includes private neighboring law, which was dealt with separately in Section 1.2 for reasons of clarity.

The basis of private building law is the law governing contracts for work and services (§§ 631 et seq., German Civil Code (BGB)), and private law standards for legal protection of adjoining neighbors (§§ 903 et seq., § 936 and § 1004 German Civil Code (BGB); the neighbor laws of the federal states, if applicable).

Within the framework of the warranty, planners must comply with the recognized rules of technology. If they do not do so, a liability risk arises regarding the warranty according to the German Civil Code (BGB) §633, and according to the German Construction Tendering and Contract Regulations (VOB/B) [21], §13. Planners and contractors guarantee that, at the time of acceptance, the work

(1.) has the contractually assured properties,

(2.) complies with the recognized rules of technology and

(3.) is free from faults and defects which cancel or reduce the value or suitability for the normal or intended use according to the contract.

It is therefore recommended to include specific agreements in the contract for work and services. These agreements can, for example, contain specific values or require compliance with certain rules and regulations. If there are no specific agreements, the warranty requirements can also be derived from the building description by an expert assessment from the recognized rules

of technology. There are court decisions declaring that a higher standard than the minimum noise protection required by building law had to be met in luxury residential construction.

Information on civil law agreements are included for example in:

- VDI 4100
- DIN 4109 Supplement 2, November 1989
- DIN SPEC 91314:2017-01
- DIN 4109-5 (draft stage)
- DEGA Recommendation 103
- DEGA BR 0101
- DEGA BR 0104
- VDI 2719.

11.5 Tenancy law

The German tenancy law is specified in §§ 535 to 580a of the German Civil Code (BGB). According to this law, the tenant does not have to accept noise from technical installations if the noise impact is of such extent that is unacceptable for the contracting party affected by it. If the nuisance is unacceptable, the tenant has:

- the right to demand for termination by the interfering party,
- the right to a reduction of the rent,
- the right to termination without notice, and
- the right to claim for pain and suffering.

It depends on the individual case which standard is used in the assessment. Usually, the recognized rules of technology are used.

11.6 Literature

[1] Bundes-Immissionsschutzgesetz in der Fassung der Bekanntmachung vom 17. Mai 2013 (BGBl. I S. 1274), das zuletzt durch Artikel 1 des Gesetzes vom 8. April 2019 (BGBl. I S. 432) geändert worden ist

[2] Arbeitsring Lärm der DEGA, Energiewende und Lärmschutz: ALD Schriftenreihe Band 2 (2016). Berlin, 2016.

[3] Sechste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zum Schutz gegen Lärm - TA Lärm) Vom 28. August 1998 (GMBl Nr. 26/1998 S. 503) zuletzt geändert durch Bekanntmachung des BMUB vom 1. Juni 2017 (BAnz AT 08.06.2017 B5) in Kraft getreten am 9. Juni 2017.

[4] DIN 4109:1989-11 Schallschutz im Hochbau – Anforderungen und Nachweise.

[5] Müller, G.; Möser, M.: Beurteilung von Schallimmissionen. Gesetze - Vorschriften - Normen - Richtlinien. Fachwissen Technische Akustik. Springer Berlin Heidelberg, Berlin, Heidelberg, 2017.

[6] DIN 45645-1:1996-07 Ermittlung von Beurteilungspegeln aus Messungen – Teil 1: Geräuschimmissionen in der Nachbarschaft.

[7] DIN ISO 9613-2:1997-09 - Entwurf Akustik - Dämpfung des Schalls bei der Ausbreitung im Freien - Teil 2: Allgemeines Berechnungsverfahren.

[8] DIN 45680:1997-03 Messung und Bewertung tieffrequenter Geräuschimmissionen in der Nachbarschaft.

[9] DIN 45681:2005-03 Akustik – Bestimmung der Tonhaltigkeit von Geräuschen und Ermittlung eines Tonzuschlages für die Beurteilung von Geräuschimmissionen.

[10] Bürgerliches Gesetzbuch in der Fassung der Bekanntmachung vom 2. Januar 2002 (BGBl. I S. 42, 2909; 2003 I S. 738), das zuletzt durch Artikel 1 des Gesetzes vom 20. Juli 2017 (BGBl. I S. 2787) geändert worden ist.

[11] Musterbauordnung – MBO – in der Fassung vom November 2002.

[12] Muster-Verwaltungsvorschrift Technische Baubestimmungen (MVV TB) Ausgabe August 2017.

[13] DIN 4109-1:2018-01 Schallschutz im Hochbau - Teil 1: Mindestanforderungen.

[14] Honorarordnung für Architekten und Ingenieure vom 10. Juli 2013 (BGBl. I S. 2276).

[15] DIN 4109-2:2016-06 Schallschutz im Hochbau – Teil 2: Rechnerische Nachweise der Erfüllung der Anforderungen.

[16] DIN EN 12354-5:2009-10 Bauakustik – Berechnung der akustischen Eigenschaften von Gebäuden aus den Bauteileigenschaften – Teil 5: Installationsgeräusche.

[17] DIN 4109-4:2016-06 Schallschutz im Hochbau – Teil 4: Bauakustische Prüfungen.

[18] DIN EN ISO 10052:2010-10 Akustik - Messung der Luftschalldämmung und Trittschalldämmung und des Schalls von haustechnischen Anlagen in Gebäuden - Kurzverfahren.

[19] DIN EN ISO 3382-2:2008-09 Akustik – Messung von Parametern der Raumakustik – Teil 2: Nachhallzeit in gewöhnlichen Räumen.

[20] DIN 4109-36:2016-07 Schallschutz im Hochbau – Teil 36: Daten für die rechnerischen Nachweise des Schallschutzes (Bauteilkatalog) – Gebäudetechnische Anlagen.

[21] VOB Teil B Allgemeine Vertragsbedingungen für die Ausführung von Bauleistungen.

12 The Polish regulations

12.1 Sound emissions

The operation of heat pumps involves sound emissions that essentially originate from the compressor and – in the case of air-water heat pumps – from the fan. That is the mechanical energy of the sound emitted at the place of its occurrence. The sound power level L_w has the dimensionless quantity decibel (dB). Technical data manufacturer are included in the product card and label energy product.

The ability to perceive (perception) and accompanying the reaction is not dependent on the power level acoustic as from the sound pressure level in the place of perception. The sound pressure level L_P describes pressure changes in the vibration sequence air through sound and it is also specified in decibels (dB). Usually it is given in dB (A) which it is matched to the human sense of hearing. The legal basis defining protection against noise and vibrations in the rooms is. Regulation of the Minister of Infrastructure and. Construction on technical conditions, what buildings and theirs should suit location (Journal of Laws No. 75, item 690 of 2002, as amended) and the PN-B-02151-2: 2018-01 standard. It gives the names of rooms in which the noise impact is limited. In general, these are selected rooms in buildings:

- multi-family and single-family homes
- hotel rooms
- a collective residence (eg boarding houses, dormitories, etc.)
- nurseries and kindergartens
- primary and secondary schools,
- universities and research centers
- hospitals and healthcare facilities
- courts and prosecutors
- and others such as offices, cinemas, museums, shops, swimming pools

12.1.1 Transferring sound in the building

In the case of rooms those that require noise protection are set to the highest values admissible sound in the scale A. The permitted noise levels refer to the time of use of the room, without distinction day and night time. Inside buildings, the material sound is usually transferred to the building structure. The following are some of the rules for reducing the effects of this phenomenon. The heat pump should be placed on a massive surface, not a light construction. Since the floating screed is susceptible to vibrations, at least under the heat pump should be poured screed complex. Traditional platforms under the boiler are not suitable for installing heat pumps due to their low weight.

The vibration dampers provided are usually sufficient. Complementary activities to isolate sound the material one is basically taken according to manufacturer's specifications. All incoming and outgoing wires heat pumps must be separated from the building in immediate proximity of the device. This is done through:

- Corrugated bellows in air ducts
- Corrugated pipes and heating water pipe loops
- Loops on electrical wires

- Loops or free fall sections for connecting the condensate drain to the air / water heat pump

Equivalent sound level A of noise penetrating into the room from all sources of noise located outside of it a room (in residential buildings - from noise sources located outside the apartment in the composition of which enters this room) may not exceed the values given below:

a. Residential premises in buildings residential, boarding-houses, houses pensioners, orphanages, hotels
   - on day 40 dB (A)
   - at night 30 dB (A)
b. Kitchens and sanitary rooms
   - on day 45 dB (A)
   - at night 40 dB (A)
c. Rooms in hotels of the second category and lower
   - on day 45 dB (A)
   - at night, 35 dB (A)

12.1.2 Moving sound in the open space

Noise emissions to the environment caused by air / water heat pumps should be taken into account at the design stage. This is binding both in the case of noise generated by heat pumps installed outside (noise of the outdoor unit of the split heat pump or "monobloc"), as well as noise in the air ducts carried by the pierced hole in the facade.

In the case of pumps placed outside the building must also meet the requirements on the noise generated, set out in Regulation of the Minister of Environment of 14 June 2007 on admissible noise levels in the environment (Journal of Laws No. 120, item 826) with later changes (mainly Regulation of the Minister of Environment of 1 October 2012 amending the regulation in on permissible noise levels in environment).

Permissible noise levels in the environment have been expressed by the **L_{AeqD} and L_{AaqN}** indicators that they have applicable to the determination and control of conditions use of the environment in relation to one 24 hours or L_{DWN} and L_N indicators that they have applicable to long-term running noise protection policies.

To assess the possible impact of the sound source should be calculate or measure the sound pressure level in a place where protection against noise is necessary. The basis for this calculation is using dependencies between characterizing the source with the power level acoustic L_w, and the sound level appearing on the result of its operation at a specific point observation. In the announcement of the Minister of the Environment from on October 15, 2013 regarding the announcement the uniform text of the Minister's regulation Environment on acceptable levels Noise levels in the environment are given level values sound pressure (see Table below).

The values refer to the sound pressure level on the border of a construction plot (off-site, to whose manager of this object has a title legal), in accordance with the law of protection environment (Journal of Laws 2013 item 1232).

Ordinal number	Destination of the area	$L_{Aeq,D}$ compartment time references equal to 8 least preferred hours day following respectively	$L_{Aeq,N}$ compartment time references equal to 1 least favorable hour night
1	a. protection zone A of the spa b. Areas of hospitals outside the city	45	40
2	a. Building areas residential single-family b. Areas of buildings associated with permanent or temporary stay of children and adolescents c. Areas of nursing homes d. Areas of hospitals in cities	50	40
3	a. Building areas residential multi-family b. Building areas homestead c. Recreational areas d. Housing and serving areas	55	45
4	a. Areas in the zone downtown cities over 100,000 residents	55	45

Table 12-1: Limit values of the sound pressure level L_p at the boundary of the plot

The procedure for approximate sound pressure level based on the sound power level based on the German TA Lärm guidelines is described below. First, you should count the sound pressure from individual sources and then set the total level from these many individual sources. If the result is a limit value, then an approximate evaluation should be carried out instead of an approximation, or a measurement should be made in accordance with PN EN ISO 11201: 2012, PN-EN ISO 11202: 2012 or PN-EN ISO 11203: 2012. This method is recommended if the sound pressure level determined in an approximate way is not less than the tabular value by at least 3 dB (A).

12.1.3 Determination of the sound pressure level

Determination of the pressure level acoustic single source

The sound pressure level depends on the level sound power, and sound propagation is determined in using table below. The table takes into account the conditions spatial in accordance with tehe figure below and the distance r between the source of sound and the place of immission. And in this way, in addition to sensitivity in the period increased sensitivity of

the reception of tonality of sound at night and tonality of sound, pressure level acoustic Lr (equivalent to L_p) can be calculated according to the formula (guidance VDI 2058 / TA Lärm):

$$L_r = L_w + K_{Tj} + K_{Rj} + \Delta L_p \qquad \textit{Eq. 12-1}$$

L_r Sound pressure level according to VDI 2058 / TA Lärm in dB (A) - equivalent to L_p;

L_w Sound power level in dB (A) according to the manufacturer's data from the product card;

K_{Tj} Addition of tonality according to the manufacturer's data heat pumps;

K_R Addition of 6 dB (A) in the increased period sensitivity of receiving the tonality of sound - only in the time interval daily use of the heat pump;

ΔL_p Sound attenuation according to table below in dB (A).

Solid angle indicator K_0 according to the drawing below	**Distance r from the sound source and the source of immission in m**										
	1	2	3	4	5	6	8	10	12	15	20
3 dB(A)	-8,0	-14,0	-17,5	-20,0	-22,0	-23,5	-26,0	-28,0	-29,6	-31,5	-34,0
6 dB(A)	-5,0	-11,0	-14,5	-17,0	-19,0	-20,5	-23,0	-25,0	-26,6	-28,5	-31,0
9 dB(A)	-2,0	-8,0	-11,5	-14,0	-15,9	-17,5	-20,0	-22,0	-23,5	-25,5	-28,0

Table 12-2: Correction of sound propagation ΔL_p depending on the installation location and distance from a single source sound

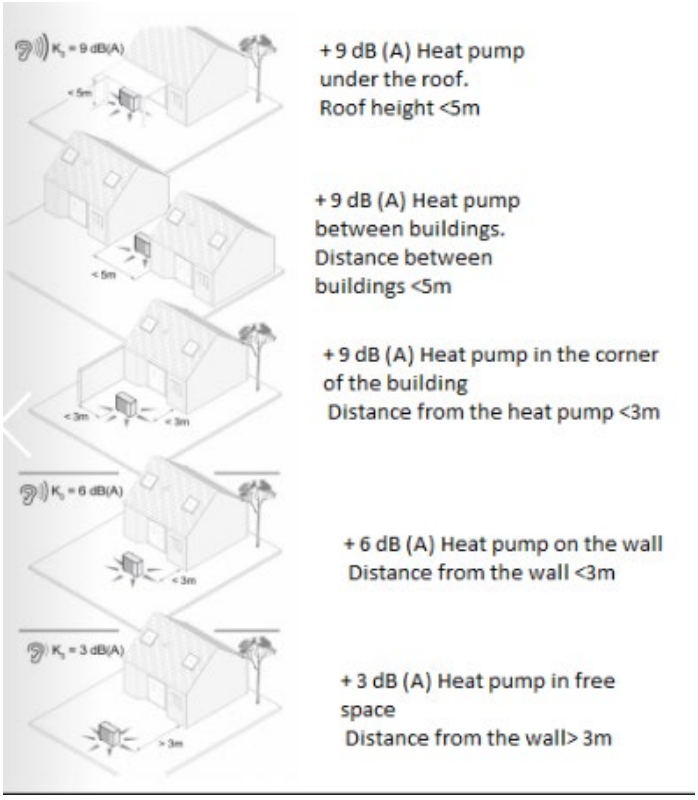


Figure 12-1: K_0 solid angle indicator depending on the place of sound reflection.

Determination of the total pressure level from many single sound sources

The total sound pressure level from many sound sources can be determined by the simplified method. To do this, first determine the sound pressure level of individual sources in the place of immission (see equation below). Based on the number of sound sources, an increase in the level from Table 12-3 can be determined. If the sources have different sound pressure levels, the highest level should be used in this method. If it is necessary to treat these sources differently, for example, many different individual sources, please use the appropriate literature.

Level increase	Number of identical sound sources				
Sound pressure	2	3	4	5	6
ΔL in dB(A)	3,0	4,8	6,0	7,0	8,0

Table 12-3: Increase in the equivalent pressure level acoustic ΔL for many identical sources sound.

$L_{P,CALC}$ total sound pressure level in dB (A);

L_P maximum pressure level acoustic of individual sources in dB (A);

ΔL increase in sound pressure level according to the table in dB(A).

Actions to reduce sound transmission in outdoor space:

- Place the sound source in the right one distances from demanding rooms noise protection

- Place the sound source in the free space, if possible and avoid reconstruction in the direction of rooms requiring protection against noise.
- The transfer of air sound can be softened by anti-noise shield. It consists of a massive construction with a sound absorbing layer from source page

12.2 Literature

[1] PN EN ISO 11201: 2012.

[2] PN-EN ISO 11202: 2012.

[3] PN-EN ISO 11203: 2012.

[4] VDI 2058 / TA Lärm.

[5] PN-B 02151-3:2015-10 "Akustyka Budowlana – Ochrona przed hałasem w budynkach – Izolacyjność akustyczna przegród w budynkach oraz izolacyjność akustyczna elementów budowlanych – Wymagania" (Building Acoustics – Noise protection in buildings – Sound insulation in buildings and of building elements – Requirements).

13 The Denish regulations

Not more know at the moment, except as indicated below:

Noise limits for residential areas

DANISH TECHNOLOGICAL INSTITUTE

Døgnperiode	**Støjgrænse L_r for boligområder**		
	Sommerhus-områder	Tæt lav boligområde (parcelhuse, række-huse mv.)	Etageboliger Blandet bolig og erhverv Det åbne land (en-keltliggende huse)
Hverdage kl. 07 – 18 Lørdage kl. 07 – 14	$L_r \leq 40$ dB	$L_r \leq 45$ dB	$L_r \leq 50$-55 dB
Hverdage kl. 18 – 22 Lørdage kl. 14 – 22 Søndage kl. 07 – 22	$L_r \leq 35$ dB	$L_r \leq 40$ dB	$L_r \leq 45$ dB
Alle dage kl. 22 – 07	$L_r \leq 35$ dB	$L_r \leq 35$ dB	$L_r \leq 40$ dB

Tabel 4.4.1 – Miljøstyrelsens vejledende støjgrænser (uddrag)

Noise indoor

DANISH TECHNOLOGICAL INSTITUTE

- BR 2010 L_Aeq < 30dB

Figure 13-1: Danish regulation – Limits in Danish noise regulations

14 The Swedish regulations

14.1 Environmental regulations

In Sweden the are several authorities which have a responsibility for noise. The Swedish Environmental Protection Agency is responsible for providing guidance concerning how the Environmental Code (1998:808) should be applied and has a national coordination responsibility as regards environmental noise. The municipalities are responsible for the supervision and assessment of measures to be taken.

The infrastructure proposition 1996/97:53 indicate that the guidelines below should not be exceeded:

- 30 dB(A)indoor equivalent sound level;
- 45 dB(A)indoor maximum sound level night time;
- 55 dB(A)outdoor equivalent sound level at façade;
- 70 dB(A)outdoor maximum sound level at patio in connection to residence.

14.1.1 External industrial noise

The Swedish Environmental Protection Agency has issued guidelines for External industrial noise. It was updated in 2015. Heat pump noise is covered by these guidelines.

	$L_{A,eq}$ Day (06-18)	$L_{A,eq}$ Evening (18-22)	$L_{A,eq}$ Night (22-06)
Neighbourhood	50 dB	45 dB	40 dB ($L_{AF,max}$ = 55 dB)

Table 14-1: Swedish regulation – Environmental guideline for industrial noise

For noise with tonal or impulsive character the limits are decreased by 5 dB

14.1.2 Noise from roads and railways

Guideline values for external noise from roads and railways

	Equivalent sound level	Maximum sound level
Outdoor at facade	55 dB(A)	-
Patio at residence	-	70 dB

Table 14-2: Swedish regulation – Noise limits for roads and raliways

14.2 Building regulations

The Swedish National Board of Housing, Building and Planning is responsible for planning aspects and for monitoring the objectives for the Swedish environmental objective "A good built environment".

BFS 2013:14 BBR 20 contains regulations and guidelines for internal and external noise sources.

14.2.1 New buildings

	Equivalent sound level	Maximum sound level 22-06
Inside from external noise source	$L_{Aeq,T}$	$L_{A,max}$
- Bedroom	30 dB	45 dB
- Kitchen/bathroom	35 dB	-
Internal noise source	$L_{Aeq,T}/L_{Ceq}$	$L_{A,max}$
- Bedroom	30/50 dB	35 dB
- Livingroom	30/- dB	35 dB
- Kitchen/bathroom	35/-dB	40 dB

Table 14-3: Swedish regulation – Noise limits inside new buildings

For sounds with tonal or impulsive character the limit is decreased by 5 dB.

The maximum sound level may not be exceeded more than 5 times per night and never more than 10 dB(A).

14.2.2 Existing buildings

The Public Health Agency of Sweden is a national knowledge agency with overarching responsibility for public health issues. The agency's remit is to promote health, prevent ill-health and protect against health threats. Since 2014 The Public Health Agency of Sweden has guidelines for indoor noise in regulation FoHMFS 2014:13.

Maximum A-weighted sound level	$L_{A,max}$ = 45 dB
Equivalent A-weighted sound level	$L_{A,eq,T}$ = 30 dB
Sounds with tonal character	$L_{A,eq,T}$ = 25 dB

Table 14-4: Swedish regulation – Noise limits inside existing buildings

The agency also have guidelines for low frequency noise in 1/3 octave bands.

Centre frequency (Hz)	A-weighted sound level (dB)
31.5	56
40	49
50	43
63	41.5
80	40
100	38
125	36
160	34
200	32

Table 14-5: Swedish regulation – Guidelines for low frequency limits inside buildings

14.3 Safety regulation

The Swedish Work Environment Authority is responsible for noise in the work environment.

The Swedish Work Environment Authority has issued regulation AFS 2005:16 (Noise), which is based on the European directive 2003/10/EC. If the noise exposure is exceeds the noise limits the cause shall be investigated and measures shall be taken immediately, see the following table.

Equivalent A-weighted noise level, 8h work day	$L_{A,eq,8h}$ = 85 dB
Maximum A-weighted sound level	$L_{A,max}$ = 115 dB
C-weighted peak level	$L_{C.peak}$ = 135 dB

Table 14-6: Swedish regulation – Safety regulation, noise limits

15 The Finnish regulations

The Finnish minister of Justice has issued decree 993/1992 which gives guidelines for outdoor and indoor noise.

Outdoor guidelines for the equivalent A-weighted sound level:

	$L_{A,eq}$ day 7-22	$L_{A,eq}$ night 22-7
Existing neighborhood, urban	55 dB	50 dB
New neighborhood, urban	55 dB	45 dB
Recreational area, non-urban	45 dB	40 dB

Table 15-1: Finnish regulation – Environmental noise limit levels

Indoor guidelines for the equivalent A-weighted sound level:

	$L_{A,eq}$ day 7-22	$L_{A,eq}$ night 22-7
Living areas	35 dB	30 dB

Table 15-2: Finnish regulation – Indoor noise limit levels

If the noise has a tonal or impulsive character the limit is decreased by 5 dB

16 The Norwegian regulations

The only reference know at the moment is the document NS 8175:2012 (Acoustic conditions in buildings - Sound classification of various types of buildings) which gives also guidelines for indoor noise.

Indoor guidelines for the equivalent A-weighted sound level:

Ambient:	Minumum $L_{A,eq}$ required
Living room	32 dB(A)
Bed room	30 dB(A)

Table 16-1: Norwegian regulation – Indoor noise limit levels

17 The Swiss regulations

17.1 Preface

Switzerland is not participating in the IEA HPT Annex 51, but it is an important and interesting market. Heat pumps have a long tradition in Switzerland. Engineers from Switzerland have made a major contribution to the development of heat pumps. Due to the high market share of heat pumps as a heating system, there are "precise" regulations concerning noise emissions. Austria as a participating country worked out this report to give an overview of the regulations regarding noise emissions in Switzerland.

17.2 Introduction

Heat pumps which use the ambient air as heat source have become more and more popular in the last years. Especially the kind of ambient air-water heat pumps is already the dominant heat pump system on the market. Different studies assume, that this trend will continue in the next years. The reasons for this development are on the one hand the low investment costs of air/water heat pumps and on the other hand the fact, that the ambient air is an easily accessible heat source. Moreover, in some cases the ambient air is the only heat source which is available. It can be assumed, that the transition from building new houses to refurbish already existing buildings will reinforce this development. But the trend to more air heat pumps holds both, challenges and opportunities. One of the biggest challenges is the noise emission of those kind of heat pumps, which is also seen as the biggest barrier to the market diffusion. (Biermayer et al., 2016)

The noise emission is consistently a reason for arguments in the neighbourhood, which sometimes even end up at courts. To avoid such situation, next to technical developments to reduce the noise emission, clear rules concerning noise emission and immission are needed. The Annex 51 should contribute to the development of standardized guidelines for establishing a clear legal situation. Especially in Austria, the current legal situation is due to many different standards, even at the municipal level, not easy to overview. In Switzerland, the situation is, in contrast to Austria, already regulated more precisely. This report will provide a summary of the current legal situation in the Switzerland.

17.3 Sold heat pumps

The development of the heat pump market in Switzerland was a success story over the last years. With the support of the federal government it was possible to increase the heat pump market significantly. Figure 17-1 shows the course of sold heat pump units from 1993 to 2016. A detailed classification dependent on the energy source is only available since 2010.

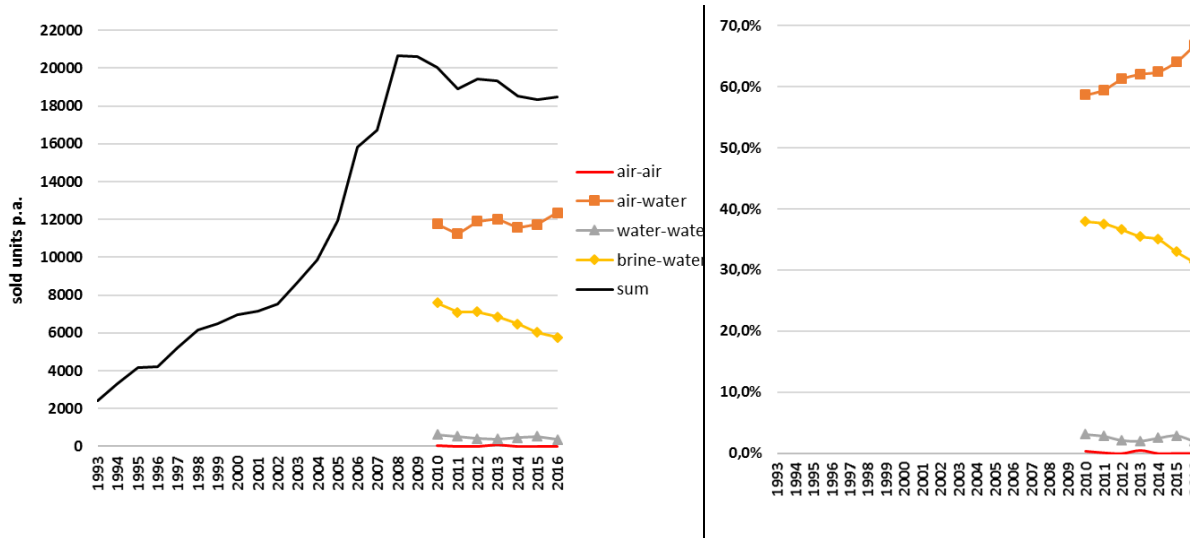


Figure 17-1: Swiss regulation – Absolute (left) and relative (right) values of sold heat pumps in Switzerland (Fachvereinigung Wärmepumpen Schweiz, 2018)

From 1993 to 2008 there was a significant increase in sold heat pump units. Until 2011 there was a slight decrease which was followed by a slight rebound in 2012 and 2013. After that the number of sold heat pump units remained constant at around 18500 units per year.

Between 2010 and 2016 the amount of sold air-water heat pump units was around 12000 units per year with only slight ups and downs of ± 5%. In contrast to air-water heat pump units the number of sold brine-water heat pump units decreased from 2010 to 2016. Consequentially, the share of air-water heat pumps increased from 58 % in 2010 to 68 % in 2016 and the share of brine-water heat pumps decreased from 38 % in 2010 to 31 % in 2016 (see Figure 17-2 (right)). In the years 2010 to 2016 the number of sold air-air heat pump units was close to 0 and the number of sold water-water heat pumps has only a minor significance.

17.4 Legal basis

The legal basis in Switzerland are mainly specified in two documents:

- The Federal Act on the Protection of the Environment (EPA, 2017);
- Noise Abatement Ordinance (NAO, 2016).

The following subchapters contains an abstract of the essential articles concerning the regulations of the acoustics of air heat pumps. It has to be noted, that this report should only give an overview of the legal matters in the Switzerland and has therefore no legal relevance.

17.4.1 The Federal Act on the Protection of the Environment (EPA)

Article 11 and 12 in the Federal Act on the Protection of the Environment contain the relevant legislative text about the acoustics of air heat pumps. Article 11 is about the (precautionary) principles and Article 12 contains limitations of the permitted noise emission (EPA, 2017).

17.4.2 Principles

The (precautionary) principle in Articel 11 of the EPA (2017) says, that irrespective of the existing environmental pollution, as a precautionary measure emissions are limited as much as technology and operating conditions allow, provided that this is economically accaptable. EPA (2017) also says that noise and vibrations are limited by measures taken at their source

(limitation of emissions). Emissions are limited more strictly if the effects are found or expected to be harmful or a nuisance, taking account of the existing level of environmental pollution (EPA, 2017). The Cercle Bruit (2015) (see chapter 17.5) substantiates this legislative text as follows:

The precautionary principle is completely independent of the noise emission limitations and has to be fulfilled in every case. New installed heat pumps fulfil this principle, if their noise emission comply with the current state-of-the art and if their location is chosen correctly. In case of doubts it has to be clarified if, independent of the existing environmental pollution, the noise emissions are reduced so far as it is technically and operationally possible and economically acceptable. (Cercle Bruit, 2015)

17.4.3 Emission limitations

Article 12 of the EPA (2017) says that emissions are limited by issuing:

a. maximum emission values;
b. regulations on construction and equipment;
c. operating conditions;
d. regulations on the heat insulation of buildings.

Limits are prescribed by ordinance or, in cases where an ordinance makes no such provision, by rulings based directly on the Federal Act on the Protection of the Environment (EPA, 2017).

17.4.4 Noise Abatement Ordinance (NAO)

The most important regulation, which deals with the acoustics of air heat pumps, is the Noise Abatement Ordinance. In the NAO (2016) concrete limits can be found. Furthermore the way how to determine these limitations is described.

17.4.5 Emission limitation for new installed systems

According to Article 7 of the NAO (2016) noise emissions from new stationary installations shall be limited as directed by the enforcement authorities insofar as:

a) this is technically and operationally feasible and economically acceptable; and

b) the noise exposure level resulting from the installation alone does not exceed the planning values

The enforcement authorities shall relax the requirements in cases where compliance with the planning values would place a disproportionate burden on the installation and there is an overriding public interest, particularly regarding questions of land use designation. The impact thresholds must not, however, be exceeded. In addition to that, article 8 of the NAO (2016) contains the emission limits of changed stationary systems.

17.4.6 Exposure Limit Values for Industrial and Commercial Noise

Number 1e in the Annex 6 of the NAO (2016) determines, that the specified exposure limits are valid for heating, air conditioning and ventilation installations, which also includes air heat pumps. In number 2 of the Annex 6 of the NAO (2016) the planning limits, the immission limits and the alarm values are stated for different "Sensitivity Levels". The values are shown in Table 17-1. The rating sound level Lr is determined by Eq. 17-1 to Eq. 17-4

As described in article 7 paragraph 1 of the NAO (2016) the planning value is the decisive value for evaluating the noise emission. Only in exceptional cases (e.g. public interest, land use designation, …) the enforcement authorities shall relax the requirements. In this case the impact threshold must not be exceeded.

Sensitivity Level (Article 43)	Planning value Lr in dB(A)		Impact threshold Lr in dB(A)		Alarm Value Lr in dB (A)	
	Day	**Night**	Day	Night	Day	Night
I	**50**	**40**	55	45	65	60
II	**55**	**45**	60	50	70	65
III	**60**	**50**	65	55	70	65
IV	**65**	**55**	70	60	75	70

Table 17-1: Swiss regulation – Pollution limits (NAO, 2016)

The "Sensitivity Levels" are stated in article 43 of the NAO (2016) and are originally regulated in article 14 ff of the Spatial Planning (SR 700, 2018). They are divided as follows (NAO, 2016):

- *Sensitivity Level I applies in zones with higher noise abatement requirements, notably in leisure zones;*
- *Sensitivity Level II is valid in zones in which operations that emit noise are not permitted,notably in residential zones and zones for public buildings and installations;*
- *Sensitivity Level III is valid in zones in which operations emitting a certain level of noise are permitted, notably in residential and industrial zones (mixed zones) and agricultural zones;*
- *Sensitivity Level IV applies in zones in which operations emitting a high level of noise are permitted, notably in industrial zones.*

Parts of land use zones rated as sensitivity levels I or II may be assigned the next higher level if they are already exposed to noise.

Article 44 of the NAO (2016) determines, that the cantons have to ensure, that the sensitivity levels are assigned to the land use zones in the building regulations or land use plans of the communes. Furthermore the NAO (2016) also specifies the way of determining the rating sound level Lr (Appendix 6, Paragraph 1, Number 3). The rating sound level consists of part rating sound levels (Lr,i) of different noise phases, which are separately calculated for day (07:00 – 19:00) and night-time (19:00 – 07:00). A noise phase is a time period with a constant noise pollution according to the sound intensity as well as the clay and impulse content. Eq. 17-1 shows the determination of the rating sound level Lr.

$$Lr = 10 \cdot \log \cdot \sum_{i} 10^{0,1 \cdot Lr,i} \qquad \textit{Eq. 17-1}$$

The part rating sound levels Lr,i are calculated for the average daily duration of the different noise phases i according to Eq. 17-2 (NAO, 2016).

$$Lr,i = Leq,i + K1,i + K2,i + K3,i + 10 \cdot \log\left(\frac{ti}{to}\right) \qquad \textit{Eq. 17-2}$$

Leq,i equivalent continuous A-weighted sound pressure level during the noise phase I;

K1,i Level correction for the noise phase i to consider the kind of noise source;

K2,i Level correction for the noise phase i to take the audibility of the tonality content into account;

K3,i Level correction for the noise phase i to take the audibility of the pulse content into account;

ti average daily duration of the noise phase i in minutes;

to = 720 minutes.

The average daily duration ti of the noise phase i is calculated from the annual duration (Ti) and the number of yearly days of operation (B) according to Eq. 17-3 (NAO, 2016).

$$ti = Ti/B \qquad \textit{Eq. 17-3}$$

For new or modified installations, the average daily duration of the noise phase i is determined from operational forecasts.

The level correction K1 amounts for air heat pumps (NAO, 2016):

- during daytime .....5 dB
- during nightime .....10 dB

The level correction K2 takes into account the audibility of the tonality content of the noise at the point of exposure and is equal to (NAO, 2016):

- for non-audible tonality content .....0 dB

- for weakly audible tonality content.....2 dB
- for clear audible tonality content.....4 dB
- for strongly audible tonality content .....6 dB

According to Rosa and Bopp (2004) the exaggeration of a third-octave band compared to the neighboring third-octave bands is basically used to determine the level correction K2. However, an evaluation has shown that especially in the low frequency range the level correction factor is too high if only the exaggeration of a third-octave band compared to the neighboring third-octave bands is used. Therefore the exaggeration of a third-octave band compared to the neighboring third-octave bands is adapted by means of a correction factor before determining the level correction K2. A detailed description of the procedure to determine the audible tonality and the level correction K2 can be found in Rosa and Bopp (2004).

The level correction K3 takes into account the audibility of the pulse content of the noise at the point of exposure and is equal to (NAO, 2016):

- for non-audible puls content.....0 dB
- for weakly audible puls content .....2 dB
- for clear audible puls content .....4 dB
- for strongly audible puls content.....6 dB

According to Cercle Bruit (2016) the determination of the pulse content is carried out by experts based on their experience. Normally HVAC-system do not cause any level peaks when switching on or off. Therefore the level correction K3 can be set to 0 dB. It can be assumed that an audible pulse content is caused by a malfunction of the system (Cercle Bruit, 2016).

The A-weighted average sound level Leq has to be measured in the middle of the open window of that rooms, which are sensitive to noise (immission location). If a measurement is not possible, it can be calculated according Eq. 17-4 (Cercle Bruit, 2015).

$$Leq = L_{w,A} - 11 + D_c - 20 \cdot \log(s) \qquad \textit{Eq. 17-4}$$

$L_{W,A}$..... sound power level

D_C ..... directivity index

$20 \cdot \log(s)$ ..... distance absorption

s ..... distance s in meter between the heat pump and the particular window

The sound power level $L_{W,A}$ of the heat pump should be known from the test results of the "Wärmepumpen Testzentrum Buchs" or from another testing institute. If this information is missing, the information of the producer can be used if they have carried out a measurement according to EN 14511-1 (2016). (Cercle Bruit, 2015)

If detailed information, as for example the distribution of the sound pressure level in the free field, is available and the orientation of the heat pump is known, the particular sound pressure level can be used for the calculation. Otherwise the sound power level has to be used (Cercle Bruit, 2015).

The directivity index D_C amounts for (Cercle Bruit, 2015):

- freestanding heat pumps ..... 3 dB
- heat pumps which are placed at the facade ..... 6 dB
- heat pumps which are placed in an internal corner ..... 4 dB

A schematic illustration of the three mentioned types of locations for determining the directivity index are shown in Figure 17-2.

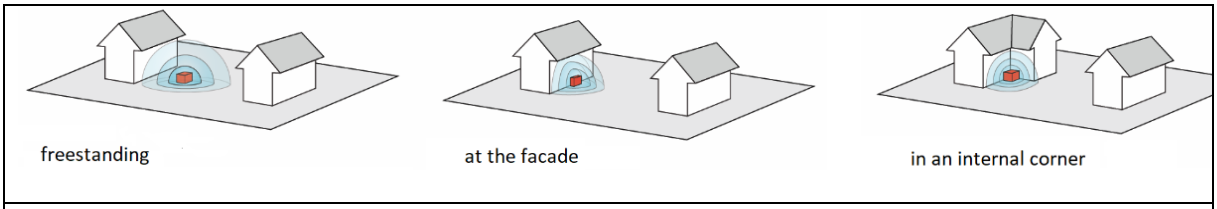


Figure 17-2: Swiss regulation – Different locations of heat pumps for determining the directivity index (Cercle Bruit, 2015)

17.4.7 Soundproofing of new buildings

Article 32 of the NAO (2016) says, that the project owner of a new building shall ensure that the soundproofing of the external building elements and partitions of rooms sensitive to noise, and of the stairs and building facilities complies with recognised codes of building practice. These are in particular for noise from stationary installations the minimum requirements, of SIA 181 (2006) of the Swiss Society of Engineers and Architects.

17.4.8 Regulation in the canton Basel

In addition to the already discussed laws and regulations there is a further leaflet about noise limitation of heat pumps published by Amt für Raumplanung (2015) in the canton Basel, which is addressed to the constructors and builders. This leaflet should, according to itself, help to fulfil the legal requirements concerning the installation of air/water heat pumps. These regulations are as follows (Amt für Raumplanung, 2015):

For heat pumps, no matter if they are installed inside or outside, apply in the canton Basel the maximum immission level of 48 dB(A) during daytime and 33 dB(A) during night-time. These limits has to be fulfilled at all time.

In zones of the sensitivity level III (see section 17.4.6) the limit of the immission level is increased by 5 dB. The assessment of the immission level is independent of the operating time of the heat pump.

The immission level is counted at the next noise sensitivity room (e.g. living room or bedroom), respectively at undeveloped area at the building line (property line + legal building distance). Furthermore the in section 17.4.2 discussed precautionary principle has to be taken into account.

The measurement of the immission level takes place with a distance of 3 m to the heat pump and in a hight of 1.5 m to the ground respectively to the pit. For more information, the document of the canton Basel also refers to Cercle Bruit (2015).

17.4.9 Conclusion

The enforcement aid from Cercle Bruit (2015) sums up both laws, the NAO (2016) and the EPA (2017), as follows: The precautionary principle (according to the Federal Act on the Protection of the Environment – see section 17.4.1) and the compliance with the planning values (according to the Noise Abatement Ordinance – see section 17.4.4) are equal. As part of the assessment of a heat pump unit both have to be taken into account and have to be fulfilled.

Moreover the Cercle Bruit (2015) provides a form to proof the noise protection. With this form, the rating sound level can be determined in a simple way. Furthermore the most important points of the current legal situation are also mentioned. In contrast to the in section 17.4.6 mentioned method of calculation according to the laws itself, Cercle Bruit (2015) makes a simplification in the determination of the rating sound level for the planning. The level correction K2 is 2 dB for weakly audible tonality content and 4 dB for heat pump units with silencers (compare K2 in section 17.4.6). The level correction K3 is 0 dB which means that the audible puls content is neglected (compare K3 in section 17.4.6). The level correction K1 is similar to the NAO (2016). The level correction factors are the same for all noise phases (e.g. K1 instead of K1,i in Eq. 17-2). This means that different noise phases are neglected and therefore a constant sound level is assumed. Beyond that Cercle Bruit (2015) also contains deductions for implemented noise protection measures.

For the canton Basel the same legal standards apply as in the other cantons and in addition to that there are some more regulations which are stated in the leaflet written by Amt für Raumplanung (2015).

17.5 Cercle Bruit

The "Cercle Bruit Schweiz", an association of cantonal noise protection experts, has the purpose of (Circle Bruit, 2017):

- Promotion of the noise abatement in Switzerland;
- Representation of the interests of the cantonal noise protection experts;
- Cultivation of relationships and exchange of experience and knowledge among the members;
- Promotion of professional competence;
- Statements and consultations.

The Cercle Bruit (2015) includes a good summary of the current legal situation and provides furthermore a leaflet for the practical evaluation of the noise protection certificate. Therefore, this report is strongly orientated at the information, which is provided from the members of Cercle Bruit. Regarding to the legal relevance of the document Cercle Bruit expresses themselves as follows (Cercle Bruit, 2017):

The enforcement aid is primarily addressed to the enforcement authorities. It concretises unspecified legal terms, which are used in laws and regulations and promotes a uniform enforcement practice. If the enforcement authorities take this enforcement aid into account, they can be sure, that they have carried out the law correctly. Other solutions than the one shown in Cercle Bruit (2015) are also permitted if they are in accordance with the law.

17.6 Implementation of Measurements

Measurements can be necessary if no information about the sound power level is available from the manufacturer, or if there are doubts about the accuracy of this information (e.g. in course of a complaint). In Cercle Bruit (2015) the requirements for this measurements are defined as follows.

In case of a noise complaint the measurement has to take place in the centre of the particular window (Article 39 NAO, 2016), as far as this is possible because of interfering noises. Otherwise the level of the interfering noises can be measured separately and subtracted from the measurement values in an energetic way. Or the sound pressure level can be measured closer to the heat pump and has to be converted according to the distance. The L_{eq} (see section 17.4.6) has to be measured for at least 30 seconds. The measurement has to be carried out two or three times. The measurement values have to be averaged energetically.

If the measurement is influenced by interfering noises, the total noise pollution can continually be measured for 5 to 10 minutes with the time constant "slow". Thereby, the minimum sound level L_{min} which occurred during the measurement can be determined. The time constant describes how fast the measurement device reacts to changes of the sound level (lower time constants lead to faster changes of the sound level). In case of the evaluation with the time constant slow it is 1000 ms. The determination of L_{min} is described in IEC 61672-1 (2013) in more detail.

If the heat pump emits constantly the same noise during the measuring period, L_{min} can be used instead of the A-weighted sound pressure level $L_{p,A}$, or respectively of L_{eq}. Moreover applies:

- The measuring arrangement should be as simple as possible as well as reproducible
- The measurement must not be influenced by interfering noises. The background noises should be clearly deeper than the sound pressure level of the heat pumps. Otherwise it has to be measured during the night or closer to the heat pump, if this is acceptable.
- The heat pump should be in a representative operation mode. If possible an employee of the manufacturer should be present.

The measuring arrangement is schematically shown in Figure 17-3.

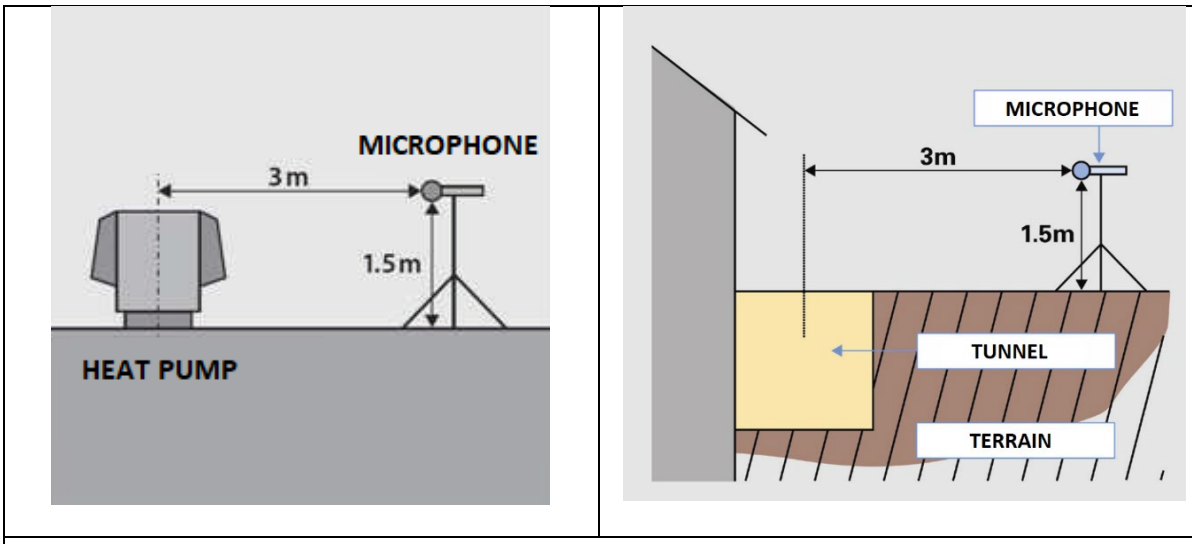


Figure 17-3: Swiss regulation – Measurement arrangement for heat pumps which are located outside (left) and for those which are located inside the building (right) (Cercle Bruit, 2015)

17.7 Noise protection measures

The topic noise protection measures is also discussed in Cercle Bruit (2015). As most important measures for noise protection the choice of the correct location as well as the choice of a heat pump with low noise emissions are identified. If the heat pump is located inside of the building the location of the ventilation tunnel is decisive (see Figure 17-3). Especially the choice of the optimum location is often limited due to the local situation. For this reason some further way to reduce the noise emission according to Cercle Bruit should be mentioned in this chapter. The stated effects should be understood as guide values. Depending on the implementation the effects can differ in certain cases. Section 17.7.1 shows measures for indoor installed heat pumps and section 17.7.2 shows measures for outdoor installed heat pumps according to Cercle Bruit (2015). Section 17.7.3 shows measures for structure-borne sound according to Graf (2002).

17.7.1 Measures for indoor installed heat pumps

Precautionary measures (Cercle Bruit, 2015):

Choice of the location ..... up to -25 dB(A)

Selection of a low-noise heat pump ..... up to -10 dB(A)

Technical Measures (Cercle Bruit, 2015):

Light tunnel small (up to a depth of 1.5 m)..... -3 to -5 dB(A)

Light tunnel big (up to a depth of 2.0 m) ..... -3 to -6 dB(A)

Lining of the tunnels/channels with sound absorbing materials ..... -3 to -6 dB(A)

Silencer in the ventilation tunnels ..... -3 to -15 dB(A)

Silencer in the weather protection grille ..... 0 to -3 dB(A)

Splitter attenuator in the light tunnel..... -3 to -15 dB(A)

Anti-noise wall in front of the light tunnel..... up to -8 dB(A)

Operational Measures (Cercle Bruit, 2015):

Reduction of the rotation speed..... -2 to -6 dB(A)

Quiet mode (during night-time) ..... -2 to -6 dB(A)

17.7.2 Measures for outdoor installed heat pumps

Precautionary measures (Cercle Bruit, 2015):

Choice of the location ..... up to -25 dB(A)

Selection of a low-noise heat pump ..... up to -10 dB(A)

Technical Measures (Cercle Bruit, 2015):

Sound jacket ..... up to -8 dB(A)

Ducts..... -2 to -6 dB(A)

Anti-noise wall ..... up to -8 dB(A)

Operational Measures (Cercle Bruit, 2015):

Reduction of the rotation speed..... -2 to -6 dB(A)

Silent mode (during night-time)..... -2 to -6 dB(A)

17.7.3 Measures for structure-borne sound

Structure-borne sounds are mechanical vibrations which are spread out in structures for example as compression or as bending waves. The attenuation of structure-borne sound is very low in metal and especially in welded constructions. But also bolted constructions are not much better because of the friction between the single elements.

In contrast to the airborne sound, the structure-borne sounds can often be reduced much easier if the correct measures are taken. The spreading of the structure-borne sound can for example be reduced with a so called structure-borne insulation and with anti-drumming.

Most relevant structure-borne sound insulations Graf (2002):

- Structure-borne sound insulation of the compressor
- Structure-borne sound insulation of the fan
- Structure-borne sound insulation of the pipes

The key aspect in each case is the elastic mounting of the relevant component. More detailed descriptions of the different ways to reduce structure borne sound as well as some examples can be found in Graf (2002).

17.8 Court decisions related to noise emissions of heat pumps

In this chapter some court decisions concerning noise emissions of air heat pumps are mentioned and the resulting consequences are discussed. The first and the second case are taken out of the enforcement aid from Cercle Bruit (2015).

17.8.1 Federal Supreme Court Decision 1C_506_2008

A short summary of the Federal Supreme Court Decision 1C_506_2008 is given within this report. A more detailed description can be found in Circle Bruit (2015).

Community Metzerlen-Mariastein (canton Solothurn), objection against the construction permit of a single family building with a heat pump. According to the noise protection regulation (Article 7 NAO, 2016) noise emissions of new stationary systems have to be reduced as far as it is technical and operational possible and economically viable. Moreover the immissions of the heat pump system must not exceed the planned values. This means, that the requirement of the compliance of the planned values and the precautionary principle are count cumulative. Therefore it has to be proven that the precautionary principle is fulfilled, even if the planned values are not exceeded. The building permit authority is therefore not allowed to permit the person who applies for the building application to choose freely between the different options which observe the planning values. They have to make sure, that the chosen option is the one, which fulfils the precautionary principle the best.

As a result, the enforcement authority has to examine in each case individually, if there is a further noise reduction measure which has to be implemented according to the precautionary principle.

17.8.2 Comment to Article 11 of the Federal Act on the Protection of the Environment

As the legislature has renounced to define the state-of-the-art in the EPA (2015) Cercle Bruit (2015) made a comment on Article 11 of the Federal Act on the Protection of the Environment.

As there is no definition of the state of-the-art in Article 11 of the EPA (2015) the Federal Council has stated a definition in Article 4 of the NAO (2016) which is valid in the whole field of immission protection. It is specified, that those measures are counted as the state-of-the-art, which are either successfully tested in Switzerland or in foreign countries, or those which are successfully used in experiments and can be transferred to practical applications. The aim of this definition is to reduce the time between the release of a new development and its enforceability by the authorities. The state-of-the-art is therefore defined as the level of development of advanced technologies for the reduction of emissions. It is enough if the practical suitability seems to be given. A successful trial operation is therefore sufficient if it has been carried out considering practical conditions.

17.8.3 Canton court case 7H 15 138

A short summary of the Canton court case 7H 15 138 is given within this report. A more detailed description can be found in Kantonsgericht (2016).

Initial situation:

An appeal against the construction permit has been lodged with the argument that the heat pump does not adhere the necessary distance to the property line. The necessary distance for elements of buildings is 4 m but the heat pump is located only within a distance of 2 m to the property line. The complainant claims that the heat pump has to be seen as a part of the building because a fixed connection to the building is existent. The owner of the heat pump replied that a heat pump has to be seen as a plant and that the regulation is therefore not valid for heat pumps. Moreover from his point of view an advantage of a replacement of the heat pump is not given since the actual position of the neighbours building is not in the proximity of the position of the heat pump.

Court decision:

An air/water heat pump (with the present dimensions) has not to be seen as part of the building but as a plant. Therefore they have (under some reservations) not to consider any limit distances according to the building inspection department.

Wires or pipes which connect the heat pump with the building does not make the heat pump a part of the building. But it has to be investigated if according to the precautionary principle any measures can be taken which lead to an additional reduction of the noise emission. Such measures can also include a change of the installation site.

17.8.4 Federal Court decision about the noise emission of a heat pump system

A court case regarding the noise emissions of an air heat pump started in 2012 and was finally in the news and also published by Aargauer Zeitung (2016). An argument about an air-water

heat pump lasted for more than three years in a Gipf-Oberfricker residential area. In fall 2012 a resident complained about the heat pump of a neighbour. The heat pump has been installed without a permission and would not adhere the noise limit. The case was processed in several instances till it ended up at the Federal Court which agreed partly with the complainant.

Even though the federal judge came – as before the cantonal building department and the Higher Administrative Court – to the conclusion that the noise limit has not exceeded. In the decision it was referred to the precautionary principle.

The federal judge instructs the municipal council to re-evaluate the situation according to the judgment. Particularly a relocation of the heat pump has to be considered. One possibility would be to transfer the heat pump, which is at the moment located on the outside, to the inside of the building.

17.9 References

Aargauer Zeitung, 2016. Streit um Wärmepumpe - Bundesgericht rügt Gemeinde (2016/02/05). Aargauer Zeitung, Aarau

Amt für Raumplanung, 2015. Lärmbegrenzung bei Wärmepumpen - Ein Merkblatt für Planer und Bauherren. Amt für Raumplanung Abteilung Lärmschutz, Basel.

Biermayr, P., Dißauer, C., Eberl, M., Enigl, M., Fechner, H., Leonhartsberger, K., Maringer, F., Moidl, S., Schmidl, C., Strasser, C., Weiss, W., Wonisch, P., Wopienka, E., 2016. Innovative Energietechnologien in Österreich Marktentwicklung 2015. Bundesministerium für Verkehr, Innovation und Technologie, Wien.

Cercle Bruit, 2015. Lärmtechnische Beurteilung von Luft/Wasser-Wärmepumpen - Vollzugshilfe 6.21. Cercle Bruit, Solothurn.

Cercle Bruit, 2016. Lärmtechnische Beurteilung von Heizungs-, Lüftungs-, Klima- und Kälteanlagen - Vollzugshilfe 6.22. Cercle Bruit, Solothurn.

Cercle Bruit, 2017. http://www.cerclebruit.ch/ (2017/09/02).

EN 14511-1, 2016. Luftkonditionierer, Flüssigkeitskühlsätze und Wärmepumpen mit elektrisch angetriebenen Verdichtern für die Raumheizung und –kühlung. Europäisches Komitee für Normung, Brüssel.

Fachvereinigung Wärmepumpen Schweiz, 2018. http://www.fws.ch/statistiken.html (2018/01/02).

EPA, 2015. Federal Act on the Protection of the Environment. The Federal Assembly of the Swiss Confederation, Bern.

EPA, 2017. Federal Act on the Protection of the Environment. The Federal Assembly of the Swiss Confederation, Bern.

Graf, H., 2002. Lärmreduktion bei Luft/Wasser-Wärmepumpenanlagen - Grundlagen und Massnahmen. Bundesamtes für Energie, Oberburg.

IEC 61672-1, 2013. Electroacoustics - Sound level meters - Part 1: Specifications. International Electrotechnical Committee, Geneva.

Kantonsgericht, 2016. Rechtsprechung zu Bau- und Planungsrecht 4. Abteilung Fallnummer 7H 15 138. Kantonsgericht, Luzern.

NAO, 2016. Noise Abatement Ordinance. The Swiss Federal Council, Bern.

Rosa, E., Bopp, U., 2004. Bericht über die Beurteilungshilfe zur Bestimmung der Tonhaltigkeit von Wärmepumpen nach Anhang 6 der Lärmschutz-Verordnung. Bundesamt für Energie, Bern.

SIA 181, 2006. Schallschutz im Hochbau, Schweizerischer Ingenier- und Architektenverein, Zürich.

SR 700, 2018. Bundesgesetz über die Raumplanung. Die Bundesversammlung der Schweizerischen Eidgenossenschaft, Bern.

17.10 Acknowledgement

The work on “IEA HPP Annex 51” is financially supported within the framework of the “IEA Research Cooperation” on behalf of the “Austrian Federal Ministry for Transport, Innovation and Technology” (bmvit) (FFG project number: 864146).

18 The Korean Regulations

There is no dedicated regulation on noise for heat pumps or air conditioners in South Korea.

However, requirements for Ecolabel are including maximum noise levels.

18.1 Ecolabel for Air conditioners

The Ecolabel EL401:2013 "Air conditioners" [3] [EL401-1998/11/2012-36] defines the criteria for Eco-label for air conditioners including "'single package type' and 'split type'.

With related to the noise of the products during cooling operation shall comply with Table 18-1.

Types		Noise Standards [dB(A)]	
		Interior	Exterior
Single package		≤ 55	≤ 60
Split	Rated cooling capacity < 4kW	≤ 45	≤ 55
	4kW ≤ Rated cooling capacity < 10kW	≤ 50	≤ 60
	10kW≤ Rated cooling capacity< 35kW	≤ 55	≤ 65
	Rated cooling capacity≥35kW	≤ 55	≤ 70

Table 18-1: Korean regulation – the criteria of noise

18.2 Ecolabel for multi air conditioners

The Ecolabel EL409 "Multi Air Conditioners" [EL409-2011/4/2013-132] defines the criteria for Eco-label for multi air conditioners.

A "Multi Air Conditioner" consists of one or more outdoor units and two or more indoor units, with a cooling capacity per outdoor unit greater or equal to 23 kW.

With respect to noise in the cooling operating of the product, the following requirements shall be satisfied. However, in case that outdoor unit is installed in the space partitioned is exempted.

Item	Rating cooling-capacity [kW]	Noise [dB(A)]
Indoor unit	< 4	≤ 45
	< 10	≤ 50
	≥ 10	≤ 55
Outdoor unit	< 40	≤ 60
	≥ 40	≤ 70

Table 18-2: Korean regulation – other criteria of noise

18.3 The KS mark

The KS mark indicates conformity with applicable Korean Industrial Standards (KS), and is granted by the certification body, the Korean Standards Association (KSA). In most cases,

[3] http://www.me.go.kr

obtaining the KS mark is a voluntary measure designed to enable manufacturers to enhance their competitiveness and empower consumers by providing information about the quality of products.

For air conditioners the sound power level is described in KS C 9306. Table 3 (see Table 18-3)provides the indoor /outdoor sound power level limits according to the cooling capacity range of the products.

Cooling capacity (W)	Indoor		Outdoor	
	packaged	split	packaged	split
Capacity ≤ 2500	55	45	60	55
2800 ≤ Capacity ≤ 4700	60	50	65	57
5200 ≤ Capacity ≤ 8100	65	55	70	60
8300 ≤ Capacity ≤ 20000	-	60	-	65
21000 ≤ Capacity ≤ 35000	-	65	-	

Table 18-3: Korean regulation – table 3 of KS C 9306

19 The Japanese regulations

Source; DAIKIN Industries Ltd – Osami KATAOKA

In Japan, there is a general noise regulation, but allowable sound pressure level are depending on region and purpose.

This regulation also apply to heat pumps and air conditioners.

Table 19-1 and Table 19-2 provides the sound pressure levels application in Tokyo City and in Nara prefecture respectively.

	6AM-8 AM	8AM-7PM	7PM-11PM	11PM-6AM
1st class residential	40dBA	45	40	40
2nd class residential	45	50	45	45
Commercial	55	60	55	50
Industrial	60	70	60	55

Table 19-1: Japanese regulation – Maximum sound pressure levels in Tokyo City

	6AM-8 AM	8AM-6PM	6PM-10PM	10PM-6AM
Other than industrial	50dBA	60	50	45
Industrial	65	70	65	55

Table 19-2: Japanese regulation – Maximum sound pressure levels in Nara Prefecture

Basically, these values are measured at the boundary of a facility location.

Eco-cute heat pump water heaters for residential use based on CO_2 cycle are a specific issue. These heat pumps are operated during night to consume excessive energy produced by nuclear power plants and to store hot water. They are quiet but at midnight, there are several cases of people who sued the manufacturers due to insomnia caused by Ecocute products.

20 Appendix - List of standards

EN 14511: 2018

Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling.

- Part 1: Terms, definitions and classification;
- Part 2 : Test conditions;
- Part 3 : Test methods;
- Part 4 : Requirements.

EN 15879-1:2010

Testing and rating of direct exchange ground coupled heat pumps with electrically driven compressors for space heating and/or cooling - Part 1: Direct exchange-to-water heat pumps..

EN12102

Air conditioners, liquid chilling packages, heat pumps and dehumidifiers with electrically driven compressors for space heating and cooling — Measurement of airborne noise — Determination of the sound power level.

- Part 1: Air conditioners, liquid chilling packages, heat pumps for space heating and cooling.
- Part 2: Heat pump water heaters.

EN ISO 3740

Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards (ISO 3740).

EN ISO 3741

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms (ISO 3741).

EN ISO 3743-1

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for small, movable sources in reverberant fields - Part 1: Comparison method for hard-walled test rooms (ISO 3743-1).

EN ISO 3743-2

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for small, movable sources in reverberant fields - Part 2: Methods for special reverberation test rooms (ISO 3743-2).

EN ISO 3744

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane (ISO 3744).

EN ISO 3747

Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering/survey methods for use in situ in a reverberant environment (ISO 3747).

EN ISO 9614-1

Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points (ISO 9614-1).

EN ISO 9614-2

Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 2: Measurement by scanning (ISO 9614-2).

EN ISO 9614-3

Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 3: Precision method for measurement by scanning (ISO 9614-3).

EN 16147: 2017

Heat pumps with electrically driven compressors — Testing, performance rating and requirements for marking of domestic hot water units.

21 FIGURES INDEX

Figure 2-1: EN 12102 – Device under test positioning 14
Figure 2-2: EN 12102 – Device under test, examples of positioning 15
Figure 2-3. EN 12102 – Oudoor air unit ducted inlet/outlet 17
Figure 2-4: EN 12102 – Individual exhaust air unit 17
Figure 3-1: 626/2011 – label 20
Figure 3-2: 626/2011 – label, acoustic detail 20
Figure 3-3: 811/2013 – Low-temperature heat pump space heater 22
Figure 3-4: 811/2013 – Heat pump combination heater 22
Figure 3-5: 812/2013 – Labelling of a heat pump water heater 24
Figure-8-1: Austrian regulation – Installed heating systems in Austria in 2013 (Benke et al., 2015) 39
Figure-8-2: Austrian regulation – Absolute (left) and relative (right) values of sold heat pump units in Austria (Biermayr et al., 2017) 39
Figure 8-3: Austrian regulation – General three step assessment scheme (Österreichischer Arbeitsring für Lärmbekämpfung, 2008) 45
Figure 8-4: Austrian regulation – Noise calculator of the Austria Heat Pump Association (Wärmepumpe Austria, 2018) 52
Figure 8-5: Austrian regulation – Hemispherical enveloping surface (Wärmepumpe Austria, 2014) 54
Figure 8-6: Austrian regulation – Cubic enveloping surface (Wärmepumpe Austria, 2014) 54
Figure 11-1: Fields of law and the resulting noise protection regulations. 72
Figure 11-2: Regulations for noise protection depending on the application of heat pumps 73
Figure 12-1: K_0 solid angle indicator depending on the place of sound reflection. 88
Figure 13-1: Danish regulation – Limits in Danish noise regulations 90
Figure 17-1: Swiss regulation – Absolute (left) and relative (right) values of sold heat pumps in Switzerland (Fachvereinigung Wärmepumpen Schweiz, 2018) 98
Figure 17-2: Swiss regulation – Different locations of heat pumps for determining the directivity index (Cercle Bruit, 2015) 103
Figure 17-3: Swiss regulation – Measurement arrangement for heat pumps which are located outside (left) and for those which are located inside the building (right) (Cercle Bruit, 2015) 106

22 TABLES INDEX

Table 2-1: ISO 374X family standard for sound power level determination 11
Table 3-1: 206/2011 – maximum power level requirements 19
Table 3-2: EN 12102 – test conditions 20
Table 3-3: 813/2013 – maximum sound power levels 21
Table 3-4: EN 12102 – test conditions 21
Table 3-5: 814/2013 – maximum sound power levels 23
Table 4-1: Ecolabel table 15 – noise emission limits by heat generator technology 25
Table 6-1: French Regulation – requirements for heating (boilers) or air-conditioning 29
Table 6-2: French Regulation – correction terms for short time duration of noise 29
Table 6-3: French Regulation – threshold values for outdoor side sound power level of heat pumps (source: NF PAC scheme rules July 2017) 31
Table 7-1: United Kingdom regulation – MCS020 calculation procedure 35
Table 7-2: United Kingdom regulation – MCS020 calculation procedure 36
Table 8-1: Austrian regulation – Planning Values for noise immission (ÖNORM S 5021, 2017) 41
Table 8-2: Austrian regulation – Overview of effects of different sound pressure levels during night at the outside (Österreichischer Arbeitsring für Lärmbekämpfung, 2011) 48
Table 8-3: Austrian regulation – Overview of effects of different sound pressure levels during night at the inside (Österreichischer Arbeitsring für Lärmbekämpfung, 2011) 48
Table 8-4: Austrian regulation – Overview of noise immission limits in the federal provinces (Doppler, 2015) (IG Umwelt und Technik, 2007) 49
Table 9-1: Italian regulation – different kind of building divided by intended use 59
Table 9-2: Italian regulation – groups of categories with omogeneous limits 59
Table 9-3: Italian regulation – definitions of different areas 60
Table 9-4: Italian regulation – emission limits for every kind of zone 61
Table 9-5: Italian regulation – immission limits for every kind of zone 61
Table 9-6: Italian regulation – limits valid for all non-zoned national soil 62
Table 10-1: Spanish regulation – table B1 of royal decree 1367/2007 “Limit values for noise imission applicable to port infrastructures and activities” 65
Table 10-2: Spanish regulation – table B2 of royal decree 1367/2007 “values of limit noise transmitted to adjoining room by activities” 66
Table 10-3: Spanish regulation – Noise limits in Andalusia 67
Table 10-4: Spanish regulation – Noise limits in Balearic Islands 67
Table 10-5: Spanish regulation – Noise limits in Castilla – La Mancha 68
Table 10-6: Spanish regulation – Noise limits in Castilla y Leon 68
Table 10-7: Spanish regulation – Noise limits in Cataluña 69
Table 10-8: Spanish regulation – Noise limits in Extremadura 70
Table 10-9: Spanish regulation – Noise limits in Galicia 70
Table 10-10: Spanish regulation – Noise limits in Madrid Community 71
Table 11-1: Maximum permissible A-weighted sound pressure levels in external rooms requiring sound protection, generated by building service equipment. Table 9 in DIN 4109. 78
Table 11-2: Requirements for maximum permissible A-weighted sound pressure levels in rooms requiring sound protection in one's own home, generated by air conditioning systems in one's own living area. Table 10 in DIN 4109 78
Table 12-1: Limit values of the sound pressure level L_p at the boundary of the plot 86

Table 12-2: Correction of sound propagation ΔL_p depending on the installation location and distance from a single source sound 87
Table 12-3: Increase in the equivalent pressure level acoustic ΔL for many identical sources sound. 88
Table 14-1: Swedish regulation – Environmental guideline for industrial noise 91
Table 14-2: Swedish regulation – Noise limits for roads and raliways 92
Table 14-3: Swedish regulation – Noise limits inside new buildings 92
Table 14-4: Swedish regulation – Noise limits inside existing buildings 93
Table 14-5: Swedish regulation – Guidelines for low frequency limits inside buildings 93
Table 14-6: Swedish regulation – Safety regulation, noise limits 94
Table 15-1: Finnish regulation – Environmental noise limit levels 95
Table 15-2: Finnish regulation – Indoor noise limit levels 95
Table 16-1: Norwegian regulation – Indoor noise limit levels 96
Table 17-1: Swiss regulation – Pollution limits (NAO, 2016) 100
Table 18-1: Korean regulation – the criteria of noise 112
Table 18-2: Korean regulation – other criteria of noise 112
Table 18-3: Korean regulation – table 3 of KS C 9306 113
Table 19-1: Japanese regulation – Maximum sound pressure levels in Tokyo City 114
Table 19-2: Japanese regulation – Maximum sound pressure levels in Nara Prefecture 114

www.heatpumpingtechnologies.org

Heat Pump Centre
c/o RISE - Research Institutes of Sweden
PO Box 857
SE-501 15 BORÅS
Sweden
Tel: +46 10 516 5512
E-mail: hpc@heatpumpcentre.org

www.heatpumpingtechnologies.org

Report no. HPT-AN51-4