

Report Partners:



Welsh Government, Energy Division, Energy Division

AIR SOURCE HEAT PUMP NOISE & PERMITTED DEVELOPMENT RIGHTS IN WALES

Phase 1 Report (redacted version)

Contract Ref: ASHP-PDR/2022-23

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REPORT STATEMENT

Sustainable Acoustics have collaborated with Apex Acoustics for this project.

Sustainable Acoustics have completed this report with Apex Acoustics, using all reasonable skill and care and with an understanding of the aims, objectives and scope of the work as made available to them and as agreed with the client at the time of preparation.

This report is issued to the client under the terms and conditions of the appointment to Welsh Government, and Sustainable Acoustics or Apex Acoustics cannot accept any responsibility to any third party to whom this report may be circulated, in part or in full, or for any matters arising which may be considered outside the scope of works. Any such parties rely on the contents of this report solely at their own risk.

The contribution of direct carbon GHG equivalent generated in the resources used to prepare this report has been offset traceably for the contributions of Sustainable Acoustics. Apex Acoustics have committed to assessing their carbon impact and offsetting it traceably for Phase 1 of this work, making this carbon neutral work.

GDPR statement: This document has been prepared with the protection of personal data of central importance. The report is designed to be read in a non-redacted form (up to and including Appendix 2). This is suitable for sharing in the public domain. Appendix 3 contains the full supporting details which does include personal information by consent of those providing it, plus details of a confidential nature intended for use by the Welsh Government only (as illustrated by the water mark). Please be cognisant of this when sharing the full document, as further consents may be required to allow access the Appendix 3, which it should be recognised will be beyond the data handling obligations of the authors and subject to GDPR.

EXECUTIVE SUMMARY

Phase 1 work establishes that noise is one of the factors blocking widespread domestic air source heat pump (ASHP) deployment in Wales. The biggest constraint for ASHP deployment in Wales is the 3 m Permitted Development (PD) rights rule. There is no evidence supporting the need for the 3 m rule to limit the adverse impact of noise.

The noise assessment prescribed in MCS 020 also presents an obstacle to installations proceeding. When installers perform the calculation and the result is a failure, they abort all efforts on that installation; the installers have little idea of how to overcome the noise constraint. This means that the low density “straightforward” sites are being prioritised, and medium- or high-density housing areas are not considered. Phase 2 work is proposed to explore this further and prototype test information that may help overcome these obstacles.

It is the view of the authors that it is essential that any updates to PD rights and MCS 020 are carefully coordinated to ensure that benefits gained from simplifying the planning process for ASHPs are not then lost by a process for grant funding, which is more onerous than the planning requirements.

It is a commonly held belief that ASHPs are noisy. However, there are currently relatively few formal complaints about noise from ASHPs, and there are only a small number of examples of installations completed using MCS 020 that have resulted in justified complaints. We believe that limited deployment is the current reason for low complaint numbers.

Further work is required (beyond compliance with the MCS) to evaluate the noise burden to the population from ASHP installations. This work will be used to inform a larger piece of work by the UK Government on this topic.

SUMMARY

The purpose of this Phase 1 report is to address the primary question of whether noise is a central factor affecting air source heat pump (ASHP) placement outside domestic properties in Wales.

It also sets out to summarise the latest evidence on ASHP noise from what is known in the literature, from manufacturers' perspectives, and Local Authorities' experience, as well as from any studies conducted during actual deployment and use. The results of this first phase of work are intended to inform and shape the second phase, which will look for practical means to reduce noise as an obstacle to the uptake of ASHPs and large-scale deployment in the domestic setting.

It was found that noise is a primary factor that presents an obstacle to the uptake of ASHPs in various ways, and that noise is an important factor that must be considered in the installation if noise problems are to be avoided. Noise from ASHPs is perceived by residents and Environmental Health practitioners to be problematic, and noise does currently constrain the viability of some ASHP installations through the Microgeneration Certification Scheme MCS 020 Planning Standard (1) (summarised in Appendix 1). This standard is required for securing grant funding, and also part of achieving the Permitted Development (PD) rights. As funding and installations are intrinsically linked with the MCS 020 Planning Standard, there are two distinct routes within the standard to reduce the obstacle that noise presents, before considering PD:

- 1) Facilitate installers' compliance with the MCS 020 Planning Standard with provision of information, education and case studies; and
- 2) Review and update the MCS 020 Planning Standard.

There is a widespread general perception that noise from an ASHP could prevent householders from thinking about an ASHP, and there is also evidence from energy providers that current restrictions and the MCS 020 standard present an obstacle to deployment on a large scale. In Phase 1 we have not collected evidence to determine the potential extent of this obstacle, which is proposed to be explored further in Phase 2.

COMPLAINTS

To decide whether evidence of complaints related to ASHPs exists, the Institute of Acoustics (IOA) questionnaire results on the topic were considered, as well as interviews with Welsh Local Authorities. Although the IOA survey returned only 117 responses, these included 73 (62% of respondents) by environmental health practitioners, 30 (26%) noise consultants and 14 (12%) members of the public. This is a good quality source of data for this project, as Welsh Government asked its Local Authorities to respond to this survey to allow feedback to be provided. The scale of responses from Environmental Health practitioners also includes a call by the Chartered Institute of Environmental Health (CIEH) to its members to complete the survey, so includes practitioners from across the UK. The data therefore represents a combined response. A summary of the findings set out in Appendix 3 is provided below:

- 76% (88 no.) of respondents said that noise from ASHP was an issue.
- 10 no. had made a complaint of noise from an ASHP (which was 56% of the public responses), and in all cases the ASHP belonged to a neighbour. Of these, nine people directed that complaint to the owner of the ASHP, eight people directed the complaint to the Local Authority and four people

directed the complaint to the MCS (some people reported the complaint to more than one recipient).

- 4 no. respondents had received complaints from the owner of the ASHP.
- The main cause of the complaint received by respondents was noise at night (7 no.), but there were 6 no. that reported that noise during the daytime was the cause of the complaint, with 5 no. reporting complaint was due to broadband noise, 4 no. due to tonal components, 3 no. due to its transience or intermittency and 2 no. due to its roughness (some respondents reported more than one reason).
- British Standard BS 4142 was the favoured method of assessment, where an assessment was completed.
- 13% (16 no.) of the Local Authorities established at a Statutory Nuisance existed, and in 38% (6 no.) of those cases an abatement notice was served.
- 24% (12 no.) said the scheme used MCS 020.

This evidence provides some indication that complaints are being made and are reaching Local Authorities, who are acting formally in some cases.

All 22 Local Authorities in Wales were contacted to ask if they have received complaints about noise from domestic ASHPs and to request them to join a short interview to explore their experiences to date. 91% responded (allowing for those with shared services). 59% of the total Welsh Local Authorities Environmental Health representatives were then interviewed, plus an additional four (18%) representatives of planning departments.

Whilst there were examples within the interview responses of complaints of noise reaching Local Authorities, the numbers were generally linked with installations associated with social housing schemes, due to the scale of the installations, or through individual cases. Formal action had been taken in some cases, but the numbers are currently very low. This was largely expected, from analysis of the MCS MID data, to be due to the generally low number of installations in Wales. Areas of higher installation numbers occurring via the MCS scheme were generally noted to be situated in low density, rural areas. The concern of adverse noise impact was a consistent thread emerging from interviews, with concern over relaxing PD rights. The risk of resource strain on Environmental Health/Protection Departments was raised as a concern, as well as how to deal with cumulative noise impacts from large scale deployments. Currently, the lack of proper consideration of background sound levels in the MCS 020 calculation was a concern. There was also concern that allowing ASHP installations in more densely populated areas could set a precedent that could severely affect the soundscape quality at the precise moment that Welsh Government were asking Local Authorities to have regard for their soundscapes. BS 4142 was recognised as the gold standard for assessing potential noise impact of ASHPs, although a few Local Authority personnel were aware of the joint CIEH and IOA Professional Advice Note, calculation sheet and Briefing Note for the public.

OPPORTUNITIES TO FACILITATE INSTALLERS' COMPLIANCE WITH MCS 020

Data from various manufacturers has been assembled during Phase 1 of this project, showing heating power against sound power.

Three opportunities to reduce noise being an obstacle were identified and are proposed:

1. Web-based calculation tool

A web-based tool that draws on the MCS Installations Database (MID) of approved ASHPs, but also includes sound power level, could be used to either demonstrate compliance with MCS 020, or be used as a search tool to identify which ASHPs would comply with the noise constraints of a particular installation.

2. Template example solutions

A series of template example solutions could be presented that illustrate typical situations and the range of ASHPs that could be adopted. Homeowners and installers can easily relate to examples for different residential archetypes, so that they can easily understand whether noise may constrain their desire for an installation or not.

3. Ready reckoner design charts

A simple chart can show the minimum distance to a neighbouring property for the various installation details, e.g. partial or full barrier, against one wall or in a corner. This could be used by installers to quickly identify the feasibility of a particular site, or do so from GEO mapping tools (such as GIS or Google Earth imagery, for example).

One aspect that has not been widely explored in Phase 1 is the developers and MCS 020 users' perception of noise as an obstacle.

The process of establishing if noise is likely to be a constraint to an installation emerged from discussions with energy providers who are seeking to deploy ASHP on a large scale, accessing the funding provided by the government's grants. Evidence to understand whether noise was an absolute obstacle to deployment, or whether it simply made the process more difficult and hence less desirable, has not yet been observed or traced in detail. We do not know if this obstacle happens because those applying the MCS 020 and PD rights do not have sufficient information about how the installation could comply, or whether this is because they already understand well what would be required (e.g. a noise barrier and mitigation) and the additional costs of doing this means that the installation is not commercially viable.

Therefore, a proposed priority for Phase 2 is to conduct interviews with the supply chain that includes installers, social housing landlords, independent ASHP consultants, more energy suppliers and others who may be faced with noise as an obstacle to installation. With their perspectives understood, the appropriate materials can be developed to remove the blocks to large scale deployment.

A financial incentive may be required if the Welsh Government wishes to incentivise installers to reduce the adverse impact caused by noise, beyond the minimum standards set by MCS 020. This could include an additional payment per decibel below a defined threshold, or reduce the grant values available but increase it up to the maximum grant value the quieter the unit is. Clearly this would require a robust framework well beyond the existing Boiler Upgrade Scheme (BUS), but it would have the effect of intensifying and potentially accelerating the current trend of manufacturers, for whom the research indicates that low noise units are currently a driver to a competitive edge.

OPPORTUNITY TO REDUCE THE NOISE CONSTRAINTS OF MCS 020

Through the Phase 1 work, we have identified a range of opportunities to review the noise limitations of MCS 020. The Annex 51 (2) documents set out the current characterisation of sound from ASHPs, which could be further improved by considering:

- Directivity
- Frosting / defrosting
- Frequency content
- Operational point
- Transient effects
- Cumulative impacts on the quality of soundscapes

The calculation of noise transmission in the MCS 020 Planning Standard is very similar to many other European countries' national calculation for noise from ASHPs. Allowable noise impacts vary widely, however, with different countries adopting a wide range of allowable impacts, some with different day and night-time noise limits.

Updating the MCS calculation methodology is potentially an international project of many years' duration, but in the authors' view it is necessary. If there is a requirement for a new type of laboratory test, robust scientific evidence to demonstrate the need for this would be required. Therefore, updating the MCS calculation method is not considered further within this project. It is recommended that it is reformed however, to address the flaws that have been identified.

It has been understood from initial discussions with energy providers, that noise from ASHP is one of the main factors affecting the selection of suitable candidate locations, along with energy efficiency considerations. The constraints imposed by the MCS calculation on the potential for suitable locations is one of the reasons for this, and there is evidence that this is leading to aborted sites, which are identified at risk. Financial losses are then resulting as a result of the failed surveys. This provides a strong incentive for energy companies to triage a short list of candidate sites, which have the lowest risk of failure. This results in deployment only in the least-challenging rural locations.

OTHER CONSTRAINTS TO PERMITTED DEVELOPMENT RIGHTS

Installing ASHPs using PD rights is seen by energy providers as essential for allowing large scale uptake of ASHPs, as the cost and perceived complexity of submitting a planning application is often a major obstacle for homeowners. However, the PD restrictions are a significant factor likely to be reducing the success of candidate sites.

It is understood that the purpose of the minimum distance of 3 m to the property boundary included in the PD restrictions is a secondary precaution, or 'safety net', to provide a buffer zone as a form of noise mitigation. However, it presents a significant obstacle to the deployment of ASHPs in more densely populated areas, especially those dominated by building types such as terrace housing and flats. One energy provider shared in the interview that they do not currently consider deployment in Wales at all because of the minimum distance of 3 m to the property boundary. The minimum distance to the property boundary is likely to be an unnecessary constraint if the MSC 020 "pass" threshold for noise is achieved.

Whilst simplicity is preferred it is understood that this distance constraint doubles as a noise constraint, but would be better represented simply as a noise constraint (a noise limit on an adjacent garden, for example, if that is the concern), rather than an arbitrary distance constraint and the MCS 020 noise assessment. Alternatively an unscreened distance to a window or garden may be a more relevant option than the nearest boundary. If the ASHP units are quiet enough (or additional mitigation added to address the noise pollution potential that is generated) then a minimum distance is not needed, except to provide sufficient space around the unit, as described by the manufacturer.

In addition, the geometric, volumetric constraint imposed by PD of the ASHP outdoor compressor unit may inhibit the development of quieter ASHPs as it is generally necessary to make units larger to incorporate noise control measures to reduce the noise output or change the character of the sound. The indication of energy providers is that the existing volumetric constraint in Wales (1 m^3) does not overly limit the selection of quiet units, whereas the tighter restriction applied in England (0.6 m^3) results in some of the quietest units having to be excluded for installation with PD.

Preventing installation on flat roofs and on walls and facades facing highways, where the visual impact appears to be the main concern, overrides the opportunity to locate a unit in an optimal location for noise control purposes and is therefore also potential overly prohibitive. The majority of Local Authority planners that were interviewed did not agree that these requirements should be amended, suggesting that visual impact is more of a concern than noise impact, whilst their colleagues in Environmental Health favoured a more pragmatic approach. This difference of priority needs strategic direction to consider a compromise on a country-wide scale, and PD can help to facilitate this change by striking a balance between protecting amenity and visual impact, but allowing ASHPs to be installed in large enough numbers to make a significant contribution to the decarbonisation aims of the Welsh Government.

The Heat Pump Association (HPA) considers that noise is currently a major factor driving design of ASHPs, and believes that most manufacturers are developing quieter units. A lot of work has been done, both in the UK and throughout Europe, to qualify and quantify the noise issues with ASHPs; much can be taken from this prior work without reinventing or repeating it.

The immediate distinct opportunities to reduce noise as a conflict to the uptake of ASHPs have been identified in Phase 1, for further exploration in Phase 2, with the exploration of possible changes to the MCS 020 calculation methodology postponed to the UK Government project 'Review of Air Source Heat Pumps Noise emissions and Local Authority Guidance'.

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1. INTRODUCTION

1.1. SCOPE

The terms of reference indicate that this project seeks to:

- “briefly address our assumption that noise is the primary environmental or nuisance concern associated with ASHPs, hence it being the central factor of ASHP placement outside domestic properties,
- review the evidence of noise pollution for domestic scale ASHPs, and
- suggest specifications for
 - ASHP noise and vibration outputs;
 - ASHP build quality; and
 - installation details at domestic premises including location within properties which would simplify the permitted development rights and enable ASHP units to be placed closer to property boundaries.

The outputs of this project should provide evidence on the impact of ASHPs on neighbouring properties. This will enable Welsh Government to review permitted development rights to assess the need to apply for planning permission within the context of seeking to increase the uptake of ASHPs within Wales”.

It is recognised that Phase 1 of the work is restricted to focusing on considering whether noise is the central factor affecting ASHP placement outside domestic properties, and reviewing the evidence associated with noise as an environmental pollutant and or potential cause of nuisance (taken to assume its common law meaning).

1.2. METHODS

1.2.1. WP1: Review of IEA HPT Annex 51

A summary of the information contained in over 600 pages of the full Annex 51 (2) reports is provided in Appendix 2, where the sections most relevant and useful to this project are extracted. Within the Annex 51 documentation, there is a 2-page summary and an umbrella report of 51 pages, but there is much useful information in the detailed reports. As well as the fundamental issues of noise sources, Annex 51 provides an overview of how noise is treated across Europe, how the sound power level test is defined for energy related product (ErP) labelling, and how the source sound characterisation and assessment of the noise impact may be improved. Signposting is provided to other European countries that have gone much further than Wales or the UK in making information about noise available and accessible.

In a recent presentation to the UK’s Institute of Acoustics (IOA) Noise and Vibration Engineering Group, the plans to follow on from Annex 51 were set out, which will build on the work of Annex 51 in a project known as Annex 63 ‘Placement Impact on Heat Pump Acoustics’. Work on Annex 63 started in January 2023 and it is planned to commence formally in May 2023 for three years. Annex 63 is due to include work on optimal placement as a combination of energy efficiency

and a greater consideration on psychoacoustics¹. A follow-up interview with the representative of Annex 63 will be completed as part of the Phase 2 work.

1.2.2. WP2: Literature Review

The literature review was undertaken by first searching Google Scholar for the term “ASHP noise” to identify some relevant papers that reference noise issues with domestic ASHPs, and residents’ attitudes towards noise from ASHPs. For the most relevant papers since 2008, a search of papers that referenced those papers was made. The references and papers referencing those papers were reviewed for comments on noise and ASHPs. In general in the literature, noise is mentioned in a wide variety of papers, but there were no papers identified that focus primarily on noise from ASHPs.

1.2.3. WP3: Interviews with Manufacturers

We used our contacts with some manufacturers to arrange interviews, while for others we called the telephone numbers on their website, or filled in web forms requesting an interview. In most cases we were able to establish contact with an appropriate person, such as the UK product manager for ASHPs, the technical manager, or other similar role. The term “manufacturer” has been interpreted broadly to include those companies supplying products and services to the ASHP industry, such as noise barriers and laboratory testing services, as well as original equipment manufacturer (OEM) suppliers.

Some people inevitably put their company marketing spin into the discussions, while others were more candid in talking about industry issues and differences of approach. All interviews were conducted by teleconference, and the notes are included in Appendix 3 (Confidential); all sources are anonymised in the main body of this document for GDPR purposes, but all references are traceable through to original sources.

1.2.4. WP4: Interviews with Associations, MCS and Energy Suppliers

We used our contacts within the Microgeneration Certification Scheme (MCS) and made contact with the Heat Pump Association (HPA) and arranged online video interviews through introductions to key energy suppliers. We used an interview script as a guide to direct consistent questioning to provide a consistent framework. The responses were captured in written records and have been summarised in the relevant work packages.

1.2.5. WP5: Interviews with Professional Bodies and Local Authorities

With an introductory letter from Welsh Government to Welsh Local Authorities we arranged interviews with environmental health representatives and, where it was found to be feasible, planning representatives. Interviews were conducted online as video interviews using an interview script as a guide to direct consistent questioning.

¹ Website for the IEA collaboration can be found at: www.heatpumpingtechnologies.org/annex63

1.3. FINDINGS

1.3.1. WP1: Review of IEA Annex 51

Appendix 2 provides a review of the International Energy Agency (IEA) Heat Pumping Technologies (HPT) Annex 51 'Acoustic Emissions of Heat Pumps' (2). Six countries collaborated (Sweden, Denmark, France, Germany, Austria, and Italy) to share information and find ways to improve the acceptability of ASHPs.

As an overview of the information, the programme was provided across seven deliverables, although in many cases there is more than one report for each deliverable. The reports can be found on the Annex 51 website².

1.3.2. WP2: Literature Review

No literature has been identified that primarily addresses the correlation between assessment methods and outcomes (i.e. acceptance or annoyance) specifically of noise from ASHPs. A range of papers has been produced as a result of work undertaken for Annex 51, but these are not repeated here (as the information is already reviewed as part of WP1). Other data provided in Appendix 3 (Confidential) includes information on other countries' approach to the assessment, and technical notes and references regarding the assessment of tonality. Overall, the literature indicates that members of the public do have concerns about noise from ASHPs.

A section of the literature that has not been systematically investigated, as it was not included in the original scope, is the portrayal of noise from ASHPs in the mainstream and social media. Anecdotally, there are frequently reports in mainstream media about ASHPs and noise, as well as discussions on social media³.

It is strongly recommended that the Welsh and UK governments carefully consider the narrative they use and promote around ASHPs. In Austria, for example, alternative systems to ASHPs (such as district heating schemes) use the fact that they are quiet as part of their marketing strategy. This perhaps explains why there is a wide range of thresholds, from the low threshold providing strict controls to the higher and more permissive threshold of some adverse noise impact occurring. It is clear that the public do have concerns about noise, and these concerns can be reasonable.

1.3.3. WP3: Manufacturers

The interviews with manufacturers are provided in full in Appendix 3 (Confidential Section).

None of the six manufacturers interviewed claimed to have received complaints regarding noise from ASHPs, noting that these would tend to go to the installer rather than the manufacturer. The

² <https://heatpumpingtechnologies.org/annex51/>

³ E.g. <https://forums.moneysavingexpert.com/discussion/4357449/air-source-heat-pumps-noise-nuisance-for-neighbours>

HPA was also interviewed, which provided an overview from the perspective of manufacturers and installers.

Manufacturers are keen to advise that reducing noise emission from ASHPs is a priority for them, and many manufacturers have low noise products. However, there is a balance to be struck between the size of a unit and its noise level, with quieter units often being larger due to additional sound insulation. In addition, some elements of some units, such as pumps, flow switches and user interface, can be installed inside the property ('split systems'). However, the compressor, which is typically the noisiest element of an ASHP, along with the fan, remains outside.

Manufacturers highlighted that the energy-related product (ErP) label requirements changed in 2019, now allowing manufacturers to show the sound power level with a partial load on the ASHP. As this is quieter than the sound power level of a unit operating at full capacity, almost all manufacturers use this to their commercial advantage, which makes the comparison of ASHP harder as it is not always clear how different loadings will affect the sound power level.

More than one manufacturer advised that there should be a requirement for the sound power level during standard load, or a specific capacity, to be used to enable clearer comparison of the noise emission from different units. Any tonality in the acoustic character of the ASHPs should also be identified, although the authors of this report are aware that, technically, tonality is highly influenced by the ambient noise environment in which the ASHP is installed. It is therefore not possible to do this without some consideration of the acoustic environment it is being located in, which is done as part of a BS 4142 assessment.

Another key consideration raised by manufacturers is that installers are more likely to misunderstand the calculation process if the MCS 020 calculation is too complicated, therefore it is essential that the MCS 020 standard is straight-forward, but also robust. One manufacturer has created an online calculation tool for installers to use, and several countries provide a tool that is in the public domain. One manufacturer also commented that a database including ASHPs models and suitable distances to boundaries or windows of habitable rooms with and without a barrier would be useful.

1.3.4. WP4: Industry Bodies & Energy Providers

The MCS, IOA and CIEH were contacted and the MCS was interviewed. The IOA and CIEH co-operated by encouraging their members to complete the IOA ASHP survey. Three energy providers were also interviewed, referred to here as Provider A, B and C.

Provider A does not currently install ASHPs in Wales as their calculation procedures are set up for the English requirements, which indicates that if the requirements were consistent throughout the UK there may be more installation options for homeowners wanting to install an ASHP. Whilst they currently only install ASHPs in England, the views are still considered valuable for informing the discussion regarding noise from ASHPs.

The representatives from Provider A advised that the main constraint for installing ASHPs using PD rights is the requirement for a minimum distance to the boundary of the curtilage of the property. This was confirmed by Providers B and C with C saying it was the biggest block to deployment of ASHP under PD, forcing units to be located in the middle of some gardens. They identified this as one of the reasons sites are aborted as not currently suitable. The representatives from all providers queried why a minimum distance is required if it could be

proven that noise levels to neighbouring residents were acceptable. Provider C said they would not install closer than 1.5 m to a boundary at the front of a dwelling to prevent malicious damage risks.

They also queried why the size of the ASHP unit is an issue as larger units can be quieter, and manufacturers are “currently struggling to make well-performing units that meet the size requirements”. They suggested that the visual impact could be addressed in other ways. Provider C felt that the volumetric requirement was reasonable and would allow the quieter units it has available to be installed, and considers a maximum size of 1 m³ to prevent commercial scale of units.

It became clear during the discussion with Provider A that whilst they had not received any noise complaints, noise and the requirement of a minimum distance to the boundary, and resulting constraint on installation location, are currently the major reasons for rejecting installation of an ASHP at a property. Provider A completed a Royal Institution of Chartered Surveyors (RICS) Surveyor assessment at each site at their own risk, with abortive sites costing them financially, which caused a disincentive to consider sites likely to have a higher risk of not being viable, according to the PD requirements and MCS 020 noise calculation.

The representatives of Provider A and Provider C included a noise lead and a commercial lead, who advised that they do not install an ASHP if a planning application is required, because the planning application process is too costly and time-consuming for customers to undertake. Furthermore, Provider A only installs ASHPs using the MCS 020 as that is the only procedure for gaining a Boiler Upgrade Scheme (BUS) voucher with one preferred manufacturer. Provider C had a wider range of units available from different manufacturers, and was aware that some housing developers have begun installing ASHP on pitched roofs/ inside roof spaces.

1.3.5. WP5: Local Authorities

Detailed results are provided in Appendix 3 (Confidential) with a summary provided in Table 1 and Table 2. Care must be taken if extrapolating Planning Officer responses due to the small sample size of Planning Officers interviewed; it cannot be assumed that the small sample size is representative of the profession. Interviews with additional Planning Officers would provide a more reliable sample.

Table 1: Summary of Responses from Local Authority Interviews on PD Restrictions

Would you suggest a change to the condition that an ASHP cannot be installed as Permitted Development if:	Percentage of Respondents Responding Yes	
	Environmental Health/ Protection	Planning Officers
It would result in the presence of more than one air source heat pump on the dwellinghouse or within the curtilage of the dwellinghouse	42%	0%
A standalone wind turbine is installed within the curtilage of the dwellinghouse	42%	0%

Would you suggest a change to the condition that an ASHP cannot be installed as Permitted Development if:	Percentage of Respondents Responding Yes	
	Environmental Health/Protection	Planning Officers
The volume of the air source heat pump's outdoor compressor unit (including any housing) would exceed one cubic metre	33%	0%
Any part of the air source heat pump would be installed within three metres of the boundary of the curtilage of the dwellinghouse	58%	75%
The air source heat pump would be installed on a pitched roof	8%	0%
The air source heat pump would be installed on a flat roof where it would be sited within one metre of the external edge of that roof	8%	0%
The air source heat pump would be installed within the curtilage of the dwellinghouse if the dwellinghouse is a listed building	33%	0%
The air source heat pump would be installed on a site designated as a scheduled monument	33%	0%
The air source heat pump would be installed on a wall or roof which fronts a highway	33%	0%

Table 2: Summary of Responses from Local Authority Interviews on Additional PD Requirements

Do you agree with the requirement that the ASHP must have a minimal effect on the:	Percentage of Respondents Responding No	
	Environmental Health/Protection	Planning Officers
External appearance of the building	17%	100%
Wider amenity of the area	9%	100%

A common concern of Environmental Health/Protection personnel was the consideration of cumulative effects of multiple noise sources. Where Environmental Health/Protection personnel did not indicate that they would suggest a change it was typically because they considered the condition to be a visual impact planning consideration, not a protection of amenity issue from noise, therefore many of the interviewees chose not to comment on these questions.

Another common comment was that whilst there haven't been many complaints regarding noise from domestic ASHPs yet, many Environmental Health/Protection personnel foresee a sharp increase in the number of ASHPs being installed in the near future and they are therefore concerned that the number of complaints will also increase as a result and require formal investigation as a Statutory Nuisance.

Whereas many of the Environmental Health/Protection personnel would suggest a change to the PD conditions, the Planning Officers were more reluctant to reduce the current restrictions; the only restriction they would suggest a change to is the restriction that an ASHP cannot be installed using PD rights if it would be within 3 m of the boundary of the property. The Planning Officers suggested that this could be reduced if the noise impact could be demonstrated to be acceptable. The majority of the Planning Officers suggested that the visual impact on the appearance of the public realm was a key consideration for them and should not be changed.

Planning Officers from Local Authority 'L' would like the scope of the PD rights to extend to include no ASHPs within conservation areas, and no ASHPs on any roof, the latter sentiment also repeated by several other Planning Officers and Environmental Health/Protection personnel. Several Local Authority representatives stated that the requirement that the ASHP should have a minimal effect on the wider amenity of an area is too vague: what counts as a "minimal effect" and what is included in the "wider amenity"? Furthermore, several Local Authority representatives raised concerns about the assumptions made in the MCS 020 calculation about the background noise level, generally agreed to be an inaccurate assumption in many parts of their areas.

They also expressed concern over increase in resourcing demands for Environmental Health/Pollution departments that may result if a larger number of ASHP planning queries are received and if the number of complaints requiring enforcement action increases if the MCS assessment was not adequate, particularly as PD cannot require people to service and maintain their ASHPs.

2. DISCUSSION

2.1. PERMITTED DEVELOPMENT RIGHTS

Permitted Development (PD) rights rely on the use of the MCS Planning Standards, which include MCS 020 (1). According to [planningportal.co.uk](https://www.planningportal.co.uk) (3):

“The Microgeneration Certification Scheme includes clear standards to support the installation of wind turbines and air source heat pumps. The main purpose of the scheme is to build consumer confidence in microgeneration technologies.

The scheme includes certification for products and installer companies. One of the limits of permitted development rights for wind turbines and air source heat pumps is that equipment must be installed by an installer who has been certificated through the scheme using a certificated product.”

It is understood that most installations of domestic ASHPs rely on government grant incentives, currently the Boiler Upgrade Scheme (BUS) in England and Wales offering £5,000 towards an air source heat pump. This funding is tied to the use of MCS 020, therefore any PD rights that were to deviate from the MCS 020 would need an alternative route to achieve eligibility with MCS 020. Therefore, PD and any update to the MCS 020 assessment are locked into the qualification of the grant. Therefore, any update to MCS or PD need to be carefully co-ordinated.

As described above, there are at least three levels of certification for an installation to take place in compliance with these standards:

- 1) The installer must be certified (the grant is installer-led, i.e. the installer or the energy provider instructing the installation applies for the grant);
- 2) The product must be certified; and
- 3) The noise impact must be in compliance with the certified standard.

Hence the practical question of whether the noise constraints in PD rights excessively constrain ASHP installations becomes:

Are the noise standards in MCS 020 assessment appropriate to adequately protect residential amenity and quality of life without being excessively prudent?

If the standards are too permissive, there is a potential for adverse impacts of noise, or detriment to the quality of the soundscape in a locality. For example, the potential for sleep disturbance to materially affect the quality of life of residents, is a serious risk to health and wellbeing which the limited complaints evidence indicates could be a possible outcome.

If standards are too restrictive, however, it results in the unnecessary additional cost of more detailed acoustic assessments by professionals and administrative effort of the homeowner to apply for full planning permission, which is seen by energy providers as an obstacle to the large-scale uptake of ASHPs. There are also serious risks associated with failure to mitigate climate change.

An appropriate balance is therefore required between these potential adverse outcomes, which becomes a political decision, which may also have regard for the national interest. In other

countries such as Austria that are ahead of Wales in the roll-out of ASHPs, they are widely regarded as “the noisy technology”⁴, compared with district heating systems, for example. The significance of public perception of the sound of ASHPs is very important to note here. In many southern European countries, for example, the sound of domestic heat pumps providing cooling is widely accepted as a pervasive soundscape.

This Phase 1 report provides the background evidence and context for this debate to take place and a decision to be made, based on the literature review and discussions with manufacturers, associations, professional bodies, Local Authorities and energy suppliers. This allows an evidenced based approach to inform decision making and policy.

However, one criticism of the current system is that the noise standard in MCS 020 is still too complex and not easy to understand or get right for installers, who are not acousticians. It is felt likely on the strength of our findings from Local Authorities that currently the assessment is not reliably or consistently being applied in such a way that helps understanding of how satisfactory compliance relating to adverse impact from noise can be achieved. A review and potential reform of the MCS 020 assessment method is therefore advised for consideration. MCS indicated in their interview that they keep guidance under review and would be open to consider this if required to.

2.2. MCS 020 STANDARD

The full process of the MCS 020 calculation is shown in Appendix 1.

Despite its potentially far-reaching implications, the noise assessment in MCS 020 is described in a perfunctory manner: while it is intended to be simple to follow, its brevity leaves a variety of ambiguities, and it includes entirely unnecessary steps, such as the inclusion of an arbitrary background sound level for setting ASHP source noise levels.

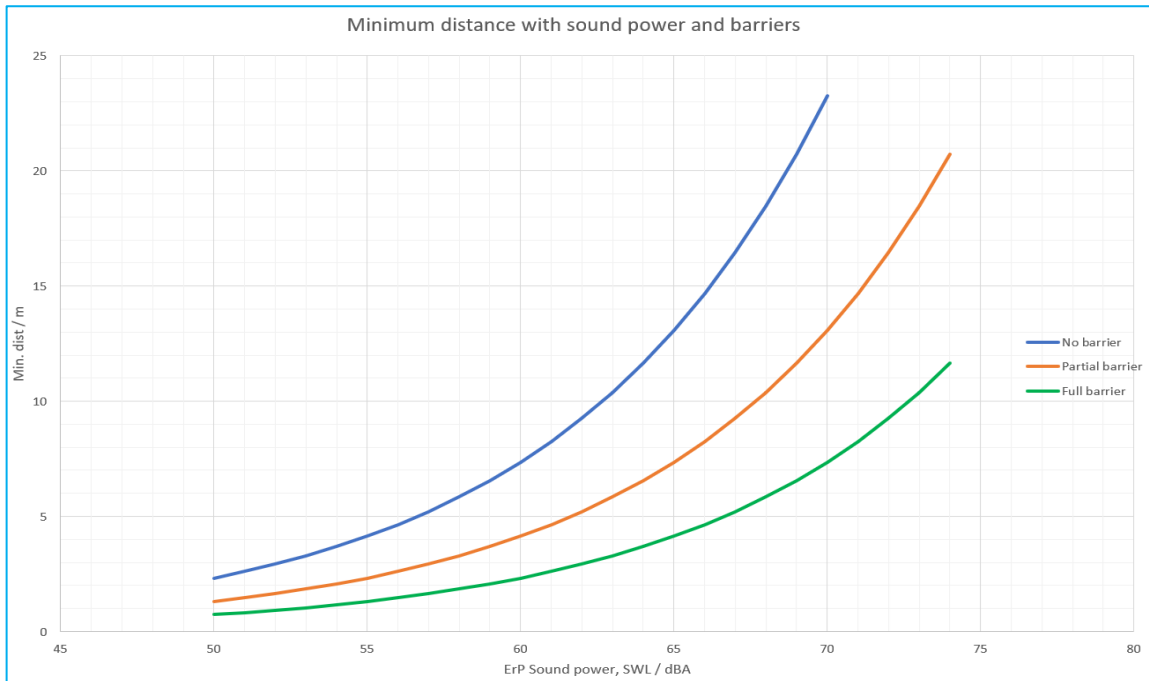
The methodology can more simply be represented with a single graph, as illustrated visually in Figure 1 overleaf.

The blue line shows the noise constraint as a distance on the y-axis, based on the sound power plotted on the x-axis, where there is a direct line of sight between the ASHP and the receptor location.

The orange line shows the same where there is a barrier that partially obscures the line of sight (see Step 5 in the MCS 020 Appendix 1), and the green line where the barrier completely obscures the line of sight.

⁴ Christoph Reichl, Annex 51 comment during meeting dated 6th March 2023.

Figure 1: The MCS 020 noise constraints where $Q = 4$, i.e. installed on the ground against a wall



2.3. MANUFACTURERS' SOUND POWER DATA

All ASHPs installed under the MCS must be certified, and the list is publicly available on the [MCS website](#).

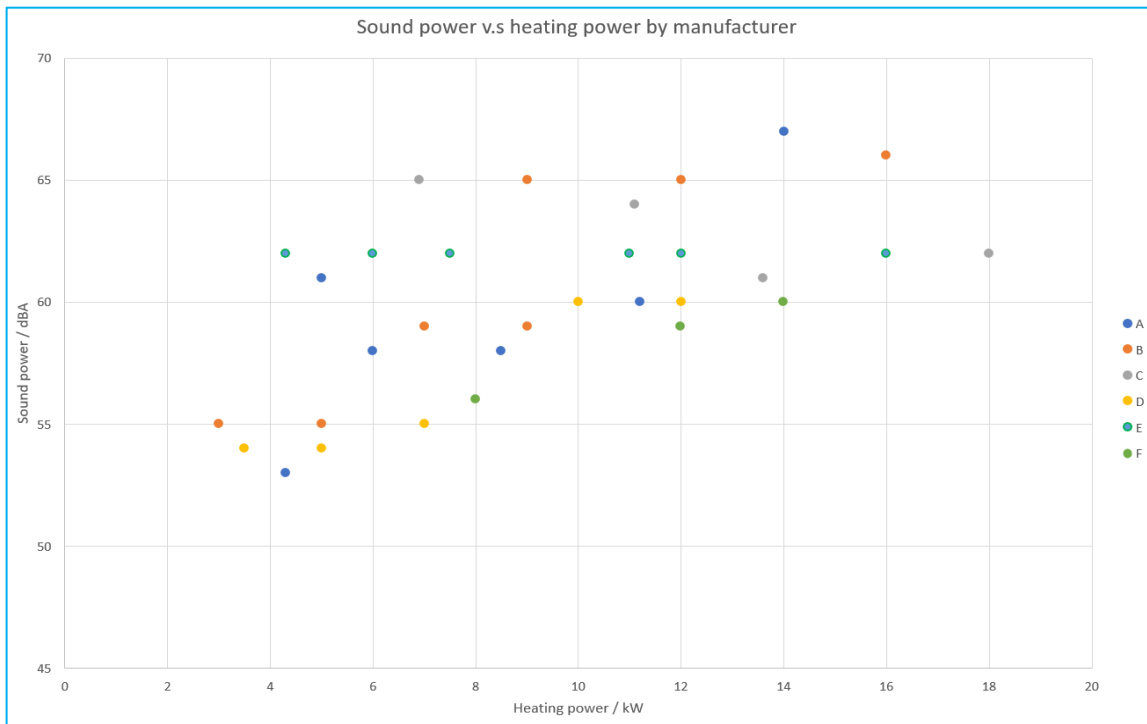
The product directory indicates that there are currently 1,772 ASHPs that are certified, at the time of writing. On the website, the seasonal coefficient of performance (SCOP) is listed, but the sound power rating is not.

Through interviews with the UK product or technical managers for ASHP manufacturers, the relevant manufacturer's literature has been identified, as discussed throughout WP3 in Appendix 3 (Confidential).

It is frequently difficult for professionals to identify which ASHP is the most appropriate product, and then find the corresponding sound data in the manufacturer's literature, therefore it is practically impossible for a homeowner to go through this process themselves with confidence that they are using the appropriate data and will not cause themselves or their neighbours an adverse impact from noise. This perhaps explains the focus on noise as a key question that exists from the initial moment a site is considered by either an installer or persons instructing a surveyor or by the occupier themselves.

The relevant sound power levels and associated heat outputs illustrated in Figure 2 have been recorded for the five most popular manufacturers in the MCS MID, along with one other that is also represented on the Quiet Mark scheme.

Figure 2: Sound power level compared with heating power for the most popular brands installed under the MCS, and an additional Quiet Mark certified range.



See notes of the discussion with Quiet Mark in Appendix 3, WP3, Ref I (Confidential) as to how the Quiet Mark assessment is carried out. Appendix 3 (Confidential) also provides manufacturer’s data references.

It can be seen from Figure 2 that the range of sound power levels for any given heat requirement is up to 10dB at around 7kW heating power from different manufacturers. It is noted that there appears to be a reduction of this range by approximately 5dB in the 10 to 12kW region, which may be worth exploring this apparent closer agreement in noise level produced.

Taking ranges of heat output, these can be plotted on the sound power v distance chart, as illustrated in Figure 3 overleaf.

Figure 3: The typical sound power level range of ASHPs in different heat output categories

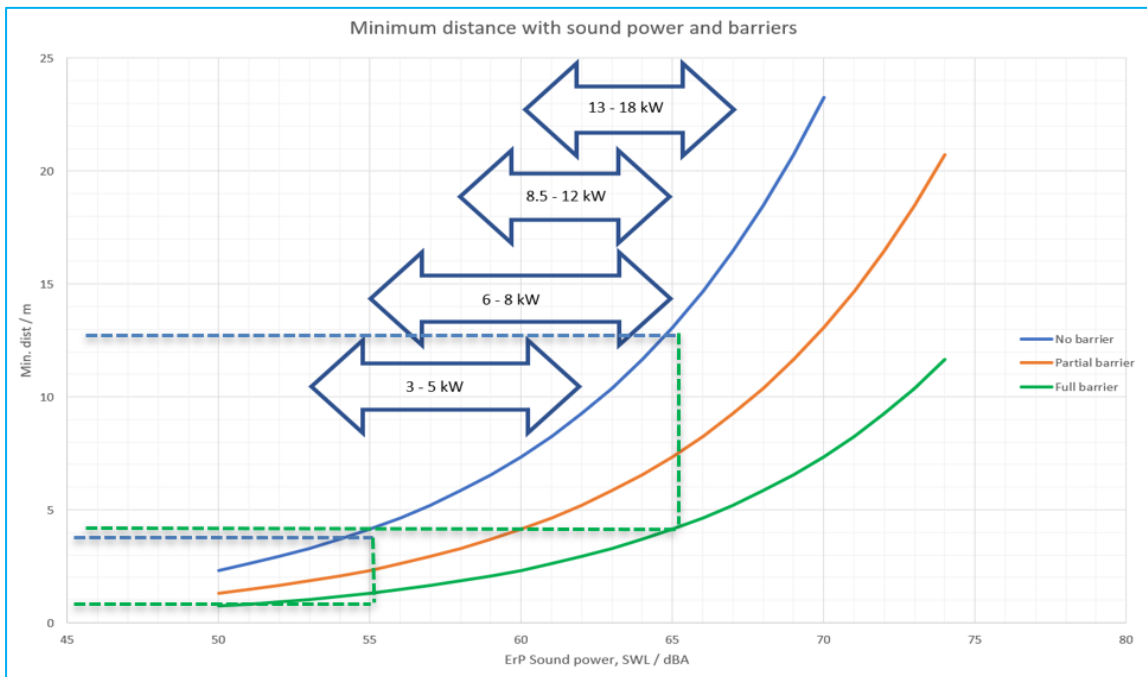


Figure 3 illustrates, for example, that if you need an ASHP in the 6 kW - 8 kW range and will install on the ground against a wall, it will need to be between 4 m and 13 m from the nearest assessment point with no barrier in between, depending on the manufacturer and model selected. Similarly, if a full barrier can be included as mitigation measures, those distances are between just over 1 m and 4 m.

This overview of potential products that may be acoustically suitable with certain installation details is not available to either homeowners or installers, some brands have a reputation for being “quiet”, whether backed by evidence accurately or not. Generally, plumbers, for example, have brands of boilers that they prefer to work with, or have incentives to use. They therefore become familiar with that brand’s literature and components [Appendix 3, WP3, Ref G (Confidential)]; it is not known from this work package how many ASHP installers similarly install one brand of ASHP, but it is known that one energy provider only uses one manufacturer whilst another prefers a range, based on commercial incentives.

For design purposes, the information illustrated in Figure 3 could be made available and presented in a format that would enable homeowners or installers to determine where they could install an ASHP that complies with the MCS 020 as it currently is, and which machines are acoustically “feasible” on that site. See Section 3 of this report for more details on opportunities.

2.4. UNDERSTANDING NOISE ISSUES WITH ASHPS

Within and beyond the application of MCS 020, the noise issues with ASHPs can be considered in three distinct areas:

- Source noise characterisation;
- Noise transmission; and
- Noise impact and assessment at receptor (whether the occupier or neighbour).

The market appears to be dominated by global heat pump manufacturers, who design and supply for the European market and climate, varied as it is. However, there appear to also be a range of UK companies that traditionally made fossil fuel boilers, who have recently entered the ASHP market with new products.

2.4.1. Source Noise Characterisation

The characterisation of the sound from ASHPs is essential to understand its potential impact. The standards for laboratory testing of heat pumps (detailed in Appendix 3, WP3, Ref H - Confidential), include:

- BS EN 12102-2 (4), specifies methods for testing the sound power level of air/water, brine/water, water/water and direct exchange/water heat pump water heaters and heat pump combination heaters with electrically driven compressors and connected to or including a domestic hot water storage tank for domestic hot water production.
- BS EN 14511-3 (5), describes the test conditions, and refers to the ISO 3740 series (6) (laboratory tests), or ISO 9614 (7) (sound intensity method) for the acoustic tests.

All manufacturers spoken to use the ISO 3740 series laboratory tests, although we believe some manufacturers are using the sound intensity method. The results are likely to differ, but we only have anecdotal evidence for how much this difference may be.

- BS EN 14825 (8), specifies the temperatures, part load conditions and the calculation methods for the determination of seasonal energy efficiency, seasonal space cooling energy efficiency, seasonal coefficient of performance, seasonal space heating energy efficiency and seasonal energy performance ratio. There are a wide range of different thermal conditions (24 different tables depending on the application).

One manufacturer (Appendix 3, WP3, Ref B - Confidential) suggests that the environmental conditions are ambiguously defined, for example, a heat pump can be classified as Low Temperature (water output temperature 35°C), Medium Temperature (55°C) or High Temperature (65°C). The compressor and fan speeds would differ if providing water at different temperatures. An ASHP that is capable of delivering water at 65°C or above can also be classified as a “Medium Temperature”, and tested as such, meaning that classifications can occur which may be misleading in terms of the noise produced under these conditions.

In order to be compliant with the regulations, the manufacturer declared results must be within 2 dB of independent laboratory tested results where tests are carried out for audit or market surveillance purposes.

Laboratories are unable to comment how many heat pumps have passed or failed market surveillance testing, due to their confidentiality constraints. Market surveillance testing is a more common phenomenon in Europe than the UK, according to those interviewed [Appendix 3, WP3, Ref B - Confidential].

There are at least three acoustic test points for an ASHP when using air at 7°C, water flow temp of 55°C (A7/W55):

- Full load;
- Quiet mode,
- ErP labelling.

The power output delivered varies for each test, as do the fan and compressor speeds.

The Quiet or Quietest modes simply limit the compressor and fan speeds that the machine will run at. [Appendix 3, WP3, Ref E - Confidential].

The ErP labelling sound power is based on operation at 38% load.

While the MCS 020 indicates that the “highest sound power level” should be used, some manufacturers (e.g. Appendix 3, WP3, Ref B - Confidential) believe that other manufacturers provide the ErP label performance, which may be 3 dB or 6 dB lower, for example, because this is the only sound test point that must be published.

This is one area where the MCS 020 could be more explicit. The German approach (see Appendix 3, WP2 - Confidential) is based on the highest full-load sound power during the daytime, but permits low-noise or quiet mode operation during the night-time.

The defrost cycle is automatically controlled after frosting occurs, which is a function of the environmental conditions (air temperature and humidity), and heating load of the ASHP (see Appendix 1). There is therefore no regular time period between defrosting cycles, and the standards do not include measurement of the sound levels during the defrost cycle. Tests carried out (Appendix 1) reveal that there is a variety of sounds, e.g. valves opening and closing, pressure being released, that may attract additional attention, while the overall continuous equivalent sound level ($L_{Aeq,T}$) is much lower than during normal operation for the machines tested. There is currently no industry-standard characterisation of sound from the defrost cycle.

Annex 51 (2) describes how the sound power level varies with the load as well as the external air temperature and water supply temperature (see Appendix 2).

A ‘seasonal sound power level’ characteristic is proposed, which is based on a weighted average of the sound power level at different temperatures in the same way that the Seasonal Coefficient of Performance (SCOP) describes an annual-average thermal efficiency. There is no evidence presented that this may align better with resident’s response to the sound from ASHPs, although it would appear to be a more logical and representative approach of the continuous equivalent sound level ($L_{Aeq,T}$) sound emissions.

Even those models that receive a Quiet Mark certification are only assessed on an overall A-weighted continuous equivalent sound level performance (See Appendix 3, WP3 Ref I - Confidential), despite Quiet Mark assessing the sound quality beyond the dB rating of products (9), but not publishing dB levels. Units achieving Quiet Mark certification are listed on the Quiet Mark website, and several of these are included in the manufacturers' data presented above.

There are no established laboratory tests for tonality.

The German assessment methodology for ASHPs (10) includes a penalty for tonality and intermittency, as does BS 4142 (11), which also refers to DIN 45681 for the measurement of the tonal penalty, as well as a database of ASHPs with their rated sound power levels, and any tonal penalty.

However, the DIN 45681 and the objective method in BS 4142 rely on comparing the prominence of tones with the level of noise in adjacent frequency bands (see Appendix 2), therefore it is not meaningful to characterise a source of sound as tonal in this way as the judgement can only be made with the specific sound in the context of an ambient noise environment. This is a technical issue that requires further work at a standards level. The implication of requiring manufacturers to carry out an additional test is very significant, and unlikely to be something that could be achieved in short timescales.

The round robin laboratory tests carried out (see Appendix 2.4) revealed a range of around 3 dB in the results between all the laboratories. There is also commentary that suggests that not all laboratories were able to correctly control the thermal conditions for the sound tests. According to one manufacturer (Appendix 3, WP3, Ref B – Confidential), the laboratory test requires overriding the normal control system in the ASHP, to force it to operate thermally as required in the standards for the sound test. The risk of accusations of falsifying or providing misleading data is an apparent risk they identified.

Overall, there are many reasons why the sound emitted from an ASHP at any particular time may differ significantly from the ErP certified sound level, and an in-situ test could also only capture a limited range of operating scenarios, and conditions will never be exactly the same as those during the test. Further work to understand the relationship between in-situ sound impacts (including effects of modulating thermal output and noise levels, tonality, roughness, defrosting cycle sounds) and the current or a future laboratory characterisation of the sound emissions seems essential, although this would be a large project, and was not tackled in Annex 51, for example. It may only be partially tackled by the plans for Annex 63, which is at least 3 years away from reporting.

One aspect of annoyance was examined in laboratory psychoacoustic tests [see Appendix 2, 2.13] using 5 second sound samples normalised to the same A-weighted continuous equivalent sound level from an ASHP running at different set points, with the sound emissions measured at defined distances over a hemispherical surface in different directions. These tests revealed that the single descriptor most closely associated with predicting annoyance was the peak roughness of the sound (i.e. the perception of rapid amplitude modulation of a sound); inevitably, using more descriptors reduced the uncertainty in predictions. The level of detail required to make measurements of a source in this way, in different directions in an anechoic chamber, reveals a little of the potential complexities of treating sources in this way.

2.4.2. Noise Transmission

The MCS 020 has two factors in the calculation of noise transmission from source to receptor location, through characterisation of:

- The number of reflecting surfaces around the heat pump; and
- The extent of a barrier/screening between the heat pump and receptor location.

There is currently work underway (see Appendix 3, WP3, Ref J - Confidential) to determine how effective sound absorbent noise barriers may reduce the transmission of noise to receptor. This work compares more detailed noise transmission models with field measurements to evaluate the uncertainties associated with different approaches. Inevitably, simpler approaches will lead to more uncertainty, but the technical effort required to undertake more sophisticated calculations of noise transmission compared with the simple model used in MCS 020 is significantly greater, and only available to acoustic consultants.

There is a publicly available online calculator (12) published by the German Heat Pump Association (see Appendix 2) to determine if an ASHP will comply with the noise regulations. There is a similar calculator in Danish (13), which can be translated in the browser window.

2.4.3. Noise Impact and Assessment

MCS 020 permits a rated total sound pressure level from the unit of 37.7 dBA at the nearest receptor location, which is a point 1 m in front of a door or window of a habitable room of another property.

Many European countries have a noise limit of 35 dB at night (see Appendix 2, but higher limits in the daytime). MCS 020 does not permit distinguishing between daytime and possible set-back to quiet mode during the night-time. This is also proposed by the CIEH and IOA joint guidance and alternative calculation to the MCS 020, which assumes a penalty on the MCS 020 for sound character (20).

Although it is normal across Europe to use absolute thresholds for noise impact, the usual approach used in the UK is to use a threshold relative to the prevailing background sound level, typically using the methodology within BS 4142 (11), which has developed since 1967 into a mature and objective way to assess noise from fixed plant. While the application of BS 4142 enables penalties to be attributed to the specific noise level for sound character, there is in fact almost no possibility to do this as there is currently no objective data on the tonality of ASHPs without completing measurements in the field (as discussed in Appendix 2).

Ideally, the method of rating the impact from noise would correlate with the annoyance of this sound as experienced by people, in context. This has meaning when considering the soundscape and the impact upon it. As discussed in Section 2.4.1, when the overall A-weighted equivalent sound level is equalised, the psychoacoustic indicator providing the best association with annoyance has been demonstrated to be peak roughness (see Appendix 2.13).

During the interviews, another risk was identified: creeping background and the cumulative impact of the combined noise from a large number of ASHPs installed in an area, whether all at once or over time. This consideration has also been addressed in Annex 51 (2), where some work has been carried out to consider the effects of cumulative noise. This is an area that will be further investigated in Annex 63 (14) (see Appendix 2).

2.4.4. Obstacles to Deployment

Responses provided in WP4 (Appendix 3 - Confidential) indicate that the PD restrictions and MCS 020 calculation result in ASHPs in most medium- to high-density domestic sites requiring planning applications, as demonstrated by the approach of energy suppliers who are not deploying in Wales presently (Energy Provider A is one example).

The MCS 020 creates a “pass” threshold which does not recognise the reduced noise impact of units below lowest point, i.e. lower noise units do not achieve a lower noise level at the assessment point because of the effect of assuming a background noise level of 40 dBA; if the assumed background sound level was removed, quieter units would achieve a lower calculated noise level at the assessment point, which would create at least a score that may provide an incentive for installing quieter units in areas more sensitive to noise. This was a point made by the Heat Pump Association in their interview (see Appendix 3, L – Confidential).

Noise impact to neighbours is currently a very important factor when determining suitable sites for ASHP installation, and it is currently one of the key factors driving site selection, sometimes risking the compromise of the most energy efficient location in order to meet the PD rights requirements, or forcing aborted site surveys leading to financial loss for energy providers who are funding the site surveys at risk. This discourages energy providers from taking risks to deploy ASHPs in medium- to high-density areas, where the chances of meeting the PD requirements and the MCS 020 “Pass” threshold is low.

2.4.5. Concerns from the Front Lines of Environmental Health and Planning

Evidence of complaints is low at present, but there are some examples which have resulted in formal action by Local Authorities, and these do include examples where ASHPs were alleged to have been installed using PD, using the MCS 020 check. One concern is the pressure on Local Authority resources that reviewing a large number of ASHP applications may require for a large scale roll-out of ASHPs through the standard planning route, however the risk of these becoming statutory nuisances complaints if it were to occur via PD was to occur in medium- to high-density residential areas is also a serious concern. This was particularly raised by Cardiff, in their interview, where there was also concern about setting a precedent, which could have large scale implications for residents. A precautionary approach was therefore preferred, until there is greater confidence that the MCS 020 checks are adequate.

The MCS 020 calculation does not appear to be adhered to for all installations that should have had it completed, or at least there is concern that it is leaving a gap in the protection of people from noise that would be expected if a BS 4142 (11) assessment was completed; the existing MCS 020 calculation is flawed in the view of many authorities because it assumes the same background level everywhere. This was not considered to be reflective of a situation that existed in many areas in their authorities for all of those authorities interviewed.

The implications for cumulative impacts from the installations that occur all at once or over time in medium to high density residential areas was of concern, as this could change the soundscape in the area. A strategic approach was thought to be needed but it was evident that this was thought to be difficult to achieve in practice. A preferred method is that noise control measures are included in the calculations from the beginning to minimise the risk of this cumulative impact occurring, given the lifespan of units is approximately 25 years.

3. OPPORTUNITIES FOR PHASE 2

A significant finding from Phase 1 is the pivotal role of the MCS 020 Planning Standard, which is the gateway to securing the grant funding. Energy providers therefore consider sites initially using the PD rights constraints, with the 3m rule being the most relevant to the initial selection of the candidate sites. Whether the MCS 020 “pass” threshold can be met is one of the next key checks that occurs at the triage filtering stage for candidate sites, or during the initial site survey.

Enabling widespread installation of ASHPs with PD in Wales that are not compliant with MCS 020 is unlikely to facilitate the uptake of ASHPs. Therefore, there are two routes to reduce the obstacle that noise may currently represent are:

- 1) Update MCS 020 to be a robust measure preventing adverse impact with the ability to be more permissive, if appropriate, or where mitigation measures can be applied.
- 2) Provide practical information to simplify and facilitate compliance with MCS 020.

3.1. INFORMATION TO SIMPLIFY & FACILITATE MCS 020 COMPLIANCE

3.1.1. Opportunity #1: Webpage to Identify “Noise-Compliant” ASHPs

The ‘noise test’ in MCS 020 is presented as an analysis of an installation to test compliance and minimise the risks of causing adverse noise impact. However, when considering whether an installation is viable at a particular location, a designer or commissioning body (who is likely to ultimately be the installer) has the following information:

- Potential location, hence the minimum distance to an assessment point and number of reflecting surfaces around;
- Whether there is a full barrier or partial barrier between the ASHP and assessment point; and the potential location,
- The heating power (kW) required to satisfy the heating requirements and thermal efficiency of the dwelling.

From this information, a list of the available certified appliances could be easily generated, from details submitted and held on the MCS database. This list could be sorted by thermal performance (SCOP), or by another parameter. Providing this information as a web tool would enable installers to use it easily, and give a full range of the available products. A report of the results could then be emailed to the installer and occupier, in the same way that the German Heat Pump Association provides reporting from filling in a web form. It is likely that much of the information necessary to complete this assessment is available through discussion with the homeowner and observations of online satellite imagery (e.g. GIS, OS or Google maps).

3.1.2. Opportunity #2: Template Examples of Good Practice

A series of template example solutions could be presented that illustrate typical situations and the range of ASHPs that could be adopted. Homeowners and installers can easily relate to examples in different types of location so that they can easily understand whether noise from a selected unit may constrain their desire for an installation or not. Providing the consumer with that choice, underpinned by examples informed by real case studies may assist the drive for

quieter selections. A range of the most common situations may be identified through consultation with the Welsh Government, for example, considering archetypal settlements in the following settings:

- Rural: detached, semi-detached, terraced;
- Suburban: detached, semi-detached, terraced;
- Urban: terraced, maisonettes, flats.

The list could also relate to potential updates to MCS 020 (see Section 3.2). In each setting, the dwelling archetypes could be identified, as above (although clearly archetypes are not exclusive to settings). The London Energy Transformation Initiative (LETI) Retrofit Guide (15) provides energy performance for dwelling archetypes. Similar information is provided in Deliverable 7 of Annex 51 (see Appendix 2). A 'Good Practice Guide to the location selection for ASHPs' such as this may be championed by MCS, which could be a chapter in the MCS Domestic Heat Pumps: A Best Practice Guide (16).

3.1.3. Opportunity #3: Ready Reckoner Design Charts

A simple chart can show the minimum distance to a neighbouring property, for the various installation details, e.g. partial or full barrier, against one wall or in a corner. This could be used by installers to easily and quickly identify the limit on the sound power level for a particular installation, for example; at present this information is only possible to generate by iteratively and laboriously undertaking the MCS 020 calculation. The chart could also be used by homeowners to understand if an ASHP with a particular power output would be feasible at their property.

3.2. DEVELOPMENT OF MCS 020

3.2.1. Opportunity #4: Revised Noise Limits

As discussed previously, the indication of a 'background sound level' in MCS 020 is actually a distraction that hampers presenting the benefit for having quieter units. This because a maximum absolute level of 37.7 dBA is permitted for ASHPs by the calculation, due to the assumption of the same background sound level in all areas. Other European countries adopt different noise impact limits for daytime and night-time periods, and for different types of location (e.g. the German regulations). Different noise levels could therefore be considered in urban or suburban areas for the daytime and night-time, with presumptions about the background noise climate in each classification determined statistically from the National Noise Incidence Survey (17). If the evidence indicates that it is appropriate, updating the noise impact limits could be relatively simple. However, no consensus has been reached thus far on whether this can be justified. An alternative is to remove the background assumption so that the result achieved a minimum absolute standard (currently 37.7 dBA) but allows quieter units to achieve quieter and therefore better score to which financial incentives could be attached.

3.2.2. Opportunity #5: Improved Characterisation of ASHP Sound and its Impact

It would be prudent to review the current burden of noise, as experienced by residents from ASHPs.

The IOA survey result (covered more fully in Appendix 3, WP5 - Confidential) illustrates that only half of the complaints are due to the broadband noise, and the remainder due to tonal,

modulating or intermittent noise. Although the survey represents a very small sample, it garners information from professionals and suggests that the regulation of ASHP noise by a characteristic A-weighted equivalent continuous sound level may not offer the optimum correlation with residents' response to the sound and its character. The laboratory listening tests undertaken with Annex 51 suggest that for the tested samples, the psychoacoustic peak roughness indicator is the single best descriptor associated with annoyance; all these tests were carried out at the same A-weighted equivalent continuous sound level. Re-characterisation of the source noise is a complex project that may take up to ten years to complete and requires a new model for annoyance to be widely accepted within the academic community, along with a suite of new technical standards to be written and adopted (e.g. BSi/ ISO or through guidance from organisations like the IOA and ANC). The standards would need to cover the laboratory test for characterisation (which must also include directional information), the model for sound transmission (which may require an impulse response to be calculated from a directional source) and how the impact is to be evaluated. The guidance could set out characterisation guidance for acoustics field tests, which could provide a uniform basis for case studies as an evidence base for examples. The timescale of this work is well beyond the immediate need, although the guidance could follow work on case studies that will be begun as part of Phase 2.

3.2.3. Opportunity #6: Revised sound propagation model

As noted in Annex 51 (2), the sound emitted by an ASHP may be modified if an absorbent material is placed on the wall behind the heat pump, or on two walls if it is in a corner, or if the ground is soft. ISO 9613 can be used to calculate this, but that theoretical result may be some way from the reductions achieved in reality, which can be revealed by measurement.

This type of straightforward, cost-effective mitigation intervention coincides with work currently being undertaken to investigate this effect between the University of Salford and a material supplier with an accelerated knowledge transfer programme (AKTP, see Appendix 3, Ref J - Confidential), to evaluate the effectiveness of sound absorbent barriers. This is discussed in Annex 51 (2), and could also be a relatively simple upgrade to the MCS 020 calculation process.

4. CONCLUSIONS

Work undertaken as part of Phase 1 of this project for the three work packages WP 1, 2 and 3 has been amalgamated and synthesised to portray the current issues around noise and ASHPs.

WP4 and WP5 explored the existing experiences for Associations such as the MCS and HPA and considered data from professional bodies such as CIEH and the IOA as well and directly with interviews conducted with environmental health professionals and planners from over half of Welsh Local Authorities.

Opportunities have been identified for ways in which these obstacles may be overcome and explored further in the Phase 2 work.

It is possible to conclude that the relatively low number of complaints to Local Authorities about noise from ASHPs at present is likely to be due to installations largely taking place in low density rural areas. There is however concern in many Local Authorities in Wales over how the deployment of ASHPs in more densely populated urban areas can be achieved under existing PD rights, and whether the existing MCS 020 assessment provides adequate protection from noise.

Noise from ASHPs is perceived to be a problem, and is a reason that some units are not compatible with some installation scenarios, with evidence that some sites are rejected as a result failing to meet the MCS 020 Planning Standard, which is then acting as an obstacle to large scale deployment in Wales.

Noise has also been identified by the manufacturers as a key product design driver, with the HPA recognising this trend for quieter units and considering it as important as energy efficiency as a design consideration, presenting an opportunity to accelerate this advancement in technology through incentives.

Options have been proposed that are realisable in Phase 2, and further options that would be realisable on a longer timescale are provided to improve the acceptance of ASHPs and their noise emissions.

At the outset of this work, it was not appreciated that the current financial incentives (the Boiler Upgrade Scheme) effectively tie PD to the MCS 020 in the way that it does. Some suggestions are made that include a suggestion to reform the MCS 020 assessment process, and delete the 3m rule from the PD requirements. Also to consider linking the financial incentives of the grant with how quiet a unit is, to encourage an acceleration of the trend for manufacturers to offer quieter units.

The opportunities for Phase 2 are therefore identified within the constraints of MCS 020, with updating MCS 020 the only method for removing some restrictions.

5. ACKNOWLEDGEMENTS

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6. ABBREVIATIONS

The following abbreviations are used throughout the document.

Abbreviation	Full Phrase
ASHP	Air Source Heat Pump
ANC	Association of Noise Consultants
BUS	Boiler Upgrade Scheme
CIEH	Chartered Institute of Environmental Health
dB	Decibel
EPC	Energy Performance Certificate
ErP	Energy-Related Product
GHG	Greenhouse Gas
GIS	Geographic Information System
HPA	Heat Pump Association
HPT	Heat Pumping Technologies
IEA	International Energy Agency
IOA	Institute of Acoustics
LETI	London Energy Transformation Initiative
MCS	Microgeneration Certification Scheme
MID	Microgeneration Certification Scheme Installations Database
OEM	Original Equipment Manufacturer
PD	Permitted Development
RICS	Royal Institution of Chartered Surveyors
SCOP	Seasonal Coefficient of Performance

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APPENDIX 1: MCS 020 PLANNING STANDARD

The steps in MCS 020 calculation are reproduced below, for convenience, with only those notes that clarify the text (rather than just adding description).

Instructions

- 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).

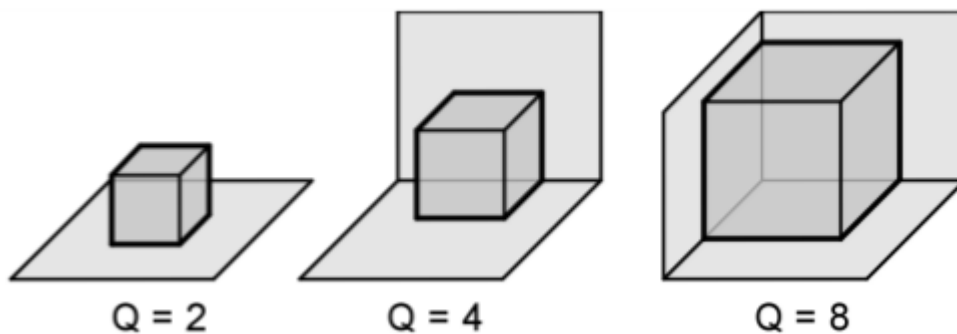
[Note 1 is purely informative]

- Use 'Note 2: Sound pressure level' and 'Note 3: Determination of directivity', below to establish the directivity 'Q' of the heat pump noise.

[Note 2 is purely informative]

NOTE 3:

The sound pressure level increases with the number of reflecting surfaces. Use the illustrations below to establish the directivity 'Q' for the installation. A reflective surface is any surface (including the ground) within 1 metre of the air source heat pump.



The following examples may be used as a guide:

Q2 = an air source heat pump with one reflecting surface (i.e. the ground or a single wall if mounted on a wall off the ground).

Q4 = an air source heat pump with two reflecting surfaces (i.e. ground mounted and against a wall or mounted off ground level against two walls)

Q8 = an air source heat pump with three reflecting surfaces (i.e. ground mounted and against two walls or mounted off ground level between three walls).

NOTE — an air source heat pump with more than three reflective surfaces (for example those within small lightwell's) will not meet the MCS planning standards.

- Measure the distance from the heat pump to the assessment position in metres.
Use table in 'Note 4: dB distance reduction' below to obtain a dB reduction.

NOTE 4: DB DISTANCE REDUCTION (STEP 4)

		Distance from Heat Pump (metres) (STEP 3 RESULT)													
		1	1.5	2	3	4	5	6	8	10	12	15	20	25	30
Q (STEP 2 RESULT)	2														
	2	-8	-11	-14	-17	-20	-21	-23	-26	-28	-29	-31	-34	-36	-37
	4	-5	-8	-11	-14	-17	-19	-20	-23	-25	-26	-28	-31	-33	-34
	8	-2	-5	-8	-11	-14	-16	-17	-20	-22	-23	-25	-28	-30	-31

Where a precise distance is not indicated in the above table, then the next lowest value for that distance should be used. E.g. if the distance was 2.5m, then the values for 2m should be used.

- 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.

NOTE 5:

A correction should be made for attenuation due to barriers between the air source heat pump and an assessment position. A correction will be necessary if an MCS Contractor is unable to see an assessment position from the top edge of the air source heat pump. Use the following instructions to determine whether a correction is appropriate:

For a solid barrier (e.g. a brick wall or a fence) that completely obscures an MCS

Contractor's vision of an assessment position from the top edge of the air source heat pump attenuation of -10 dB may be assumed.

Where a solid barrier completely obscures an MCS Contractor's vision of an assessment position from the top or side edges of the air source heat pump, but moving a maximum distance of 25 cm in any direction to the air source heat pump allows an assessment position to be seen, attenuation of -5 dB may be assumed.

If it is possible for an MCS Contractor to see any part of an assessment position from the top or side edges of the air source heat pump no attenuation may be assumed.

- Calculate the sound pressure level from the heat pump at the assessment position using the following calculation:
(STEP 1) + (STEP 4) + (STEP 5)
- 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'.

- Determine the difference between STEP 7 background noise level and the heat pump noise level using the following calculation:

$$(\text{STEP 7}) - (\text{STEP 6})$$

- 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.

Please note that the left-hand column should be used for both positive and negative differences (e.g. a difference of +3 and -3 both attract a correction of 1.8 dB).

Difference between the two noise levels (db) (+/-)	Add this correction to the higher noise level (db)
0	3.0
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
11	0.3
12	0.3
13	0.2
14	0.2
15	0.1

- Is the FINAL RESULT in STEP 9 equal to or lower than the permitted development noise limit of 42.0 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.

APPENDIX 2: WP1: REVIEW OF IEA ANNEX 51, ACOUSTIC SIGNATURES OF HEAT PUMPS OCTOBER 2022

A2.1 OVERVIEW

Reduction of acoustic emissions is important to further increase the acceptance of heat pumps. To increase this acceptance and minimise noise annoyance more focus has to be put on the acoustic emissions at steady state and transient behaviour of acoustic signatures during different operating conditions (e.g. icing, de-frosting, capacity control, cooling mode).

A webinar of proceedings is available on YouTube (18).

The structure of the Annex 51 report is shown in Table A1.

Table A1: Structure of Annex 51 reporting

Ref.	Title / Description	No. of Pages
E	Executive Summary and Document Guide – IEA HPT Annex 51 Executive Summary and Documents Guide	14
-	2-page Summary – Acoustic Signatures of Heat Pumps – 2- page_summary_Annex 51_2022	2
U	Umbrella Report – IEA HPT Annex 51 Umbrella Report	51
1.0	Introduction – IEA HPT Annex 51 D1.0	31
1.1	Measurement Techniques – IEA HPT Annex 51 D1.1	29
1.2	Regulations – Countries overview – IEA HPT Annex 51 D1.2	119
1.3	Regulations – Synthesis – IEA HPT Annex 51 D1.3	19
2.1	Selection of Heat Pumps for Round Robin Tests – Market figures – IEA HPT Annex 51 D2.1	5
2.2	Round Robin Tests – Air-to-Water Heat Pump – Heat Pump Water Heater – IEA HPT Annex 51 D2.2	48

Ref.	Title / Description	No. of Pages
2.3	Seasonal Sound Power Level – Air-to-Water Heat Pump – IEA HPT Annex 51 D2.3	12
3	Overview on Heat Pump Component Noise and Noise Control Techniques – IEA HPT Annex 51 D3	79
4	Analysis of the Effect of Operating Conditions of Heat Pumps on Acoustic Behaviour – IEA HPT Annex 51 D4	49
5	Report on heat pump installation with special focus on acoustic impact – IEA HPT Annex 51 D5	69
6	Annoyance rating and psychoacoustical analysis of heat pump sound – IEA HPT Annex 51 D6	24
7	Educational material on acoustics of heat pumps – IEA HPT Annex 51 D7.1	63
8	Workshop material and conference contributions – IEA HPT Annex 51 D7.2	15

A2.2 MEASUREMENT TECHNIQUES. REGULATIONS – COUNTRIES OVERVIEW, SYNTHESIS

The way in which EU states regulate noise emissions (in relation to heat pumps), varies widely. Not all nations divide the national territory into different areas (e.g. a zonal approach to planning), but even in the absence of areas (such as in France for example), there are still very restrictive limits, especially for the noise allowed inside homes. Some countries have wide variations of approaches within them, at a regional level.

The analysis shows that even when the approaches are similar, different methods of measurement are often adopted to determine the noise annoyance. This annoyance is then defined starting from different descriptive indices. An example concerning heat pumps is for example the penalty due to the identification of tonal sounds: this is foreseen in different countries, but each country has a different method for the calculation and application of this descriptor which in some cases heavily penalises models of heat pumps for which the frequency

of the compressor and its harmonics overlaps that produced by the rotation of the fan. But this does not happen with all descriptors used.

The national limits of the maximum permissible indoor noise level are given as a significant example of the results. They are summarised in a table and in a couple of simplified graphics.

This section consists of three parts. In the first part the reference standards and the main certification and labelling 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. 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. It can be seen in the 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.

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.

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

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 and ISO 9614 and 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. They can be summarised below:

- 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

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

NOTE: in the case of technical documentation of heat pumps, the catalogue values are often inaccurate and not very comparable with each other.

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 multi split systems.

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”.

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 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 etc.). 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 it 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.

A2.3 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.

A2.3.1 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 A2.

Table A2: 206/2011 – requirements for maximum sound power level

Rated Capacity ≤ 6 kW		6 kW < 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

The sound power level shall be measured according to EN 12102 in the temperature conditions (corresponding to EN 14511-2) reported in Table A3.

Table A3: EN 12102 – Test conditions

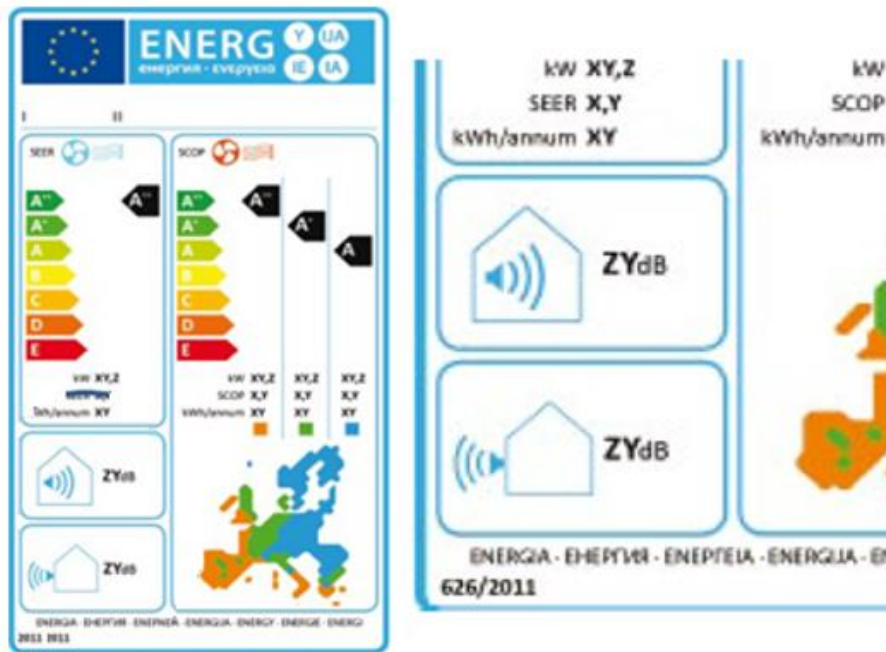
Temperatures Dry Bulb (Wet Bulb)	Air-to-Air Unit Cooling Only	Air-to-Air Unit Reverse Cycle	Air-to-Air Unit Heating Only
Outdoor air	35 (24)°C	35 (24)°C	7 (6)°C
Indoor air	27 (19)°C	27 (19)°C	20 (max. 15)°C

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.

A2.3.2 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. Figure A1 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 A1: 626/2011 – label acoustic detail



626/2011 – Label

626/2011 – Label, acoustic detail

A2.3.3 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 values identified in Table A4.

Table A4: 813/2013 – Maximum sound power levels

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	65	65	70	70	78	80	88

The sound power level shall be measured according to EN 12102 for the space heating application and in the temperature conditions summarised in Table A5 (corresponding to EN 14511-2).

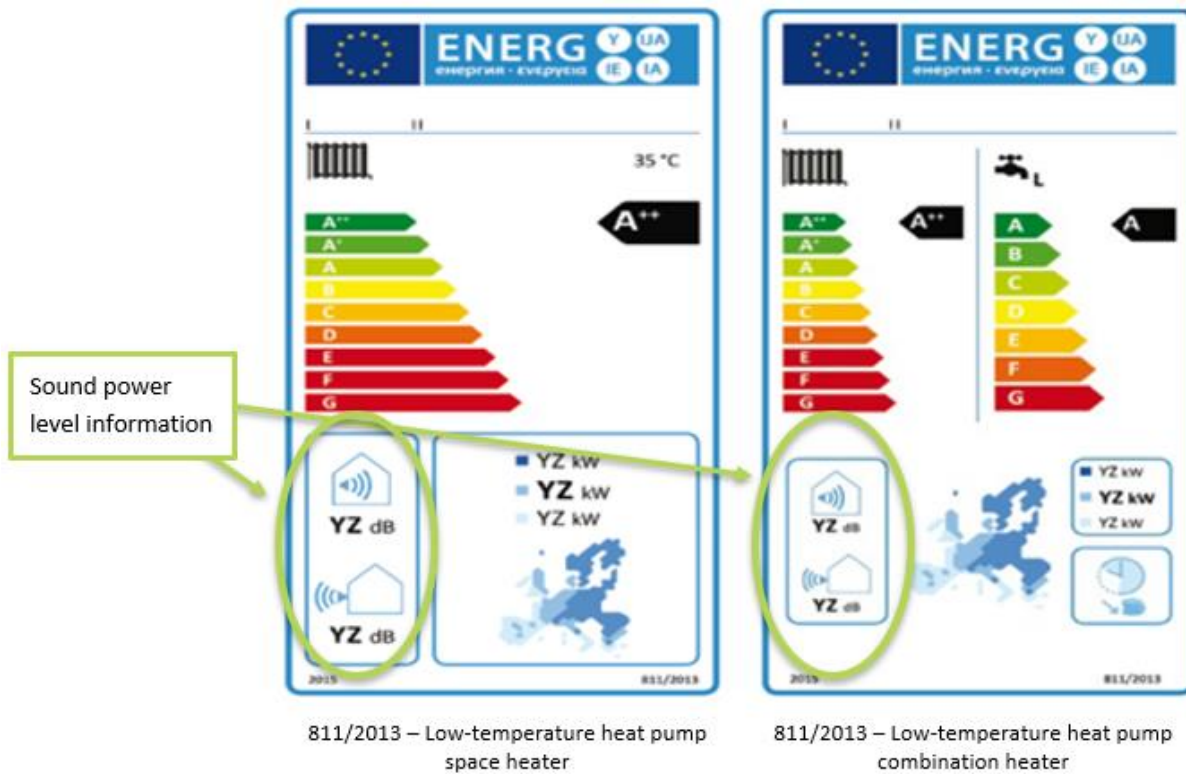
Table A5: EN 12102 – Test conditions

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	10 (12)°C	10-7°C	0-(-3)°C
Indoor heat exchanger (low temperature applications)	30-35°C			
Indoor heat exchanger (except low temperature applications)	47-55°C			

A2.3.4 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, as illustrated in Figure A2.

Figure A2: Energy Label



A2.3.5 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 those in Table A6.

Table A6: 814/2013 – Maximum sound power levels

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	65	65	70	70	78	80	88

These are the same values as 813/2013.

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 $10\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

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 $25 \pm 3\text{ }^{\circ}\text{C}$, 2nd point at $(T_{\text{set}}+25)/2 \pm 3\text{ }^{\circ}\text{C}$, 3rd point at $T_{\text{set}} \pm 6\text{ }^{\circ}\text{C}$.

(Test 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 $25\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ for the first measurement); the periods of defrosting are excluded (zero electric consumption of the compressor, the fan or the circulation's pump).

A2.4 MARKET SURVEILLANCE

For the purpose of market surveillance by the EU 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.

A2.5 EUROPEAN COUNTRY NOISE LIMITS

The national limits of the maximum permissible indoor noise level are given as a significant example of the results. They are summarised in a table and in a couple of simplified graphics (see Figure A3 and Table A7). Note, however, that the limits in the UK are misunderstood as 42 dBA, when they are in fact 37.7 dBA (the wording of MCS 020 makes this unclear).

Figure A3: Minimum indoor noise for day and night period

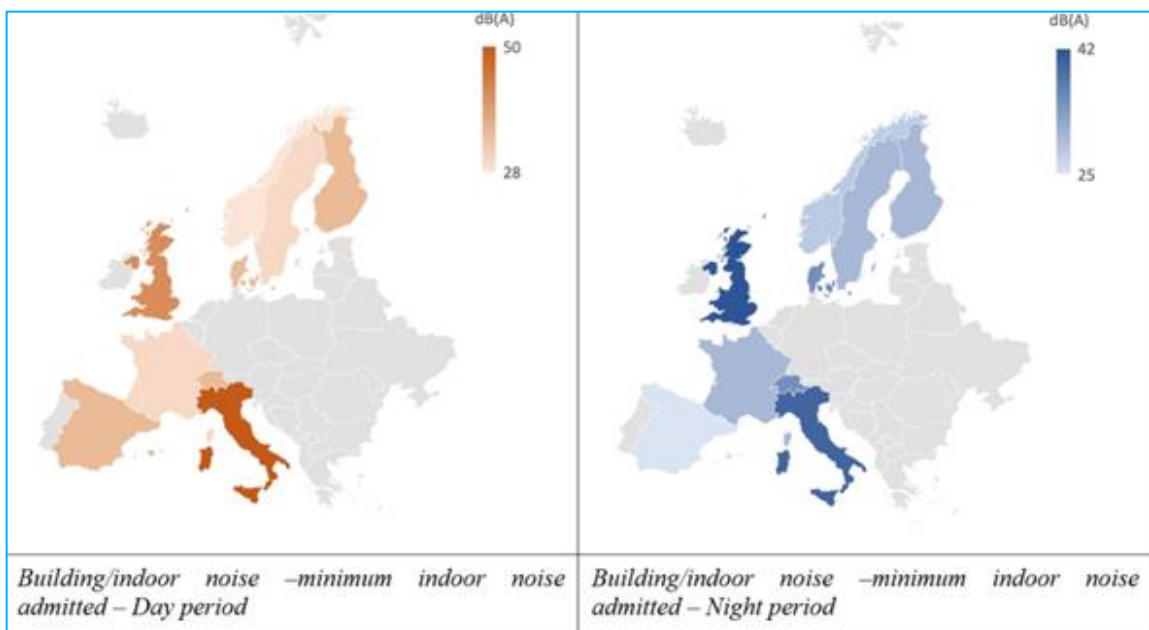


Figure A2 (overleaf provides an example of the energy label for a heat pump space heater and a heat pump combination heater showing on the left bottom side the sound power level information.

Table A7: Summary of example maximum permissible indoor noise levels

Topic	Building														
	EU Country											Other Country			
	FR	UK	AT	IT	ES	DE	PL	DK	SE	FI	N	CH	KO	JP	CN
There are Buildings acoustic insulation Laws?	Yes	Yes	Yes	Yes	Yes			Yes	Yes		Yes	Yes			
Passive acoustic requirements of buildings	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes		Yes	Yes			
Parameter used (insulation)	$D_{nT_w+C}; L'_{nT_w}$	$D_{nT_w+C}; L'_{nT_w}$	$D_{nT_w}; L'_{nT_w}$	$R'_{w_i}; L'_{nw_i}; D_{2m,nT,w}$	$D_{nT_w+C}; L'_{nT_w}$	$R'_{w_i}; L'_{nw}$	$R'_{w+C}; L'_{nw}$		$R'_{w+C}; L'_{nw+C}$		$R'_{w_i}; L'_{nw}$	$D_{nT_w+C}; L'_{nT_w+C}$			
Different requirement for terraced house and apartment			Yes			Yes						Yes (rent/property)			
Specific limit for HP or technological services/installations in general				25 dB(A) or 35 dB(A)											
Parameters for services/installations				LAeq; LASmax											
Different limit for different indoor ambient				Yes											
Minimum indoor limit (day/night)	30 dB(A) (in the Rooms)	42 dB(A) (at window)		50/40 dB(A) at window	35/25 dB(A)			35 dB(A) at property edge	30 dB(A)	35/30 dB(A)	28 dB(A)	35 dB(A) at window			

Different countries define different time periods for noise limits, as illustrated in Table 2, reproduced as Table A8.

Table A8: Environmental noise – country definition of reference periods

Topic	Environmental noise - Reference Periods														
	EU Country											Other Country			
	FR	UK	AT	IT	ES	DE	PL	DK	SE	FI	N	CH	KO	JP	CN
Different limits for Day/Night Day/Evening/Night	Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes		Yes		4 period	
Day period interval	7-22	7-22 8-22 (Sunday)		6-22	7-19	6-22	6-22	7-18	6-18	7-22		7-19		8-19	
Evening period interval	-	-		-	19-23	-	-	18-22	18-22	-		-		19-23	
Night period interval	22-7	22-7 22-8 (Sunday)		22-6	23-7	22-6	22-6	22-7	22-6	22-7		19-7		23-6	

Environmental noise limits across EU countries are compared in Table 3, reproduced as Table A9.

Table A9: Environmental noise – Noise limits

Topic	Environmental noise - Limits														
	EU Country											Other Country			
	FR	UK	AT	IT	ES	DE	PL	DK	SE	FI	N	CH	KO	JP	CN
Max limit (day/night)		60/50	65/55	70/70	65/55	70/70	55/45	55/40	50/40	55/50	no/35			70/55	70/60
Minimum limit (day/night)		50/34	45/35	50/40	50/40	45/35	45/40	40/35	50/40	45/40	no/35			45/40	50/40
Minimum indoor limit (day/night)	30 dB(A) (in the Rooms)	42 dB(A) (at window)		50/40 dB(A) at window	35/25 dB(A)		40/30 dB(A)	35 dB(A) at property edge	30 dB(A)	35/30	28 dB(A)	35 dB(A) at window			
Absolute criterion for max noise low frequency									31,5-200 Hz						
Different Regional or municipal limits	No	No	No	No	Yes	No								Yes	Yes

Topic	Environmental noise - Limits														
	EU Country											Other Country			
	FR	UK	AT	IT	ES	DE	PL	DK	SE	FI	N	CH	KO	JP	CN
Different limit for Saturday and/or Sunday	No	Yes		-	-			Yes							
Differential criterion on background noise Day/Night	5/3 dB			5/3 dB					10/5 dB						

Most countries apply penalties for tonal or impulsive noise in their regulations, as set out in Table 4, reproduced as Table A10.

Table A10: Environmental noise – Parameters and corrections applied

Topic	Environmental noise - Parameters and corrections (penalties and bonus)														
	EU Country											Other Country			
	FR	UK	AT	IT	ES	DE	PL	DK	SE	FI	N	CH	KO	JP	CN
Parameters used	L_{Aeq}		$L_{r,i}$ $L_{r,den}$	L_{Aeq}, L_c	$L_{K,x}; L_d;$ $L_e; L_n;$ L_{den}	$L_{r,i}$ L_{AFmax}	L_r (L_{Aeq}, τ)	L_r	$L_{Aeq, \tau};$ $L_{A,max}$	$L_{Aeq, \tau}$	$L_{Aeq, \tau}$				
Time period of evaluation of the parameters			1 Year	Minutes, hours, days								1 Year			
Adjustment for type of source	-	-	Train - 5; road 0; plants +5	-	-							HP: +5dB day, +10 dB night			
Penalty for impulsive noise				3 dB	3 dB	Yes	Yes	5 dB	6 dB	7 dB	8 dB	2, 4, 6 dB			
Penalty for tonal noise				3 dB	3 dB	Yes	Yes	5 dB	6 dB	7 dB	8 dB	2, 4, 6 dB			
Penalty for tonal noise in low frequency	No Penalty but taken			3 dB	3 dB										

Topic	Environmental noise - Parameters and corrections (penalties and bonus)														
	EU Country											Other Country			
	FR	UK	AT	IT	ES	DE	PL	DK	SE	FI	N	CH	KO	JP	CN
	into account														
Bonus for noise emissions in partial time period	From 1 to 6 dB			3 to 5 dB		Yes									

A2.6 ROUND ROBIN TESTS

The explanation of the operating condition of EN 12102-1 (Annex A.4) is related to the ErP regulation 813/2013 which specifies how the sound power level of heat pumps shall be (measured and declared). The standard conditions given are for an air source and low temperature heat pump: 7(6)/30-35 °C, which are also the standard rating conditions given in EN 14511 and EN 12102-1.

However, the sound power level shall be declared in association with a heating capacity ("and the same declared capacity shall be used"). Therefore the only capacity measured for the regulation at the same outdoor air temperature is the part load EN 14825 point C condition, .i.e. 7(6)/*-30.

It was confirmed by the Commission, and reported as Annex A.4 in EN 12102-1 that the conditions for rating the sound power level (for the labelling) are:

- outdoor temperature: 7(6)°C
- inlet - outlet water temperature: 30°C - 35°C
- heating capacity: part load capacity at C condition

If the unit cannot provide the capacity in these operating conditions, then the settings of the unit such as compressor frequency and/or water flow rate can be modified in order to achieve at least:

- the heating capacity
- the outlet water temperature at 7(6)°C outdoor air temperature.

This approach is often not well understood by the EN 12102-1 users. And in fact, the $\Delta T = 5K$ is not fulfilled by all laboratories.

Annex 51 concludes that the setting of the EN 12102-1 is not clearly understood and had to be changed in some ways by some laboratories: there could be a better description in the standard or another setting for the 'acoustic' condition.

Note that EN 12102-1 was updated 31st October 2022, after the end of the Annex 51 project.

A2.7 INFLUENCE OF OPERATING CONDITIONS

An overview on the influence of operating conditions on the sound power level can be done, by looking at the rotation speeds of fan and compressor, as laboratory A measured their value, unfortunately not for the lowest ambient temperature. Fortunately, these conditions lead to high capacities of the unit which were already described by #3 (EN 14511 max. frequency).

Figure 15 clearly shows that different operating conditions lead as expected to variable sound power levels and different spectrum shapes. In the present case, the standard rating condition (configuration #1) exhibits a peak at 315 Hz band which disappears when the compressor and the fan are boosted at their maximum frequency; the modal coincidences do not exist anymore. In spite of an average difference of 1.5 to 2.5 dB over the spectrum, the overall value only differs by 0.8 dB(A), due to the removal of the peaks.

In a general approach, the noise level is the highest for high capacities and the lowest for small capacities, but it is not possible to find a relation for this unit between the noise level and the

heating capacity. As an example, Figure 15 shows that configuration #5 is louder by 2.8 dB(A) than #6, due to the higher fan rotation speed (625 vs 558 rpm), despite a lower capacity.

Although the two configurations have the same fan rotation speed (908 rpm), configuration #3 is a higher sound level, by 1.3 dB in average than #7, because the compressor rotation frequency is 81 Hz instead of 34 Hz.

When the heating capacity increases (ex. for conditions with negative ambient air temperature), the sound level is close to the ones observed at the maximum heating capacity or at the max frequencies of both fan and compressor.

Figure 16 of the report (reproduced as Figure A4 below) illustrates that the explored heating capacities are not related to the overall sound power levels. On the other hand, Figure A4 demonstrates that the fan rotation speed is the first order link with the overall L_{WA} . The compressor rotation speed is also linked to the sound level, but in a second order, meaning that it can only be seen if the fan speed is the same (cf. Figure 15, #3 vs #7).

Figure A4: Relation between fan rotation speed and compressor frequency vs overall L_{WA}

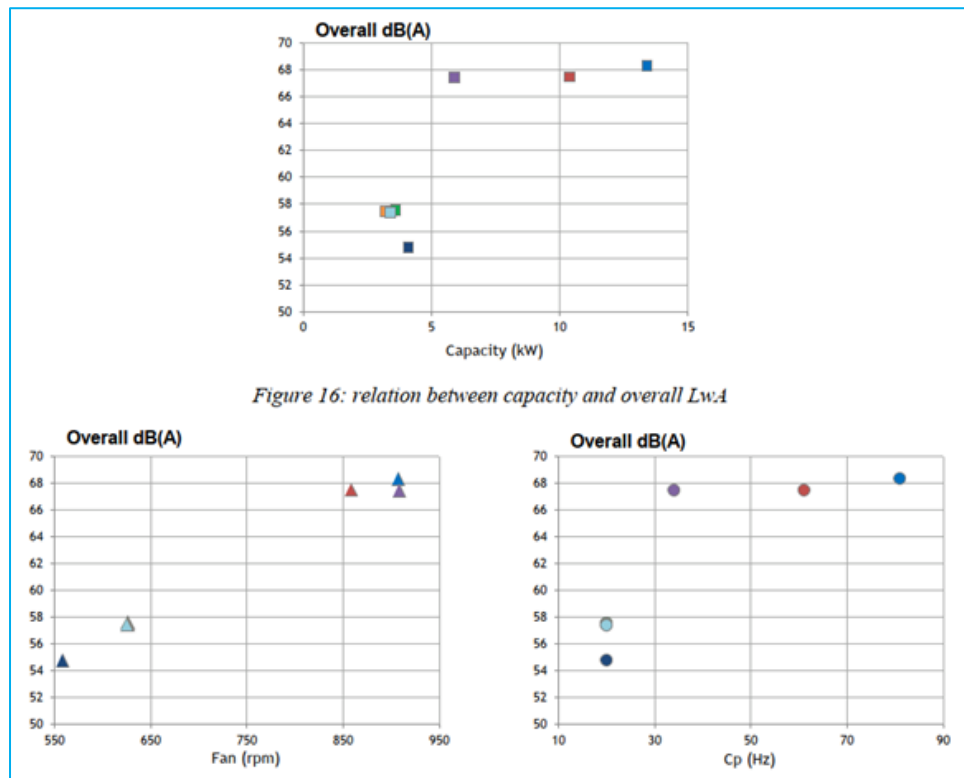


Figure 16: relation between capacity and overall L_{wA}

The noise measured according to the operating conditions given by EN 12102-1 Annex A.4, i.e. the sound level for air at 7(6) °C and water at 30/35 °C, but at the same capacity as the declared capacity at EN 14825 point C2.

It seems that manufacturers only report the ErP sound power at partial load as you described below.

MCS 020 states:

“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).”

This introduces potential ambiguity as ‘highest sound power’ does not have a specific meaning. At the ErP labelling acoustic test conditions, the range of sound power results between the round robin tests were between 57 - 60 dBA.

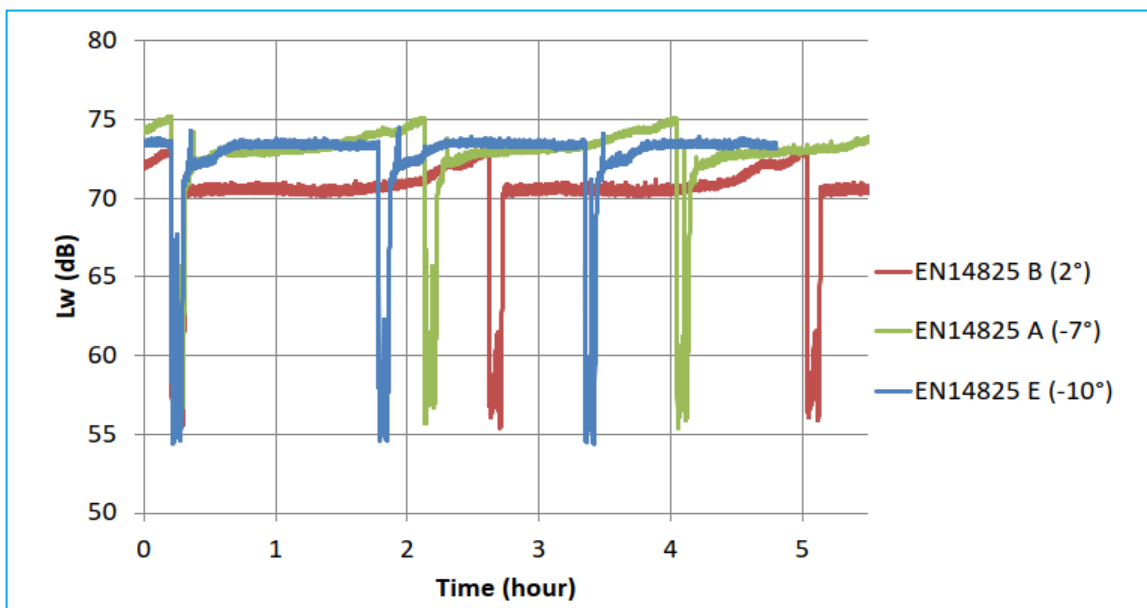
A2.8 SEASONAL SOUND POWER LEVEL, AIR-TO-WATER HEAT PUMP

This report describes the calculation of a Seasonal Sound Power Level (SLw) calculated from the results of the laboratories on the air-to-water heat pump (RRT1). For the air to water heat pump, the knowledge of the noise levels measured for different operating conditions of EN 14825 allows considering the calculation of a "seasonal" acoustic value.

The Seasonal Coefficient of Performance SCOP is representative of the efficiency of a unit over the average climate. This climate is described as a series of bin temperatures with their corresponding occurrences between -10°C and +15°C. COP values at the temperatures of -7, +2, +7 and 12°C are used to calculate this SCOP by linear interpolation between the two closest temperatures and weighting according to bin temperature occurrences (i.e. weighted with how frequently a particular temperature range occurs over the year). The distribution of temperatures in the average climate is given in Figure 43. The total of hours is 4910, representing 56 % of the full year (8760 hours).

The sound power varies at different operating points, as illustrated below. The environmental conditions are defined in EN 14825 with various letters, Condition C being that used for the ErP labelling, as illustrated in Figure A5.

Figure A5: frosting/defrosting cycles for different temperature conditions



The difference between Seasonal Sound Level SLw and EN 14511 is between 2.2 and 3.4 dB(A), whilst the difference with EN 12102-1 is between -5.7 and -6.7 dB(A). Table A11 provides the input data and results for laboratories (defrosting at ~ 55 dB(A)).

Table A11: Input data and results for laboratories (defrosting at ~ 55 dB(A))

		Lab 1	Lab 2	Lab 3	Lab 4	Average
		Lw dB(A)	Lw dB(A)	Lw dB(A)	Lw dB(A)	Lw dB(A)
EN 14825	point A (-7 °C)	71.5	68.2	68.0	70.2	69.5
EN 14825	point B (2 °C)	68.9	67.2	68.1	68.6	68.2
EN 14825	point C (7 °C)	60.1	57.0	57.5	58.7	58.3
EN 14825	point D (12 °C)	58.1	54.4	55.1	56.3	56.0
Seasonal Lw dB(A)		66.0	63.7	64.3	65.3	64.8
EN 12102-1 "acoustics"		60.3	57.2	57.6	58.7	58.4
<i>Difference</i>		-5.7	-6.4	-6.7	-6.6	-6.4
EN 14511 A7(6) W30/35		68.2	67.1	67.5	68.0	67.7
<i>Difference</i>		2.2	3.4	3.2	2.7	2.9

The calculation of a SLw is interesting as it clearly demonstrates (for this heat pump) that the averaged sound power level for the average climate is much higher than the noise measured according to the operating conditions given by EN 12102-1 Annex A.4, i.e. the sound level for air at 7(6) °C and water at 30/35 °C, but at the same capacity than the declared capacity at EN 14825 point C. These conditions are the required conditions for sound power level according to ErP regulation 813/2013 for air-to-water heat pumps.

This encourages considering a change in the definition of the measurement conditions for the 'acoustic point'. Table A2.10 indicates that the noise level measured at EN 14511 conditions (#1) seems to be more realistic, as it is very close to the EN 14825 Point B at 2 °C (around or less than 0.6 dB difference) which has been identified as the "key point" in a seasonal sound power level approach.

In conclusion, the sound power levels of an outdoor unit heat pump have been determined for several operating conditions, according to EN 14825 points A to E for the first time.

In the same approach than for the SCOP calculation, a seasonal sound power level SLw can be calculated, using the number of hours for each temperature of the average climate to weight each sound level for the overall average over the heating season. The sound data measured at -7, 2, +7, +12 °C outdoor temperature are used, and for temperatures for which there are no acoustic results, a linear interpolation is applied to the acoustic values. Then a logarithmic weighted average is calculated, using the number of hours of operation for each bin of outdoor air temperature over the average climate, and the sound power level measured or interpolated at each bin temperature. The On/Off cycling above 12 °C and the defrosting cycle effects have also been taken into account, leading to a marginal decrease of the resulting overall sound power level.

As for any weighted average, the results are strongly impacted by the combination of the two main parameters, the number of hours and the associated sound level. A high sound level with

only a few hours will not strongly contribute to the SLw. With the logarithmic nature of the sound levels, the higher values are more dominant than for algebraic calculation, meaning that the lower sound levels will be contributing less.

From these calculations, a comparison can be done with the sound power level measured according to EN 12102-1 which is 6 to 7 dB(A) lower than the seasonal approach value, indicating that this EN 12102-1 operating condition may be not representative.

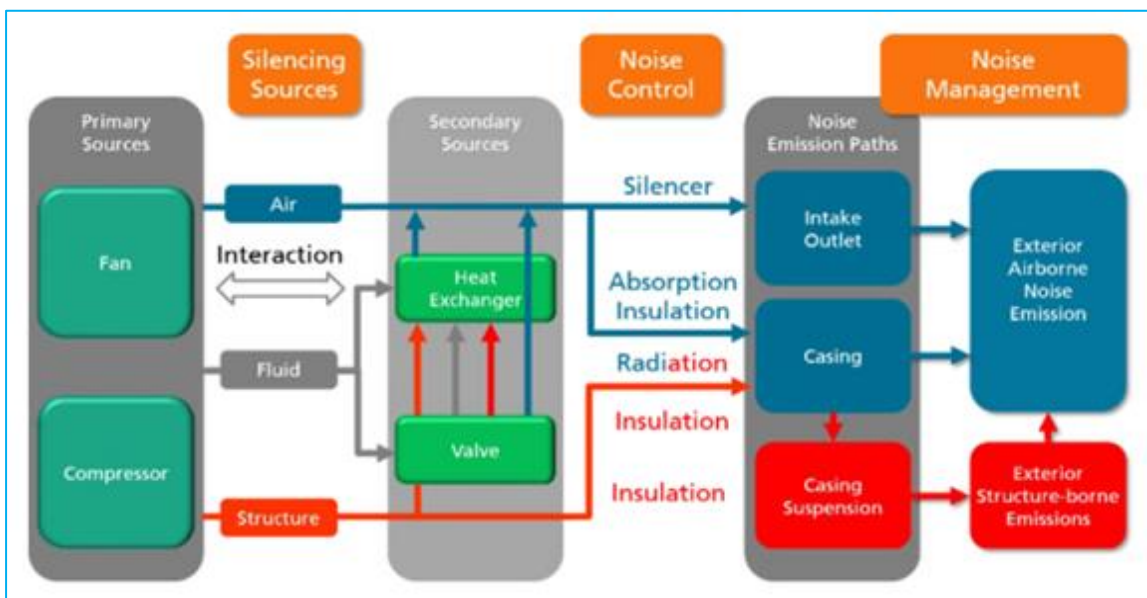
The EN 14511 standard rating condition 7(6) /30-35°C seems to be an interesting candidate condition as it gives quite close sound power levels, only 2 or 3 dB higher than the SLw. This EN 14511 test condition is easy to implement. Moreover, it could avoid performing the tests according EN 14825 at different outdoor air conditions, those below 7 °C being difficult or impossible to maintain in acoustic test rooms. This EN 14511 standard rating condition seems to reflect a more representative acoustic behaviour of the heat pump than the present EN 12102-1 Annex A.4.

A modification of the EN 12102-1 condition is desirable, both because it does not seem to be representative and because it is difficult to understand and implement in its current definition. The EN 14511 standard rating condition seems to be a good compromise between accuracy/reliability of the test and representability of the sound power level of the heat pump over the heating season.

A2.9 OVERVIEW ON HEAT PUMP COMPONENT NOISE AND NOISE CONTROL TECHNIQUES

This part has a lot of detailed information on the source of noise - principally the fan and compressor - and potential opportunities for noise control techniques. Figure A6 illustrates the components of a heat pump.

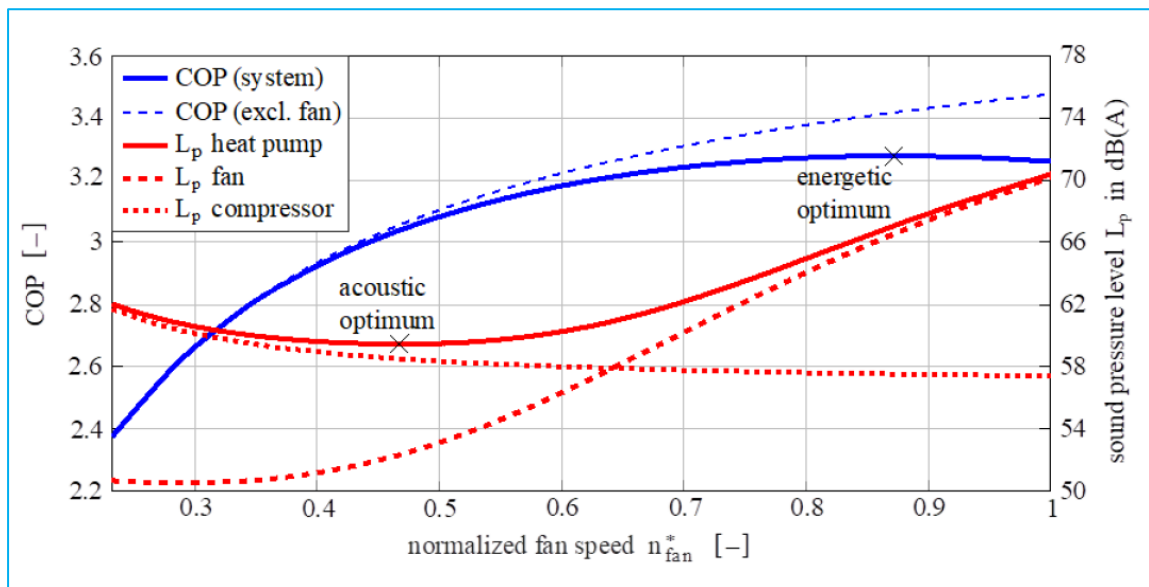
Figure A6: Components of a heat pump



A2.10 ANALYSIS OF THE EFFECT OF OPERATING CONDITIONS OF HEAT PUMPS ON ACOUSTIC BEHAVIOUR

Based on dual thermodynamic and acoustic modelling, it is shown in the extracted Figure 5 (presented as Figure A7) that the acoustic optimum operating point differs from the energetic (thermal) optimum operating point, considering fan and compressor speed.

Figure A7: Acoustic signatures of compressor and fan, as well as their sum as function of normalized fan speed, demonstrate the conflict between energetic optimal operating point and acoustic optimal operating point.



In addition, the extracted Figure 5 shows a Pareto effect between energy efficiency and acoustic emission (i.e. The overall emission) can be disproportionately reduced by a comparatively small deviation from the energetic optimum.

For a standardised speed of $\Delta n_{norm} = 0.7$ the system is reduced from COP = 3.27 to COP = 3.23. This means a reduction in efficiency of 1.22 %. The acoustic emission drops from $LL_p = 67.2$ dB(A) to $LL_p = 62.2$ dB(A). This means that a very small reduction in energy efficiency can reduce noise emissions by about $\Delta LL_p = 5$ dB(A).

This Pareto effect is used in the following sections in order to realise an energetic-acoustic optimal operation (EAO). The respective optima are strongly dependent on the ambient temperature and the heat demand. This leads to the Optima shifting during heat pump operation.

A2.11 ACOUSTICS OF TRANSIENT HEAT PUMP OPERATION

By definition, transient heat pump operations are the evolutive processes and those whose duration is limited in time. Consequently, the main reasons to reach such states are:

- Events regarding a change in the requested capacity of the heat pump:

- Start and stop processes (including the intermittent switching of models without inverter control)
- Load change and inverter modulation
- Hot water tapping
- Events regarding a change in the conditions to reach such desired capacity:
 - Change of external conditions like the progressive frosting of the evaporator
 - Change of ambient temperature
- Events as part of a defrosting cycle
- Events regarding an independent secondary source, such as the operation of the circulation pump.

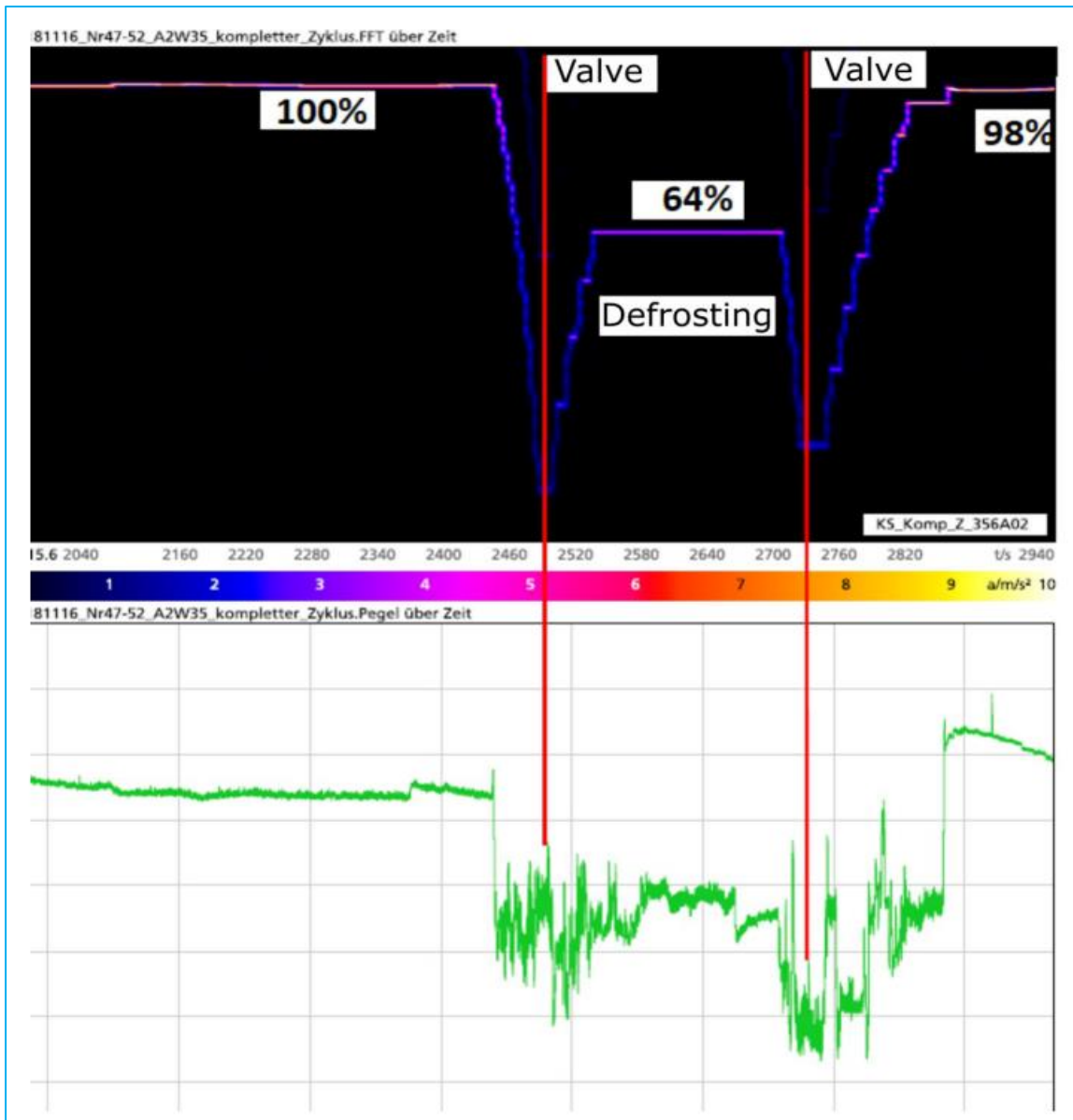
It is worth noting that some evolutive processes take place on such a big time scale, that will be explored later.

A2.12 DEFROSTING CYCLE

Although frosting of heat pumps (when ice accumulates on the heat exchanger) leads to an increase in the noise level as this occurs, the defrosting cycle happens in several steps, usually all several dB quieter than the normal operation around full capacity (see the detail of one cycle in Figure A8 or the regular drops of Sound Power Level in Figure 20):

- The fan and compressor shut down (the compressor of some models will just significantly slow down).
- The 4-way valve is operated to reverse the circuit starting at the compressor output, changing the pressure proportion in the different parts of the cooling circuit, which can lead to a strong hissing of the electronic expansion valve (EEV) when opening.
- The compressor accelerates again up to a limited speed.
- After the temporary role of condenser of the frosted evaporator has warmed it up sufficiently to allow full defrost, the compressor is shutdown (/slowed down) once more
- The 4-way valve is operated again, back into its initial position.
- (optionally, the fan operates once in reverse direction in order to evacuate the condensate, which could otherwise freeze back on its blades and affect its function)
- Finally, compressor and fan start again and accelerate up to their normal operating speeds.

Figure A8: Time evolution of a defrosting cycle, as measured at Fraunhofer ISE. The upper part shows the rotational speed of the compressor (acceleration sensor) and the lower part represents the global SPL, including brief events like the switchings of the 4-way valve.



Different operation conditions and related control strategies for noise output.

Depending on the heat pump type, the following operation conditions can occur:

- Full load (stationary energetic state)
- Part load (stationary energetic state)
- Silent mode (control strategy inducing operation at lower capacity with specific speeds)
- Defrosting mode (necessary transient operation of air-to-water devices)

A change of operating condition can cause a significant change in the noise character, while the overall noise level additionally depends on the type of heat pump and its construction. The

following example from DTI’s internal measurements (see Table A12 below and Figure 31) illustrates the difference between full load condition and silent mode condition for the same temperature condition of A7/W55 for an air to water heat pump.

Table A12: Difference between full load and silent mode conditions for A7/W55 conditions

		A7/W55_silent mode	A7/W55
Heating capacity	kW	5.4	7.3
COP	-	3.0	2.9
Power input	kW	1.8	2.5
Outdoor heat exchanger inlet	°C	7.0	7.0
Outdoor heat exchanger outlet	°C	-	-
Indoor heat exchanger inlet	°C	47.0	47.0
Indoor heat exchanger outlet	°C	55.0	55.0
Compressor speed	Hz	43	57
Fan speed	rpm	470	620
Sound power level	dB(A)	57.0	62.0

It is worth noting that the COP is essentially the same for both modes. For the silent mode, the sound power level is reduced by 5 dB, but due to a reduction in the compressor speed and the fan speed, the heating capacity is reduced by 26 % as well.

The relevance of such operation mode comes with control strategy: a model-based control approach with simplified models can be used to calculate a maximum night reduction of the compressor speed. In other words, if the compressor is the loudest component, the heat pump demand for heating/cooling energy can be divided during part load operation for one day in such a way that the heat pump runs at full load during the day and operates in a silent mode at a lower thermal output and thus at low compressor speed or sound power overnight a compromise can be achieved.

Importantly this compromise can be achieved without affecting the energy efficiency, COP.

A2.13 HEAT PUMP INSTALLATION WITH SPECIAL FOCUS ON ACOUSTIC IMPACT

The aim of this work is to select and place air-to-water heat pumps in such a way that the sound pressure level in the surrounding houses is kept low.

In the following chapters, light will be shed on several topics surrounding the placement of heat pumps. This report presents a selection of tools, which are used for calculating sound pressure levels. This includes simple formula-based tools, which are often available online on websites of heat pump manufacturers or heat pump association.

Examples shown include a Swiss, German and Austrian version. Two-dimensional visualisation is based on the same formulas, but allows the user to see the sound pressure levels in a horizontal plane surrounding the freely placeable heat pump.

All of these tools neglect absorption, reflection or frequency dependencies in the calculation, but corrections for the corner/ wall-placement “penalties” are included as a limited consideration. The underlying formula is very easy and can be calculated by hand.

To include the effects of directivity and frequency behaviour as well as absorption and reflection a much larger computational effort would have to be made. Some approaches, which try to shed light on these effects are visited next. Advanced sound propagation tools like CadnaA, SoundPlan, NoiseD3D, Mithra-SIG, IMMI, Olive Tree Lab Suite and OpenPSTD are listed.

The acoustic interaction of multiple heat pumps, including noise reduction measures, are analysed using primarily the tool IMMI.

First, the terraced housing estate chosen for an exemplary study is presented including the description of heating load, hot water provision, heating demand and the analysis of the neighbouring sites. The maximum sound propagation is calculated using IMMI following ÖNORM ISO 9613-2:2008 and ÖNORM S 5021:2010. Several scenarios have been compared: One heat pump per household, one heat pump per house and a local heating supply scenario.

In all cases heat pump selection and placement are outlined. Results are compared using a method introducing penalty points on all defined immission points (doors, windows, borders).

This is a promising case, as calculations have been repeated introducing noise barriers into the calculation. Time of day dependent sound propagation have been visited to introduce user profiles of the different buildings. Alternative tools like OpenPSTD and Olive Tree Lab Suite and the involved options are described.

In Austria, the current version of “Schallrechner” (see Figure 3-1) can be found using

<https://www.waermepumpe-austria.at/schallrechner> hosted by “Wärmepumpe Austria”. It is only available in German, but can be easily translated.

It is based only on the sound power level given by the manufacturer after choosing a heat pump out of a list (the value, however, can also be entered manually). The calculation of the sound pressure level in a user supplied distance is calculated out of this sound power adding increasing and decreasing “factors”.

In that way, multiple heat pumps, placement alongside walls or in corners, manufacturer added measures or directional dependencies can be added. As a result, the sound pressure level is at the point of the observer (which is in most cases the boundary of the garden or a window of the neighbour’s house). This is brought into context with the allowed maximum sound pressure level at day or night. Apart from the corner- and wall-placement “penalties” no absorption, reflection or frequency dependencies are included in the calculation.

A comparable calculation tool with similar name “Schallrechner” (see Figure 3-2) can be found at <https://www.waermepumpe.de/normen-technik/schallrechner/>. It is hosted by the Bundesverband Wärmepumpe e.V.

The approach of the “Fachvereinigung Wärmepumpen Schweiz” (see Figure 3-3) is a little different, because it provides as a result the list of heat pumps, which are “bewilligungsfähig”, which means “eligible for approval”. It can be found here: <https://www.fws.ch/unsere-dienstleistungen/bewilligungs-tool-fuer-luft-wasser-waermepumpen/>.

There is also a French version available: [to which the web link does not currently work].

Although as simple as the already discussed calculation, the tool of the Danish Energy Agency attempts to visualize the acoustic sound pressure levels originating from a heat pump.

A2.14 ANALYSIS OF ACOUSTIC INTERACTION OF MULTIPLE HEAT PUMPS

This part of the report is based on a bachelor thesis performed by Elisabeth Wasinger in Vienna, Austria. The full work translated in English is available from the IEA HPT Annex 51 website as a free download.

The number of installed air water heat pumps increases as part of this assessment and the cumulative sound emission is considered. In this part, it is considered how the sound spreads in a housing estate which is only heated by ASHP. The sound must not exceed a defined level at critical rooms and along the property line.

Three scenarios with different numbers of installed pumps are considered. A small number of ASHP means that the power rating of the models and thermal performance of the dwellings used must be high because one pump heats many households. The sound power level depends on the models chosen. Then, simulations with the sound prediction software IMMI calculates on the bases of the ÖNORM ISO 9613-2:2008 and the ÖNORM S 5021:2010. It concludes that one pump per house is optimal for low sound pressure levels. If noise barriers are used as mitigation a local heating is therefore the ideal scenario.

Additional simulations have been performed, where the heat pumps are not in operation all day long but there are time depending switching profiles because of the individual user behaviour of the families. The sound immission is identified for every hour of one day. It is shown that the sound pressure levels are lower when considering realistic user behaviour.

A2.15 ANNOYANCE RATING AND PSYCHOACOUSTICAL ANALYSIS OF HEAT PUMP SOUND

A desired result is an annoyance index that shows how different acoustic parameters explain the assessed annoyance response. Development of an annoyance index of heat pump noise could be beneficial when setting regulatory demands for heat pump noise.

Most commonly the A-weighted level is used to relate sound to annoyance. But other acoustic parameters may better explain the degree of annoyance, such as C-weighting or a tailored H-weighting specific to heat pumps (such as dBH for instance). It is understood that this may be one area of ongoing work in Annex 63 further work. These parameters could consider the presence of low frequency noise and tonality, which the A-weighted level inefficiently assesses. Common parameters used to assess the subjective perception of noise is loudness, sharpness, roughness, and tonality. From traffic noise, it seems clear that other noise descriptors more related to human perception such as loudness can yield a better description of the annoyance experienced by environmental noise.

A way to assess the annoyance of noise sources is to perform listening tests. In this way it is possible to gain knowledge of the acoustic parameters that influence the annoyance. A possible drawback of these tests is that it often requires to use short sound stimuli, making it difficult to assess long term annoyance. A desired result is an annoyance index that shows how different acoustic parameters explain the assessed annoyance response. Development of an annoyance index of heat pump noise could be beneficial when setting regulatory demands for heat pump noise.

This report summarises a study of annoyance related to air source heat pump noise, where a listening test was performed on an Austrian and Swedish listening panel. The report additionally present results from previous studies dealing with different aspects of heat pump noise: an Austrian study investigating the effects of different noise mitigation measures on perception and also a Swedish study investigating the noise perception of ground source heat pumps.

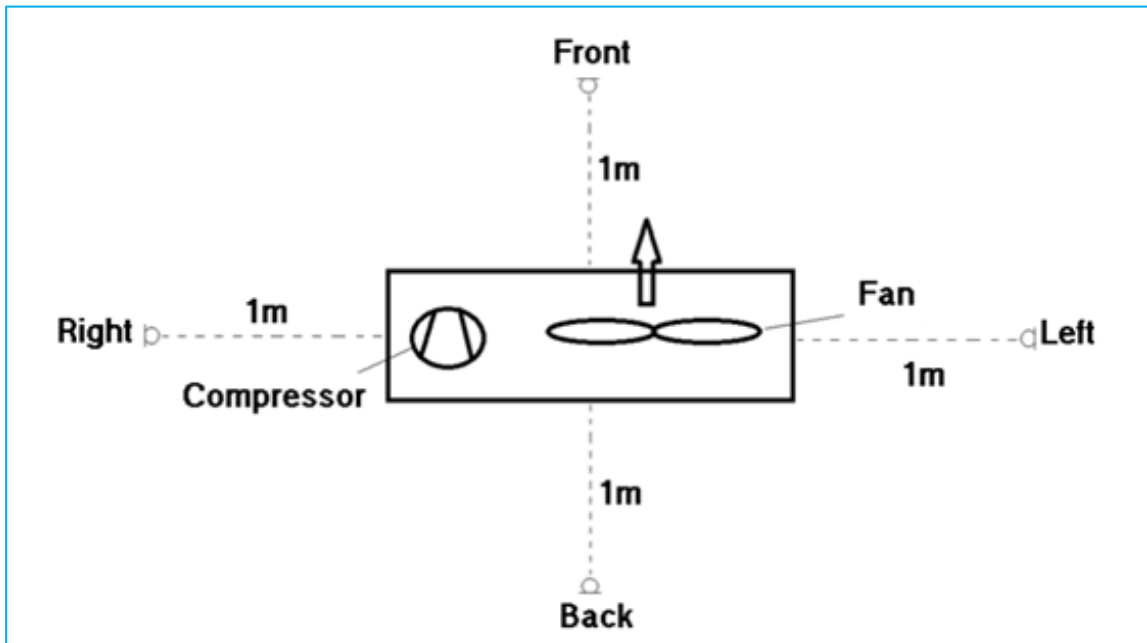
The heat pump used for these tests was an air-to-air heat pump; compressor and fan speeds are presented. The recordings were 30 seconds long from which 5-second long sound samples were extracted and equalized to 40 dB(A) to be used in the experiment. Thus the experiment did not measure how annoyance may change with change in dBA level. Table A13 provides a list of the heat pump setting used.

Table A13: List of recorded heat pump settings including fan and compressor speed and the measured A-weighted sound power level (according to IAO 3744)

Setting	Compressor speed [Hz]	Fan speed [rpm]	Input power [kW]	A-weighted sound power level, L_{WA} [dB]
Low	34	610	0.78	52.7
Medium	48	770	1.09	56.5
High	73	770	1.76	59.1
Super high	79	770	1.9	58.2
Emergency *	58	770	1.28	57.6

For each setting, measurements were made at four positions, as illustrated in Figure A9:

Figure A9: Microphone setup for acoustic measurements



A2.15.1 Psychoacoustic and Acoustic Parameters

Acoustic as well as psycho-acoustic parameters of the 5-second long sound samples were calculated using the Matlab-toolbox `psysound3`. These quantities encompassed loudness based on the Glasberg und Moore model, psychoacoustic roughness, tonality, sharpness, and loudness fluctuation.

Furthermore, C-weighted sound pressure levels (time-weighting fast) were calculated. The median as well as the 5%-percentile (the value that is exceeded 5% of the time) were calculated, denoted e.g. as S_{50} and S_5 for the median and the 5% sharpness. The loudness level in phons (which is a unit of loudness) was also determined. For all segments, the first 500 ms were discarded to avoid systematic errors due to transient response of the models.

For four levels in position and five levels in condition a total of 60 possible pairwise interactions exist for which a post-hoc analysis was performed. P-values were Bonferroni-corrected, i.e. with the number of post-hoc test performed. The main result of this analysis is that all 16 significant interactions include either the right position or the low condition or both. Thus, main effects containing either of these levels have to be treated with caution.

A post-hoc test on all possible main effects between 2 positions shows, that the recording from the right position is significantly more annoying than all other positions. However, clearly when looking at the different contributions of the condition (Figure 2-6, reproduced as Figure A10), the low condition has the opposite effect which is also significant for all pairwise interactions between the respective positions and the remaining conditions. Due to this significant qualitative interaction effect the position effect cannot be properly interpreted as such.

Figure A10: Best modes for combinations of up to 4 acoustical parameters. The red line indicates the 95% value for the explained variance if purely random parameters were used

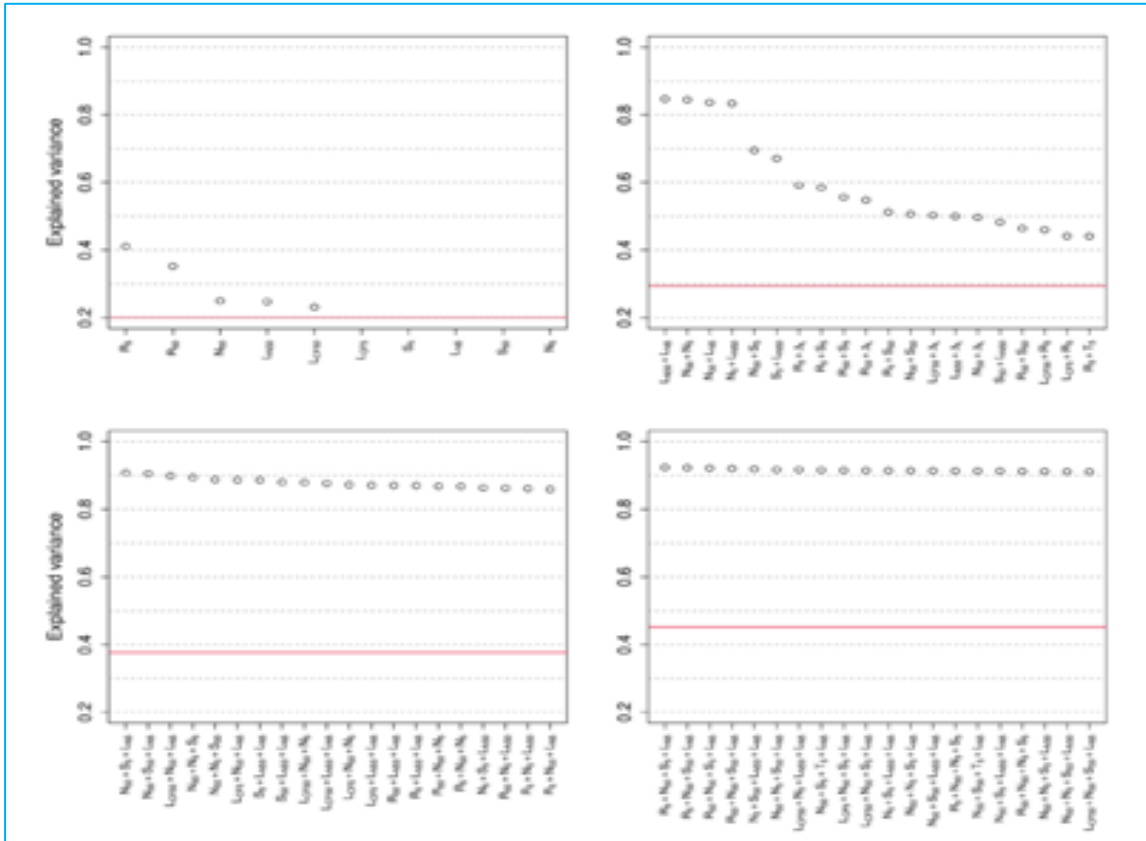


Figure A10 indicates that no single variable explains more than about 40 % of the variance whereas a combination of peak and median loudness or loudness level already explains more than 80 %. Using 4 parameters, peak sharpness as well as peak roughness together with peak loudness level and median loudness lead to the best results, although differences to the next best models are relatively minor. Using a fifth variable, adding the peak tonality yields the best model.

In conclusion the single best descriptor is the peak psychoacoustic roughness which explained about 40% of the variance. Peak sharpness, median loudness and peak loudness level explain roughly an additional 20%, 17% and 15%, respectively. Peak tonality had only a minor effect on the explained variance.

A main effect of the operating condition on the annoyance was observed. In particular the low-compressor speed condition was judged the most annoying whereas the emergency condition was judged less annoying than any other condition. In between the effects were minor. As the dBA-level was equalized to 40 dB for all conditions, this implies that the sound characteristics of the low setting were most annoying. However, the sound power level is also the lowest, with up to about 6 dB lower than for other conditions. Still, the implication is that the emission level of operating modes with similar characteristics as the low condition needs particular attention.

The position does not lead to a consistent main effect since interactions between position and condition are present. In comparison to all other operating conditions the low condition produces comparatively low annoyance ratings for the right measurement position and thus result in this interaction effects.

From the annoyance index the low annoyance of the emergency mode could be explained by a low psychoacoustic roughness. However, for the low-condition roughness as well as sharpness do not seem to be the main contributing factor. Adding loudness seems to improve in particular on the fit for this condition.

In a previous experiment on an air to water heat pump fitted with various sound-attenuating features, the dBA-level (88 %) and the loudness level (75 %) explained the annoyance ratings to a high degree. In particular sharpness showed some improvement for the explained variance of the model.

A2.16 EDUCATIONAL MATERIALS ON THE ACOUSTICS OF HEAT PUMPS

This report offers a wealth of information, over 63 pages, of the acoustic principles and their application to heat pumps. There is discussion on identifying a suitable location for an ASHP in different residential settings, for Danish residential types:

A2.16.1 One strip of houses

In the remote areas where there is only one strip of houses on each side of the road (illustrated in Figure A11) - and open terrain outside the back yards - there are good opportunities for a good location.

Figure A11: Opportunities for a good location (Ref Figure 2-25 in report)



Location A is the poor choice. The heat pump is hidden well out of the way of the owner and the pipe connections are short, but the heat pump is located just towards the neighbour's main terrace. A dissatisfied neighbour is likely.

Location B is a better choice. Utility room noise shields the neighbour's terrace. Supplemented by a noise shield against the neighbour, the noise load of the neighbour can be kept low. The pipe

connections are only marginally longer than location A. The disadvantages, however, are the noise on the owner's secondary living area. However, a noise shield on both sides of the heat pump can reduce the noise along the housing end.

Location C is the best purely due to the noise impact. Hidden behind the garden sheds, the heat pump only loads the non-noise-sensitive neighbouring area. The heat pump can be set up with completely free air movements, providing the best operating economy. The disadvantage is relatively long pipe runs (usually above ground) connections, which encourages inefficiencies in the system.

A2.16.2 Close construction

When the houses are close to each other (illustrated in Figure A12), the location of the heat pump requires great care. It is almost impossible to find a direction in which the heat pump can emit noise freely. As a starting point, a particularly quiet heat pump must be selected.

Figure A12: Location in dense construction (Ref Figure 2-26 in report)



Location A is bad. The heat pump is tucked away by the owner, but the pump will at least affect two neighbours with noise. A noise shield can only reduce the noise of one neighbour, otherwise the heat pump may not get enough air.

Location B is good. There is a great distance to the neighbour to both east and west (the noise at the road does not matter). The noise to the north can be reduced by placing a noise shield in front of the heat pump. Another option is to turn the heat pump so that it is parallel to the building's facade. The noise from the side of the heat pump is significantly lower than the front and rear heat pump. The noise to the north is thus limited simply by reversing the heat pump.

Location C is also good. The owner's own home screens the neighbours in all directions, except to the east. The intermediate road can ensure sufficient distance to the neighbour in this direction. A screen may be installed in front of the heat pump. It will partly limit the noise to the east and partly hide the heat pump so that it is not visible from the road.

A2.16.3 Townhouses

In terraced buildings (illustrated in Figure A13) the distance to the neighbour is very small. A particularly quiet heat pump must be selected. There are not many usable locations.

Figure A13: Townhouse development (Ref Figure 2-27 in report)



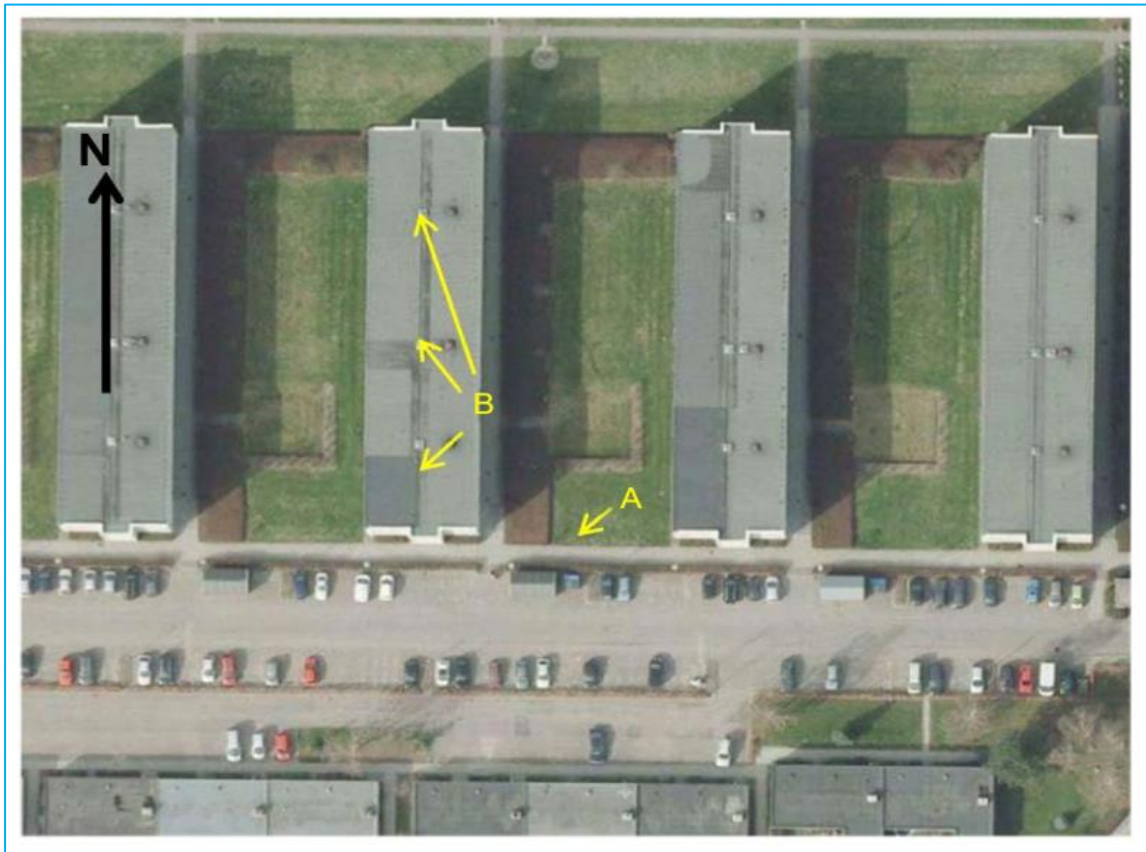
Location A is the natural location, just outside the brewery [sic]. A screen on both sides of the heat pump can protect both the neighbour's and the owner's façade and living areas. Towards the neighbour the screen should be extra high and long to ensure good noise protection. Part of both the owner's and neighbour's distant garden area will be noise burdened.

Location B can be established by setting up a noise screen on the north side (corresponds to the normal "up house" location) and the east side. The heat pump will make a noise across the road, but it is only at the restart that the noise can become critical. It is the distance to the dwelling and the sound effect of the heat pump that determines whether the noise becomes critical. Location B provides a low noise level in the gardens around the heat pump pen. On the other hand, the pipe connections become long.

A2.16.4 Apartment buildings

It can also be difficult to find a good location for its heat pump at an apartment block (illustrated in Figure A14). This guide is limited to smaller heat pumps. Heat pumps of limited size can only cover the heat consumption for a small number of apartments. More pumps per building can thus come to cause a cumulative effect.

Figure A14: Apartment Buildings (Ref Figure 2-28 in report)

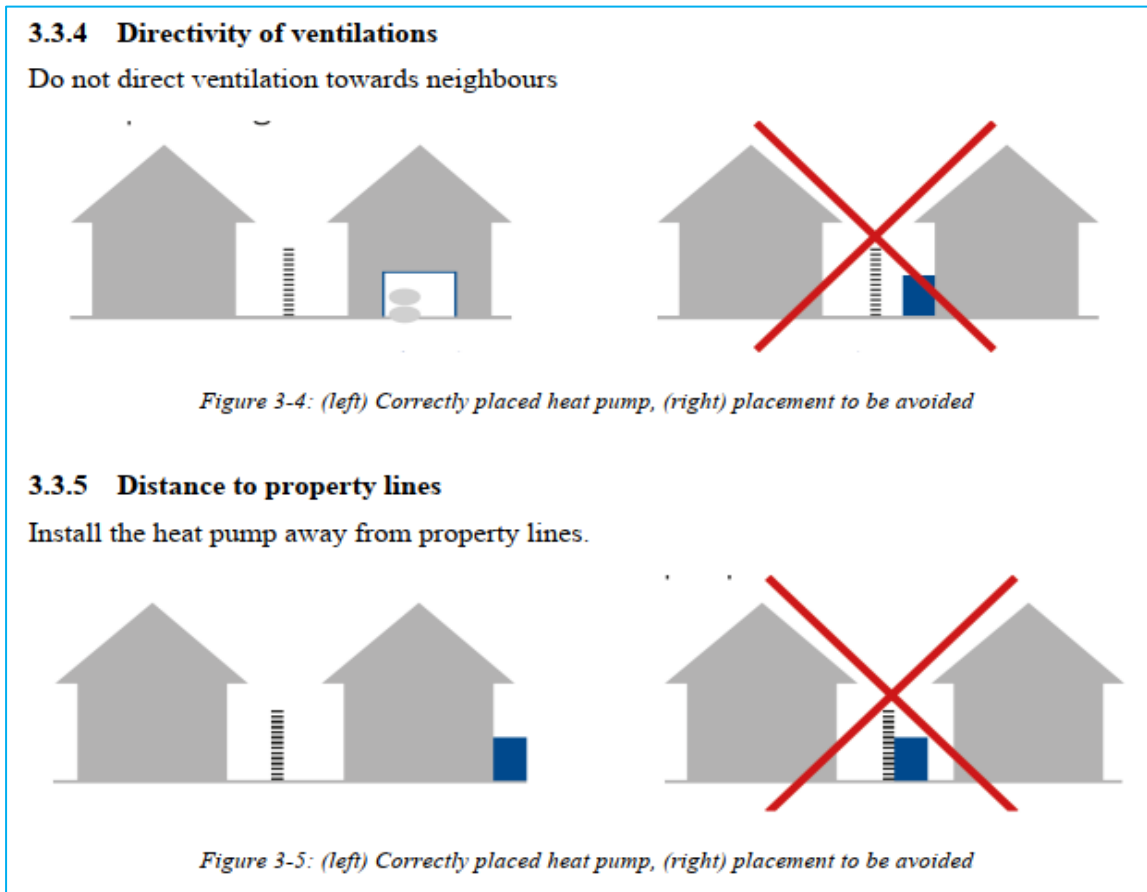


Position A can be made in a U-shaped shield, which is open to the parking space. It can shield the noise load of living areas and apartments at terrain level, but it is difficult to shield the noise from the higher situated apartments. The applicability of the solution depends a lot on the local conditions (distances, building heights, etc.). In this case, an actual noise calculation according to the guidelines of the Environmental Protection Agency should be carried out. The solution can also cause very long pipe connections.

Location B, where the heat pumps are distributed over a flat roof surface, can be a good solution. Pipe connections can be kept relatively short. By putting noise screens on the east and west sides, noise is reduced against neighbouring buildings. The heat pumps should be positioned as far inside the roof surface as possible, as the roof edges function as a noise shield as best as possible.

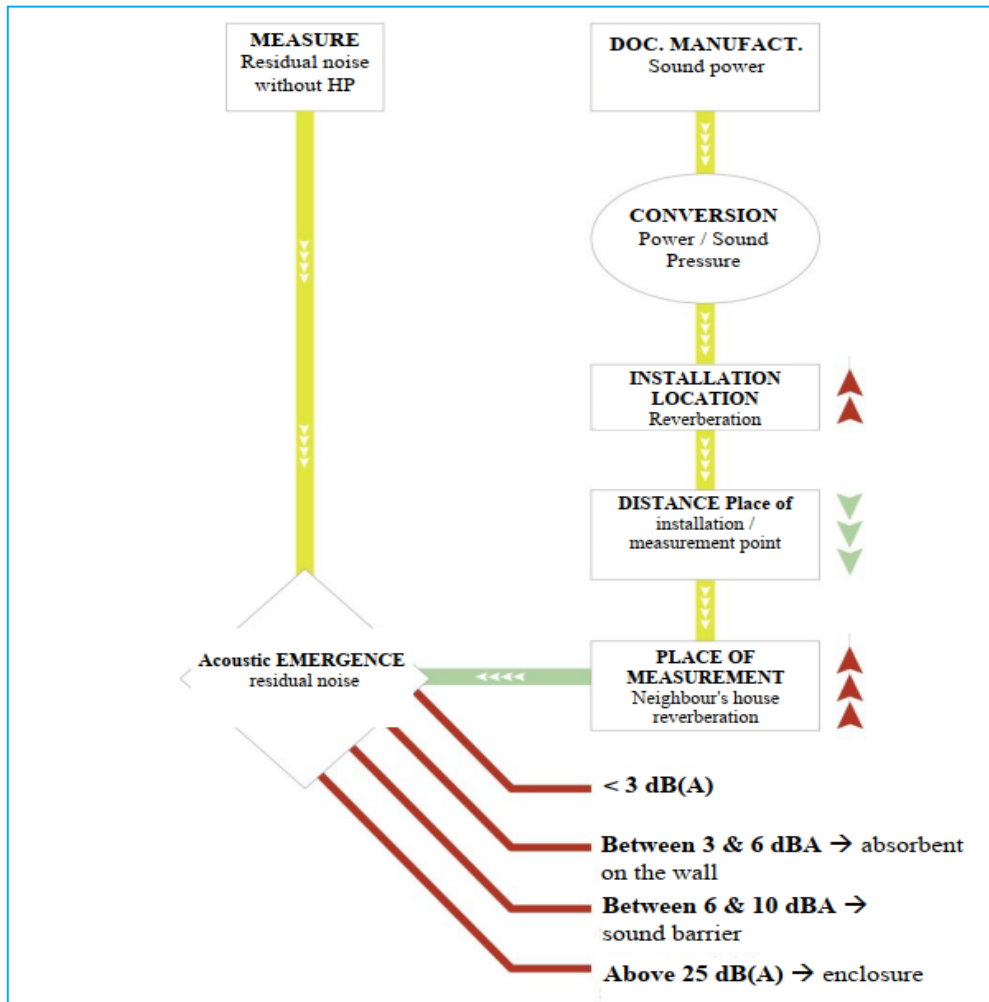
There is general guidance such as on the preferred placement of heat pumps, as illustrated in Figure A15.

Figure A15: Placement of heat pumps (Ref Figure 3-5 in report)



There is a suggestion in this document that a 3 - 6 dB reduction may be achieved by using a sound absorbent material on the wall, or up to 10 dB with a barrier (although different values are indicated for a barrier in the text below), whereas up to 25 dB can be achieved with an enclosure (see Figure A16).

Figure A16: Risk of Noise Pollution in the area (Ref Figure 5-1 in report)



A2.16.5 Absorption on the Wall, if Acoustic Emergence < 3 dB(A)

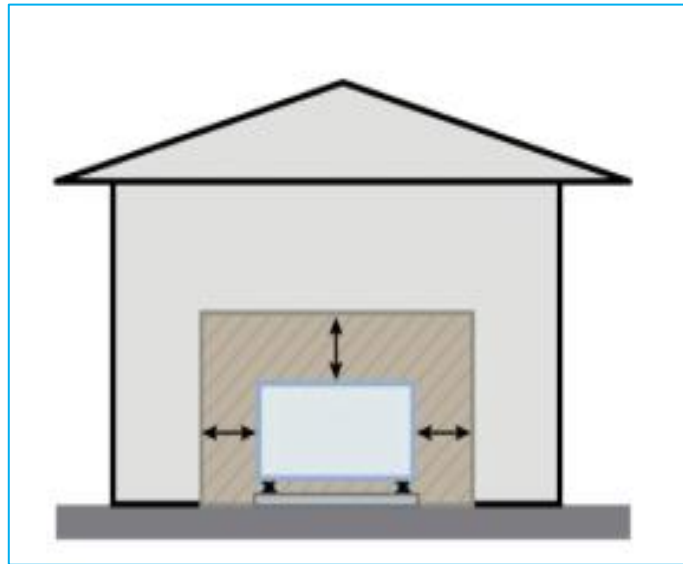
Problem: A heat pump installed against a wall generates 3 dB(A) more for the neighbourhood than if it were installed in a free field (6 dB(A) if the heat pump is in a corner) (illustrated in Figure A17).

Solution: Placement of an acoustic absorbing material on the wall(s) behind the heat pump to reduce the reflection of noise on the façade. The surface area of the absorber sheet should be larger than the dimensions of the heat pump. If the heat pump is installed in a corner, it is advisable to treat both walls.

Possible mitigation:

- Maximum 2 dB(A) if the heat pump is against a wall
- Maximum 4 dB(A) if the heat pump is in a corner

Figure A17: Absorbent on the wall (Ref Figure 5-2 in report)

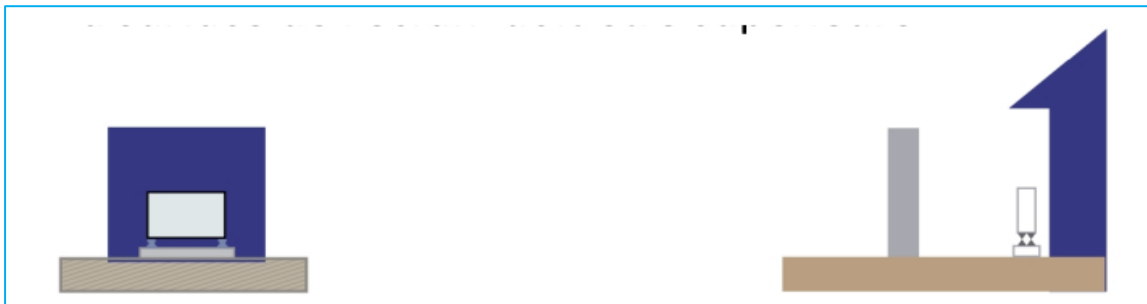


Problem: Reduce sound transmission and absorb noise in one direction. Use natural barriers wherever possible (earth banks, etc.). A hedge of trees cannot be used as a sound barrier. The effectiveness of a barrier depends on its location, size and materials (illustrated in Figure A18).

Location: The screen must be positioned as close as possible to the heat pump while allowing free air circulation.

Dimensions: The surface of the screen must be larger than the dimensions of the heat pump.

Figure A18: Sound barrier (Ref Figure 5-4 in report)



A2.16.6 Further Downloads from Annex 51 Website

There are several additional reports available for download, but the ones of most relevance to this project are:

- Bachelor work “Sound field simulations of air-water heat pumps in a terraced housing estate”
 - [Sound Field Simulations](#): a study of the sound emissions modelled from ASHPs in various scenarios in a terrace house settlement; and
 - [Appendix to Sound Field Simulations](#): plans illustrating the layouts used for each scenario in the Sound Field Simulations study.

These reports indicate that in the scenarios considered, there can be a cumulative impact of sound from the ASHPs that is detrimental to the overall sound levels. The potential for adverse interference - such as beats from very similar sound frequencies - between nearby ASHPs will be investigated under Annex 63.

APPENDIX 3 (NON- CONFIDENTIAL SECTION) - WP2: LITERATURE REVIEW

Key relevant information from the literature identified is reproduced below. All these references are either available on the web or can be provided on request.

A3.1 ACOUSTIC NOISE MEASUREMENTS OF AIR SOURCE HEAT PUMPS (EE0214), BUILDING PERFORMANCE CENTRE SEPTEMBER 2011.

This report contains a description of how heat pumps work, and measurements of ASHPs in-situ. Figures A19 and A20 provide images of ASHP noise taken with an acoustic camera.

Figure A19: Noise output from typical ASHP, casing on (Ref Picture 2-2 in report)

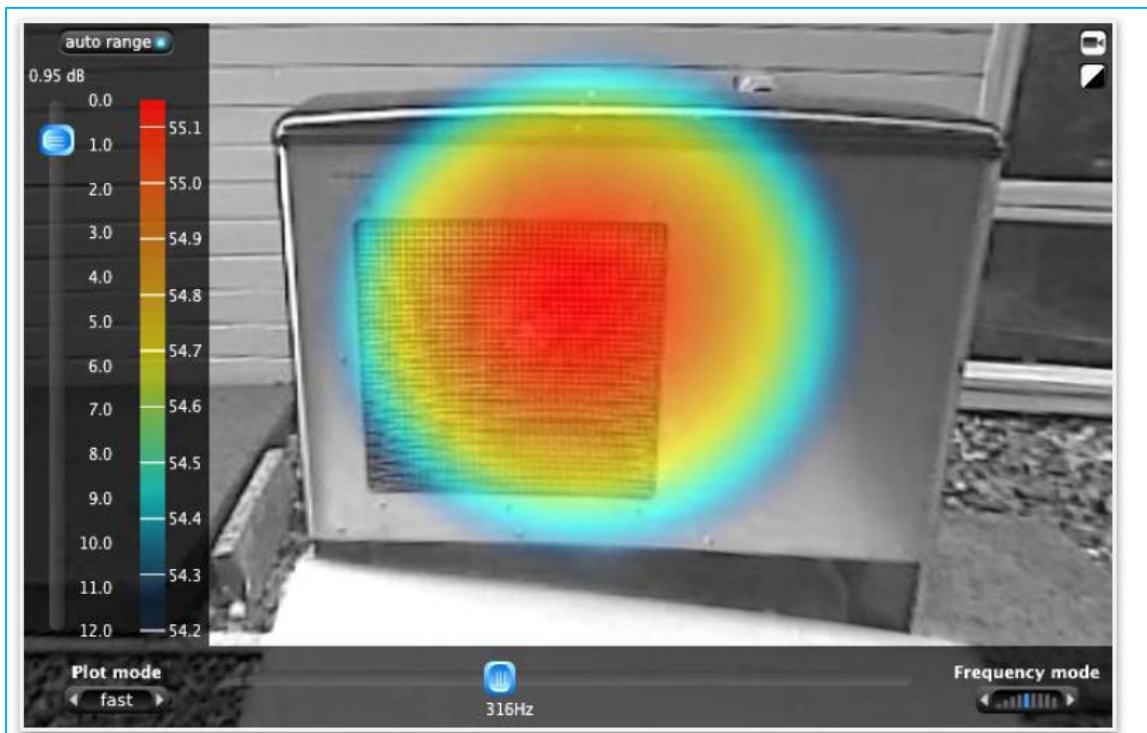
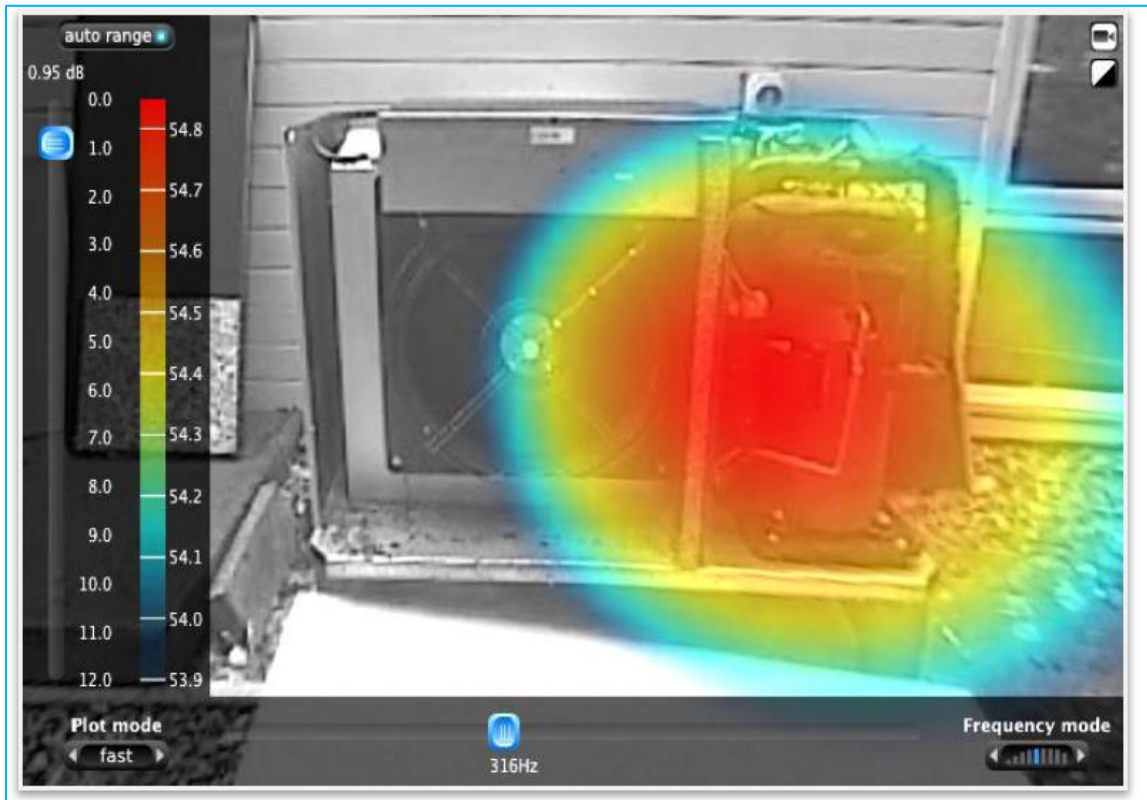


Figure A20: Noise output from typical ASHP, casing off (Ref Picture 2-3 in report)



These pictures suggest that the compressor is the only source of noise (none is visible from the fan in Figure 19 above), but Annex 51 confirms that the fan and the compressor are the main sound sources in ASHPs.

They reported that:

“It is not common for manufacturers to provide frequency information on their ASHPs. Whilst some manufacturers are known to provide basic octave band levels, no manufacturers are known to provide information on any kind of tonal adjustment that may be appropriate.”

This remains true today.

A3.2 GERMAN SYSTEM FOR ASHP NOISE CONTROL

The German Heat Pump association has a calculator with built in data for calculating the impact of ASHP noise:

<https://www.waermepumpe.de/schallrechner/>

The rules this is applying are described here:

https://www.verwaltungsvorschriften-im-internet.de/bsvwvbund_26081998_IG19980826.htm

The determination of allowable noise emissions is detailed in the Appendix, here:

<https://www.verwaltungsvorschriften-im-internet.de/BMU-IG-19980826-KF01-A001.htm>

These are the immission noise limits, extracted directly from the report:

“6.1 Immission guideline values for immission locations outside of buildings. The immission guideline values for the assessment level are for immission locations outside of buildings”.

a) in industrial areas		70dB(A)
b) in commercial areas		
	daytime	65dB(A)
	at night	50dB(A)
c) in urban areas		
	daytime	63dB(A)
	at night	45dB(A)
d) in core areas, village areas and mixed areas		
	daytime	60dB(A)
	at night	45dB(A)
e) in general residential areas and small settlement areas		
	daytime	55dB(A)
	at night	40dB(A)
f) in purely residential areas		
	daytime	50dB(A)
	at night	35dB(A)
g) in spa areas, for hospitals and nursing homes		
	daytime	45dB(A)
	at night	35dB(A)”

There are penalties for the characteristics of the noise, expressed as (K_T):

When assessed without any measurements:

Surcharge for audio and information content K_T for the part-times in which one or more tones emerge in the noise immissions to be assessed, or in which the noise contains information, the value 3 or 6 dB is to be applied for the surcharge K_T depending on the abnormality.

For systems whose noises do not contain sound or information, $K_T = 0$ dB.

If empirical values from comparable systems and system parts are available, these are to be assumed.

When assessed with measurements:

Surcharge for tone and information content

If one or more tones are audible in a noise during certain partial times T_j or if the noise contains information, the supplement for tonal and information content $K_{\tau,j}$ for these partial times is 3 or 6 dB, depending on the conspicuousness.

The tonality of a noise can also be determined by measurement (DIN 45681, draft May 1992 edition).

The tonality assessment in DIN 45681 (now 2005 version) remains a current and valid method for assessment of tonality, for a sound source only.

A3.3 FURTHER RESOURCES IN ASSESSMENTS OF TONALITY

The method described in 'ISO 20065: Acoustics - Objective method for assessing the audibility of tones in noise - Engineering method' is referenced by BS 4142. This takes an approach of assessing the level of a tone in a Critical Band (effectively the frequency bands by which humans perceive multiple tones as a single tone) and comparing it to the masking level (noise in other critical bands).

Head Acoustics' Artemis Suite (which is available to the project team) allows for a Tonality assessment using DIN 45681 which uses a similar method and will provide a penalty between 0 and 6 dB.

The 'Hearing Model' method uses a similar approach in assessing by critical band but it compares the relative levels in each band using a psychoacoustic 'loudness' measure whereas ISO 20065 and DIN 45681 use sound pressure.

As per the further resources referenced below, the hearing model provides a more robust assessment and recreates 'subjective' responses better. Objective methods should not replace subjective methods entirely but should be used as a compliment to them and provide a repeatable method for assessing tonality. They can be helpful in removing bias in subjective assessments but will sometimes miss a tone that is clearly present in a subjective assessment.

Resources:

- [Head Acoustics video tutorial](#) (covers both use of software and technical descriptions of various methods (40 minutes)
- [Internoise 2019 Paper](#) (Analysing tones in industrial and commercial sound, Matt Torjusen - comparison of BS 4142 methodology, hearing model and subjective responses)
- [Bark Scale Critical Bands](#) (Psychoacoustic scale of 24 critical frequency bands for analysing tones)
- [TTNR + PR](#) (Description of Tone-to-noise-ratio and Prominence ratio used for tonal identification)
- [Head Acoustic Hearing Model](#) (Artemis suite manual notes, very similar to below internoise paper)

- [Internoise 2018 Paper](#) (PDF Download - Head acoustics conference paper presenting hearing model).

A3.4 IEA THE FUTURE OF HEAT PUMPS, WORLD ENERGY OUTLOOK SPECIAL REPORT, NOV 2022

Energy labels (ErP) are a crucial measure to help consumers to quick and simply identify the most energy-efficient heating solutions. In most cases, energy labelling is mandatory where minimum energy performance standards are in force for heating and cooling technologies (110 countries have adopted such standards or plan to do so). In addition to energy efficiency, labels should include smart-readiness, recyclability and noise reduction features to guide consumers.

Information and awareness campaigns can also be used to debunk misconceptions among consumers about heat pump performance. Many consumers are unaware of the significant improvements that have been made in heat pump performance, including efficiency and noise, in recent years. Initiatives to promote dialogue at the community level can also bolster consumer trust in the technology, share lessons learned and impart information to homeowners considering switching to a heat pump.

Reference: A policy toolkit for global mass heat pump deployment, available at: https://www.raponline.org/wp-content/uploads/2022/11/RAP_Heat_Pump_Toolkit.pdf

R&D efforts are currently focused on smart and flexible features, reduced noise, higher efficiencies, more compact design, improved ease of installation, and lower environmental footprints associated with the materials and refrigerants used.

Restrictions on new installations

The installation of a heat pump is subject to a number of restrictions, approvals and practical constraints in most countries. Installations must usually adhere to building, fire safety, land use and electrical codes and regulations. They may also require the approval from homeowners or buildings associations, which may be concerned about aesthetics and noise, as well as from the Local Authority under planning rules.

Labels should include smart-readiness (i.e. QR links to more information for instance), recyclability and noise reduction features to guide consumers. Information and awareness campaigns can also be used to debunk misconceptions among consumers about heat pump performance. Many consumers are unaware of the significant improvements that have been made in heat pump performance, including efficiency and noise, in recent years. Labels provide a contact point through which to educate as well as inform.

A3.5 FACTORS INFLUENCING THE UPTAKE OF HEAT PUMP TECHNOLOGY BY THE UK DOMESTIC SECTOR

H. Singh, A. Muetze, P.C. Eames,

Renewable Energy, Volume 35, Issue 4, 2010, Pages 873-878, ISSN 0960-1481,

Noise has also been identified as a possible problem with the existing class of ASHPs [Reference: Shackleton RJ, Probert SD, Mead AK, Robinson A. Future prospects for the electric heat-pump. *Applied Energy* 1994;49(3):223–54.]. ASHP noise problems can be mitigated by housing them in enclosures with improved acoustic performance and employing less noisy fans and parts. Design improvements aimed at achieving lower noise levels and reducing the frosting problems increase the capital and running cost of the ASHPs.

A3.6 DOMESTIC HEAT PUMPS IN THE UK: USER BEHAVIOUR, SATISFACTION AND PERFORMANCE

Caird, S., Roy, R. & Potter, S.. *Energy Efficiency* 5, 283–301 (2012).
<https://doi.org/10.1007/s12053-012-9146-x>

This study reports user's own satisfaction with heat pumps, rather than concerning the noise impact on neighbours.

Nearly a fifth (19%) of heat pump users said that intrusive noise was a problem and this was a problem for proportionally more (33%) social residents than private householders (9%). This distinction aligns with that identified in the Welsh Survey results for noise more generally. Most of the problems for social residents were with ASHPs whose fans may be heard if the unit is located near windows or on the outside walls of living or bedrooms, which is more likely given the much smaller average size of the social housing dwellings. Although noise only affected a minority of users, it indicates an area for improvements to heat pump design and installation, especially for social housing.

A3.7 EXPERIENCE RATES OF LOW-CARBON DOMESTIC HEATING TECHNOLOGIES IN THE UNITED KINGDOM

Renaldi Renaldi, Richard Hall, Tooraj Jamasb, Anthony P. Roskilly,

[Energy Policy, Volume 156, 2021, 112387, ISSN 0301-4215,](#)

This paper presents the experience curves of low-carbon domestic heating technologies in the United Kingdom between 2010 and 2019. This study focuses on domestic heating technologies including air-source heat pumps. Using UK installation cost data for 2010 to 2019, we found that low-carbon heating technologies had experience rates of; air-source heat pumps $-2.3 \pm 5\%$, significantly lower than the reported rates of similar technologies in the literature. The resulting experience rates can be used in energy economics models and to inform policymakers in developing further deployment programs.

A3.8 ADOPTION OF AIR SOURCE HEAT PUMPS FOR LOW CARBON HOMES

[Burley, J and Pan, W](#) (2010). In: Egbu, C. (Ed) *Procs 26th Annual ARCOM Conference*, 6-8 September 2010, Leeds, UK, Association of Researchers in Construction Management, 1361-1370.

This paper explores the perspectives of the developer and householders on utilising ASHPs, through a case study with a medium-sized developer utilising ASHP for a new-build development in East England. The case study involved document analysis, face-to-face interviews with the firm's senior management team, and a postal questionnaire survey of occupants in homes installed with an ASHP.

The householders were positive of the economy, space impact, reliability and maintenance of ASHP, but negative of its visual impact and the noise issues.

Noise is reported as an obstacle in the prior literature, such as the review of micro-generation and renewable energy technologies, NHBC Foundation.

A3.9 A REVIEW OF MICRO-GENERATION AND RENEWABLE ENERGY TECHNOLOGIES

Fisher, J, Jessop, C, McGuire, K and Waddelove, A (2008). Amersham: [NHBC Foundation](#).

Noise and vibration Air source heat pumps emit noise from the fan and compressor which can cause a nuisance. They should not be sited in close proximity to bedrooms or neighbouring properties.

A3.10 ZERO CARBON: WHAT DOES IT MEAN TO HOMEOWNERS AND HOUSE BUILDERS?

Davis, I and Harvey, V (2008) Amersham: [NHBC Foundation](#).

There is concern among homeowners about the additional costs, the reliability of the technologies and environmental impacts, such as noise pollution. However, those owning new homes would, in principle, be fairly interested in purchasing a home incorporating microgeneration.

A3.11 EFFECTS OF NOISE FROM NON-TRAFFIC-RELATED AMBIENT SOURCES ON SLEEP: REVIEW OF THE LITERATURE OF 1990-2010

[Omlin, S ; Bauer, G F ; Brink, M](#)

This article reviews the literature about the effects of specific non-traffic-related ambient noise sources on sleep that appeared in the last two decades. Although everybody is faced with noise of non-traffic and non-industry origin (e.g. heat pumps etc.), little scientific knowledge exists about its effects on sleep. The findings of the present extensive literature search and review are as follows: Only a small number of surveys, laboratory and field studies about mainly neighbourhood, leisure and animal noise have been carried out. Most of them indicate that ambient noise has some effect on human sleep. However, a quantitative meta-analysis and comparison is not possible due to the small number of studies available and at times large differences in quality.

A3.12 QUESTION TO CHATGPT ON 14/02/2023: IS NOISE AN OBSTACLE TO THE UPTAKE OF ASHPS

<https://chat.openai.com/chat>

Response: Noise can be a concern for some people when it comes to air source heat pumps (ASHPs), but it is not typically considered a significant obstacle to their uptake. ASHPs are generally quieter than other heating systems, such as oil or gas furnaces, and many models have noise-reducing features such as insulated compressors and sound barriers.

While some people may be sensitive to the noise that an ASHP generates, many others find it to be minimal and not disruptive to their daily lives. Additionally, the benefits of ASHPs, such as energy efficiency and cost savings, often outweigh any concerns about noise.

That being said, it's important to note that the noise level of an ASHP can vary depending on the model and installation location. If you are considering installing an ASHP, it's a good idea to research different models and consult with a professional installer to determine the best location for installation to minimise noise disruption.

APPENDIX 3 (CONFIDENTIAL SECTION): WP3 & 4: DISCUSSIONS WITH MANUFACTURERS AND OTHER INDUSTRY BODIES

A3.13 WP3: MANUFACTURERS

The top manufacturers (according to the MCS installation database) were targeted for discussions. This appendix contains the notes from those discussions. It is not intended that this section be published beyond the working group and the Tables should be redacted for GDPR purposes - many sources who spoke to us would prefer anonymity and so the second column of this table provides a key to allow simple redaction. The references summarised in Table A14 are used from the main report.

Table A14: References

Redacted.

Manufacturer A, 14/12/22

Redacted.

Manufacturer B, 18/01/2023

Redacted.

Manufacturer C

Redacted.

Manufacturer D, 1/02/2023

Redacted.

Meeting notes

Redacted.

Manufacturer E

Redacted.

Manufacturer F

Redacted.

Installer G, 10/02/2023

Redacted.

Laboratory H, 20/12/2022

[**The answers have been approved by our Technical Director, but please note we request you anonymise our answers in any report, presentations, etc.**]

Redacted.

I - Quiet Mark, 26/01/2023

Redacted.

J - iKoustic AKTP with Salford Uni

[**This information is subject to an NDA, and should not be shared further, without full redaction**].

Redacted.

A3.14 WP4: REVIEW WITH HEAT PUMP ASSOCIATION, MICROGENERATION CERTIFICATION SCHEME & ENERGY PROVIDERS

K Microgeneration Certification Scheme (MCS), 6/01/2023

Redacted.

Figure A20: Number of ASHPs installed within each of the Local Authorities in Wales scaled with size of dots

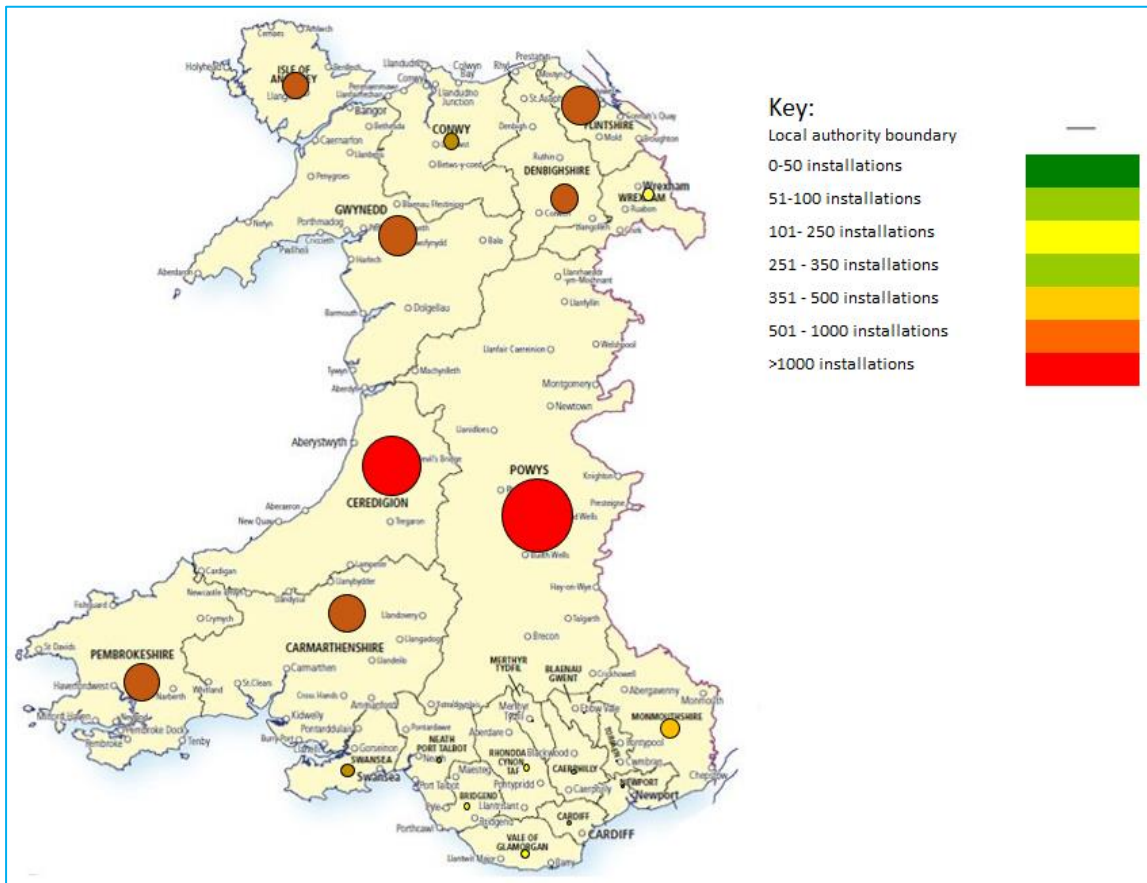


Figure A21: Number of units per person within each of the Local Authorities in Wales, scaled linearly with the size of dots.

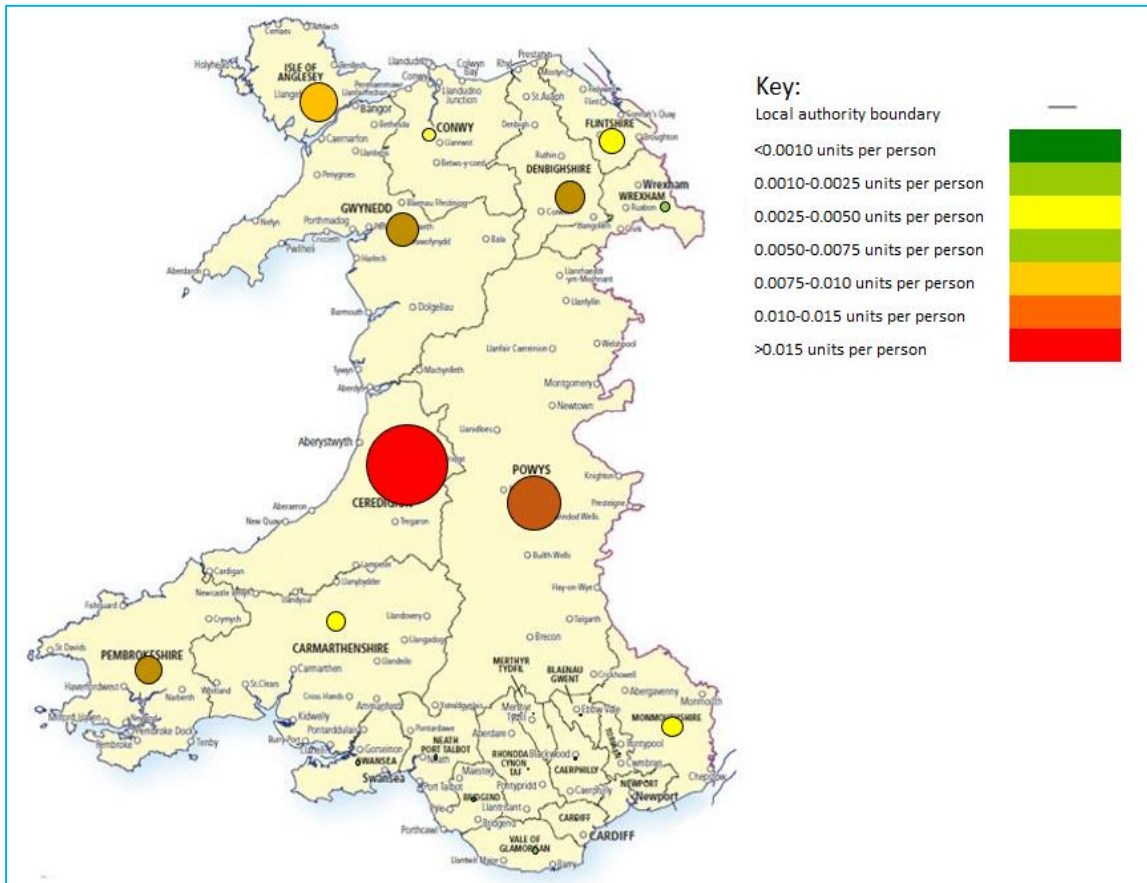


Figure A 20 illustrates that Powys Council has the largest number of ASHPs installed using the MCS MID (1396 units), followed by Ceredigion Council (1132 units). However, Figure A 21 illustrates that there are more ASHP installations per person within Ceredigion Council than Powys Council, which indicates this is the location of greatest roll out. This is a rural area, indicating that these may be driven by low density properties upgrading their oil boilers.

L Heat Pump Association, 17/01/2023

Introduction to the Heat Pump Association

The Heat Pump Association (HPA) is a trade association that promotes the use of heat pumps as a low carbon solution to heating. Its members include many of the country’s leading manufacturers of heat pumps, components and associated equipment, as well as installers, utility companies and other entities critical to the supply chain of the heat pump industry.

The HPA liaises with Government departments to provide expert advice on legislation, standards, guidance and financial incentives related to heat pumps. It aims to raise awareness of heat pumps by informing prospective specifiers of their long-term benefits, reassuring end users and providing up-to-the-minute advice on the various systems available by generating publicity using exhibitions, literature, promotions and public relations.

Discussion with the Vice Chair of the Heat Pump Association

Redacted

A3.15 WP4: ENERGY PROVIDERS

The following Energy providers were interviewed.

EP-A, 21/02/2023

Redacted

EP-B, 03/03/2023

Redacted.

EP-C, 09/03/2023

Redacted

APPENDIX 3 (CONFIDENTIAL SECTION): WP5: APPROACH CIEH (IOA SURVEY) & WELSH LOCAL AUTHORITIES TO UNDERSTAND EXTENT OF COMPLAINTS

A3.16 WP5: WELSH GOVERNMENT SURVEY - NATIONAL SURVEY

Summary of results comparing 2017-18 (sample size 2,600), and 2021-22 (sample size 11,650) for the two questions relating to noise:

- Q1: Whether bothered by noise outside your home in the last 12 months
- Q2: Cause of disturbance

The summary of results indicated the trends summarised in Table A15.

Table A15: Summary of Welsh Government National Survey, relating to noise

Question Number and Classification	2017-18	2021-22
Q1 = Yes	24% ± 2%	26% ± 1%
Q1 by Age Group	16-44 years = 31% ± 9% 45-64 years = 22% ± 3% 65+ = 16% ± 4%	16-44 years = 29% ± 2% 45-64 years = 27% ± 2% 65+ = 21% ± 2%
Q1 by Sex	No difference	Male = same as average ± 2% Female = 27% ± 2%
Q1 by Deprivation	Most 20% = 34% ± 6% Q2 = 31% ± 5% Q3 = 22% ± 4 to 5% Q4 = 19% ± 4 to 5% Least 20% = 15% ± 4 to 3%	Most 20% = 38% ± 2% Q2 = 29% ± 3% Q3 = 26% ± 2% Q4 = 23% ± 2% Least 20% = 19% ± 2%
Q2 by Cause	a)Neighbours inside = 36% b)Neighbours outside = 46% c)Traffic, businesses or factories = 45%	a)Neighbours inside = 23% b)Neighbours outside = 41% c)Traffic, businesses or factories = 41%
Q2 by classification	Urban = same as above but 1% increase for a). Rural = less for a) by 1%, 2% more for b) and 1% more for c)	Urban = same as above but 3% increase for a), 2% for b) and 1% drop for c). Rural = less for a) by 8%, 7% less for b) and 2% more for c)

Question Number and Classification	2017-18	2021-22
Q2 by Tenure	insufficient accuracy due to sample size to comment.	An increase for a) for a Social House against others, with less disturbed by c) in Social Housing than others.

A3.17 WP5: CHARTERED INSTITUTE OF ENVIRONMENTAL HEALTH AND INSTITUTE OF ACOUSTICS SURVEY



Purpose of the Survey

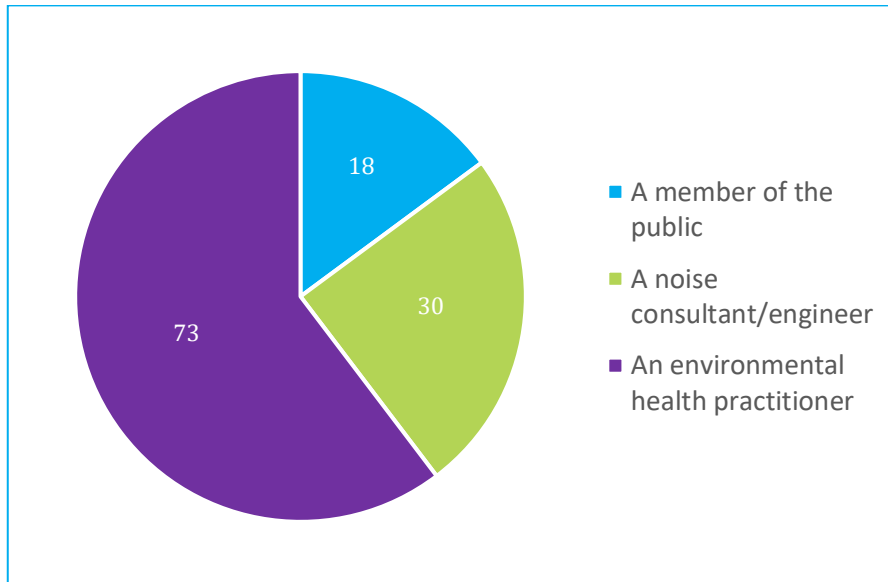
The Institute of Acoustics (IOA) Noise and Vibration Engineering Group set up a survey to collect information on ASHPs and noise in 2021 during the process of preparing a joint guidance note with the Chartered Institute of Environmental Health (CIEH), which has since been published and provides a Practitioners Note and an advice for the public. It also includes calculation which provides an alternative to the MCS calculation. This was prepared to provide a temporary bridge between that and what would be expected by BS 4142, indicating that noise impact from heat pumps installation was a concern, but the survey was set up to find out how much this was being seen in reality.

There were 121 responses at the time of writing, on average taking just under 10 minutes to complete. This included 21 additional responses since the Welsh Government put out a requirement for Welsh Local Authorities to offer their views as part of this survey.

Details of Respondents

It is interesting to note that 62% of respondents to the survey worked in Local Authority. This high percentage is likely to be reflective of the CIEH encouraging its members to complete the survey.

The results therefore offer a good indication of how English and Welsh Local Authorities are experiencing, or have views on, the concern of domestic ASHP and noise.



The fact that there were 17 members of the public completing the survey indicates that private complaint information of small data sizes was also likely to be included in this data set.

Not all questions were answered by all respondents so responses to each question are summarised in Table A16.

Table A16: Summary of results from IOA ASHP survey 2022-23 (ongoing)

Question	Responses
Do you have a ASHP at home?	1 of 121 said yes (1.7% of total or 11% of public responses)
Made complaints to someone ?	10 of 121 said yes (5.9% of total, 50% of number of public responses)
Did the ASHP belong to the neighbour?	7 of 121 said yes (100% of those who declared they made complaints)
Who did you make your complaint to?	6 (90% of those who declared they made complaints) Neighbour 8 (80% of those who declared they made complaints) LA 4 (40% of those who declared they made complaints) MCS 2 (20% of those who declared they made complaints) Supplier, manufacturer or installer 3 (30% of those who declared they made complaints) Other
What measures were taken?	0 (0%) measures taken 2 (20%) Nothing done 2 (29%) Stat. Nuisance

Question	Responses
	1 (14%) No Stat. Nuisance 2 (29%) Other
Did LA serve an abatement notice?	1 (50% of respondents to this question) yes 1 (50% of respondents to this question) no
Of 30 responses to question have you received complaints of noise or being asked to comment on them linked with ASHP?	11 (37% of respondents to this question) yes 19 (63% of respondents to this question) no Or 15% of LA respondents said yes
Of those 11 involved in complaints it was asked who was complaining	4 (36% of respondents to this question) Occupier 8 (73% of respondents to this question) Neighbour
Of the 11 it was asked if they evaluated the noise	10 (91%) yes
Those 10 were asked what the cause of the complaint was in their opinion in relation to the character of the sound	5 (50%) Broadband noise 4 (40%) Tonal noise 2 (20%) Rough modulating 3 (30%) Transient/Intermittent 6 (60%) Daytime impact 7 (70%) Night-time impact
Factors affecting the sound of the 7 responses ?	Reflective surfaces, placement, location, light wells, receptor positions.
What assessment method used?	8 (80%) BS 4142 2 (20%) Absolute levels 2 (20%) other
Taking context into account was the complaint justified?	7 (70%) yes
Was noise control possible to take to control it?	5 (50%) yes
Were those measures fully or partially successful?	5 (100% of respondents answering that noise control was possible) yes
Have you received a complaint of a domestic ASHP?	47 (60% of environmental health practitioners) yes
Was a Statutory Nuisance established?	16 (34%) yes

Question	Responses
Was an abatement notice served?	6 (38% of the 16) yes
Of those responding, the places affected were:	3 (6%) indoors windows closed 7 (15%) indoors windows open 14 (30%) outdoors 12 (49%) combination
Was the ASHP installed under Permitted Development as part of MCS scheme?	11 (23%) Yes 18 (38%) No 15 (32%) Don't know
Were you provided with the MCS 020 calculation?	6 (55%) said yes 4 (45%) said no
In the free text sharing response 92 responses (76%) of total responses were provided. Of those all identified noise as an issue with a wide range of specific concerns identified.	76% of all respondents answered this question indicating noise was an issue (a small minority of those said it was not)

A3.18 WP5: WELSH LOCAL AUTHORITY INTERVIEWS

All 22 Local Authorities in Wales were contacted to ask if they have received complaints about noise from domestic ASHPs and requested to join a short interview to explore their experiences to date.

Responses from 20 authorities (allowing for those with shared services) were received, making the response rate 91%.

In addition to the responses to the request for information, thirteen detailed interviews were completed (59%) with Environmental Health/Protection personnel at the following authorities, which is used as a key to the interview script responses that follow:

- redacted

A3.19 WP5: WELSH LOCAL AUTHORITY INTERVIEW NOTES

Redacted.