Report Partners:

Sustainable Acoustics

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Welsh Government, Energy Division, Energy Division

AIR SOURCE HEAT PUMP NOISE & PERMITTED DEVELOPMENT RIGHTS IN WALES

Phase 2 Report

Contract Ref: ASHP-PDR/2022-23

Llywodraeth Cymru
Welsh Government

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Contract Ref: ASHP-PDR/2022-23

Date of Issue: 5th January 2023

Status: **FINAL**

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CONTENTS

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 and so is suitable for sharing in the public domain. Reference to the Phase 1 report relates to the redacted public version which should be shared to satisfy the data handling obligations of the authors and subject to GDPR. Please be cognisant that sharing the full Phase 1 document may require further consents, which are beyond the data handling obligations of the authors.

Translation statement: This document has been translated into Welsh in all ways except for the figures, which are treated as images, and may contain text in English."

EXECUTIVE SUMMARY

This report examines noise and permitted development rights for air source heat pumps (ASHPs) in Wales. Phase 1 of this project found that noise is a major factor affecting ASHP deployment in Wales, primarily due to constraints imposed by the 3 metre boundary rule, and the Microgeneration Certification Scheme (MCS) noise assessment. Phase 1 report has been prepared separately.

Phase 2 of this project focuses on better understanding the obstacles to ASHP deployment related to noise, and developing responses to overcome these obstacles. A prototype acoustic design tool is presented to demonstrate how to simply identify suitable low-noise ASHPs from a modified MCS MID database for a given installation. Case studies for all common residential archetypes demonstrate the potential feasibility of ASHP installations accounting for existing noise constraints and how these may be feasibly achieved. Interviews with installers provide further insights from those gained in Phase 1 into issues of compliance with MCS requirements.

The key findings are:

- The 3 m boundary distance rule is the biggest obstacle to ASHP installation in Wales and should be removed. Interviews found general support for requirements based on permitted noise levels at receptors rather than fixed boundary distances that provide proxy buffer zones.
- Easily accessible noise data on ASHPs would allow homeowners and installers to find and select suitable low-noise units. The sound power level could be incorporated into the MCS MID database, with accompanying search tools to identify noise-compliant units. A prototype acoustic design tool has been provided to illustrate how compliance with the existing permitted noise level of MCS 020 could be carried out.
- Noise barriers/ screening are mitigation measures typically not currently installed by ASHP installers, but may help facilitate installations of ASHPs in terraced/semi-detached houses. Case studies show the value of noise barriers in these situations.
- The stepped nature of the MCS calculation adds an unnecessary additional noise constraint of 2dB. The proposed digital calculation tool would overcome this limitation, removing this anomaly.
- Detached rural houses present the easiest ASHP installations from a noise impact perspective, and are the focus of the current installations. Additional assistance is needed to facilitate installations for terraced and semi-detached houses, which represent the majority of the housing stock.
- It has been demonstrated how the current noise constraints can be achieved for the densest archetypes by a combination of selecting appropriate units using the acoustic design tool proposed, access to sound power information, and potentially some additional noise barrier mitigation, if split systems are used.
- Further work is required to determine if the current permitted noise target is adequate to deal with protection of quality of life, cumulative impacts of multiple units, tonality, directionality, intermittency and variation in noise generated over the seasons and at different heat loads; also to better understand and improve the public perception of noise from ASHPs through guidance and education.

SUMMARY

The key finding of Phase 1 of this project was that noise is one of the major factors currently affecting the deployment of air source heat pumps (ASHPs) in Wales. However, the main constraint is the 3 m to the boundary rule, which is understood to act as a proxy for noise. If this constraint is removed, the noise calculation and the permitted noise target stipulated in the Microgeneration Certification Scheme (MCS) standard MCS 020 becomes the next most significant obstacle. Complaints about installations are not a common occurrence, but there is a concern that as the more challenging deployments occur that they may become more numerous.

Given this finding from Phase 1, the focus of Phase 2 was redirected to gain a better understanding of the specific issues and obstacles relating to noise that are hindering more widespread deployment of ASHPs. This was intended to provide an evidence base to inform potential modifications to the noise requirements that would help remove unnecessary obstacles to a de-carbonising technology.

Prototype web-based tools are presented that demonstrate the value and importance of making ASHP sound power data more readily accessible to all interested parties. Currently this information can be difficult or near impossible to find even though it is legally required to be publicly available. It is necessary for installers / homeowners to be able to search for units with suitable sound power level ratings when noise constrains potential installations. Case studies have been developed for common residential archetypes that illustrate feasible solutions, if suitable access to sound power data is searchable in a database.

Interviews conducted with both large-scale installers as well as independent installers provide some consistent insights. There is general agreement that the current 3 m boundary distance rule is restrictive and the biggest single factor preventing installations in many situations, especially for terraced housing archetypes. Most installers would prefer a permitted noise target at receptor locations rather than fixed distance rules. Noise barriers are also rarely installed currently, but demonstrating their use through case studies and other guidance could significantly increase the feasibility of installations in more challenging situations such as terraced or semi-detached houses. This may not be desirable from a planning perspective, however.

The stepped approach used in the MCS 020 noise calculation methodology is found to introduce unnecessary additional noise constraints, compared to direct calculation. The calculation method adds an additional 2 dB noise penalty on average, beyond the stated aims of the MCS 020 calculation, which seems to be an aberration in the longhand calculation process. This can be corrected by simplifying the process as suggested.

Detached rural houses with larger distances to neighbours have the fewest noise constraints for early adoption of ASHP technology, and are the first to be deployed to because of the lower risk of abortive survey work and cost by the energy providers seeking to deploy in Wales. However, enabling installations in terraced and semi-detached houses, which comprise the majority of all properties in Wales, is considered an urgent priority, in order to allow ASHP installation and deployment widely, and so that equity can be achieved for occupiers of all property archetypes.

In summary, with a combination of improvements including better accessibility of noise data, development of case studies, refinements to the MCS noise calculation methodology, and removal of unnecessary permitted development restrictions, it is considered that noise constraints on ASHP installations can be significantly reduced without risking affecting the quality of life and wellbeing of residents provided further work is done to provide additional confidence that the level of control of noise is adequate. This will in turn support the widespread deployment of ASHPs across all residential archetypes.

Further work must be done into whether the permitted noise target is set correctly to cater for cumulative impacts, tonality and the range of noise generated as part of an ASHPs operation in different climatic conditions and loads to provide the confidence sought.

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".

1.2. Phase 2

Following the findings of Phase 1, the scope for Phase 2 was adjusted. The originally conceived scope had focused on developing options with the Welsh Government to consider the application of a soundscape approach and other options to reduce noise as an obstacle to the uptake of ASHPs, and prepare an impact assessment of each of the options.

Phase 1 works revealed that the preconceived direction of travel for Phase 2 was not aligned with the discovery and conclusions of the Phase 1 report. Phase 1 work found that noise is one of the major factors affecting ASHP deployment in Wales, but the reason for this is perhaps surprisingly not currently due to the levels of complaints regarding noise from ASHPs, but as a result of the assessment tool in MCS 020. This indicated that it would be premature to focus all of the efforts of Phase 2 on PDR until it was better understood what changes might be needed to remove the constraints imposed by MCS 020 and other factors affecting ASHP deployment in Wales.

It was therefore proposed to vary the Phase 2 works to focus on better understanding the reasons behind obstacles to deployment. This is to inform, feed into and accelerate the work now ongoing by the UK Government, with a view to achieving better evidence on which to base future decisions on PDR in Wales following the outcomes of a larger piece of work relating to England and the devolved nations. The change of focus for Phase 2 was proposed to better understand the obstacles associated with noise as experienced by practitioners and installers. When the obstacles are understood, the means of overcoming those obstacles can be developed.

The work packages in Phase 2 are summarised as:

1 **Towards a web-based design calculation tool**
The goal is a web-based design tool that draws on the MCS MID database of approved ASHPs, but also includes ASHP sound power level. The proof-of-concept prototype is developed as a Microsoft Excel tool.

2 **Template example solutions**
Use the (Excel) design tool from WP1 to develop the technical solutions in a series of template examples that could illustrate typical situations and the range of currently available ASHPs that could be adopted.

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.

4 **Deeper investigation with the housing association**
Understand their concern, and how / why they were not able to overcome it. This is a review WP, to understand if any better information about noise could have overcome that obstacle. Prototype test the information from WPs 1, 2, 3.

5 **Deeper investigation with the installers**
e.g. Octopus, EON and Centrica and/ or those people who report having "20 % of aborted visits" due to noise. Prototype test the information from WPs 1, 2, 3.

6 **Interview four independent ASHP consultants**
Who are essentially carrying out the same process as the larger installers. Prototype test the information from WPs 1, 2, 3.

2. METHODS

2.1. WP1: Towards a Web-Based Design Calculation Tool

The goal for this WP is a web-based design tool that draws on the MCS MID database of approved ASHPs, but also includes the ASHP sound power level so that sound can be considered from the outset. The concept is developed with a selection of manufacturers' data in a Microsoft Excel tool that were presented to installers and surveyors during the interviews of WP5 and WP6. This tool can be used to demonstrate compliance with MCS 020; in addition, and much more powerfully, this tool can be used as a design tool to identify which ASHPs could comply with the noise constraints for a particular installation. At present, there is no practical way for any homeowner or installer to know whether the potential candidate ASHP that they are considering fares well or badly in noise impact terms, compared with other machines available on the market.

Noise information for different manufacturers' machines can be difficult to identify in their literature. The proposed tool represents a democratisation of access to noise information in the design process. The noise question becomes accessible to all parties – homeowners, installers, regulators. This tool is not revealing information that is otherwise secret – manufacturers are compelled to publish this information in accordance with national and European legislation – but currently it is not possible to search and compare different manufacturer's performance for noise. Currently the thermal performance in terms of SCOP is available on the MCS MID database, but not the sound power level, although that data is essential for carrying out the noise impact calculation.

This work package develops the proof-of-concept prototype that demonstrates the capability of such a tool. Completion of this work for public use would require collaboration with MCS for a live web-based tool that has access to the MCS MID database, which is beyond this scope of work.

The prototype is developed by considering what type of information may be desirable for a homeowner, the client, or an installer to understand. It is based on the application of the MCS 020 methodology (1) without modification.

For a given site, the heating power required and most favourable location for the ASHP are currently identified by a surveyor (as part of the installer team). This means that the distance to the neighbour's window or door to a habitable room is also known. The arrangement of reflecting surfaces around the ASHP is also known, as is the presence of any partial or full barriers. Thus the inputs to the noise calculation are all known:

- Distance to receptor location;
- Reflecting Planes;
- Acoustic screening.

From this information. The permitted maximum sound power level can be calculated that would meet the permitted noise target of MCS. To determine if there is a suitable ASHP that meets this sound power constraint, it is also necessary to know the:

- Heating power required.

The first element of the prototype tool takes these pieces of information and performs a database search, to return the available manufacturer's makes and models of ASHPs that meet the sound power level limit and heating power output.

This sound power database could be held on the MCS MID database to maintain an up-to-date data set, using data that is already legally required to be made available for each unit. This data is currently not available on the MCS MID database.

2.2. WP2: Template Example Solutions

In this work package, we use the design tool from WP1 to develop the technical solutions in a series of examples that illustrate typical situations and the range of currently available ASHPs that could be adopted. Homeowners and installers can easily relate to examples for different residential archetypes, so that they can quickly and simply understand whether or not noise may constrain their desire for an ASHP installation. The simplicity of this approach addressed a key area of interest of Welsh Government's brief.

To propose sample solutions, it is necessary to identify archetypal building stock in Wales. We have not been able to identify stock archetypes for Wales alone; the most relevant data that we have identified are from the "*Building Supply Chain for Mass Refurbishment of Houses - Stock archetypes in the UK. Tabulations for the specification of refurbishment solutions*" (2).

This document's objective is to describe the UK housing stock in terms which assist in the assessment of the potential for thermal efficiency retrofit solutions. The description of the housing stock is principally based on the physical characteristics of the dwelling. The description of the stock is based upon the analysis of data from the national House Condition Surveys (HCSs) undertaken in each of the four nations. The dwelling stock is subdivided into 40 archetypes of dwelling based on built form and age. Approximately 12 of these types represent almost 60% of the dwelling stock. For these, multiple other characteristics of specific relevance to a refurbishment programme are also described.

Some of the archetypes described are similar in terms of the ASHP and noise considerations. For the purposes of this WP, template solutions are considered for three archetypes. It is also necessary to determine an appropriate heating power requirement for each archetype considered, assuming that these do not undergo a deep energy retrofit prior to installing a heat pump. The Excel tool from WP1 is used to calculate the noise constraints, barrier requirements and examine the acoustic feasibility of ASHP installation in typical places.

2.3. WP3: Ready Reckoner Design Charts

'Ready reckoner' design charts provide a simple visual means of quickly identifying any noise constraints associated with a potential design decision. A variety of visualisations of noise constraints are explored and presented, connecting heating power requirements, sound power levels, and distance constraints all in one place.

2.4. WP4: Deeper Investigation with Local Authority Example

A follow-up interview with the Local Authority which identified a particular case study was conducted to explore the particular example given in more detail. A two-hour interview was conducted as an online video call.

2.5. WP5: Deeper Investigation with Energy Providers and Installers

The three energy providers that were interviewed for Phase 1 were approached again to understand in more detail:

1. What issues are experienced when complying with MCS 020 ?
2. What changes to the MCS 020 calculation method would benefit the installation of ASHPs ?
3. Is noise an insurmountable obstacle for some building archetypes ?
4. What is the cost implication of additional noise mitigation measures implemented?

Two of the energy providers provided a second interview, with one abstaining. Interviews were conducted as online video calls.

2.6. WP6: Interview Independent ASHP Consultants

Requests for an interview were sent to 14 independent ASHP installers, however, only one installer responded positively. The interview was conducted as an online video call. This low response rate is picked up in the limitations section of this work.

3. FINDINGS

3.1. WP1: Towards a Web-Based Design Calculation Tool

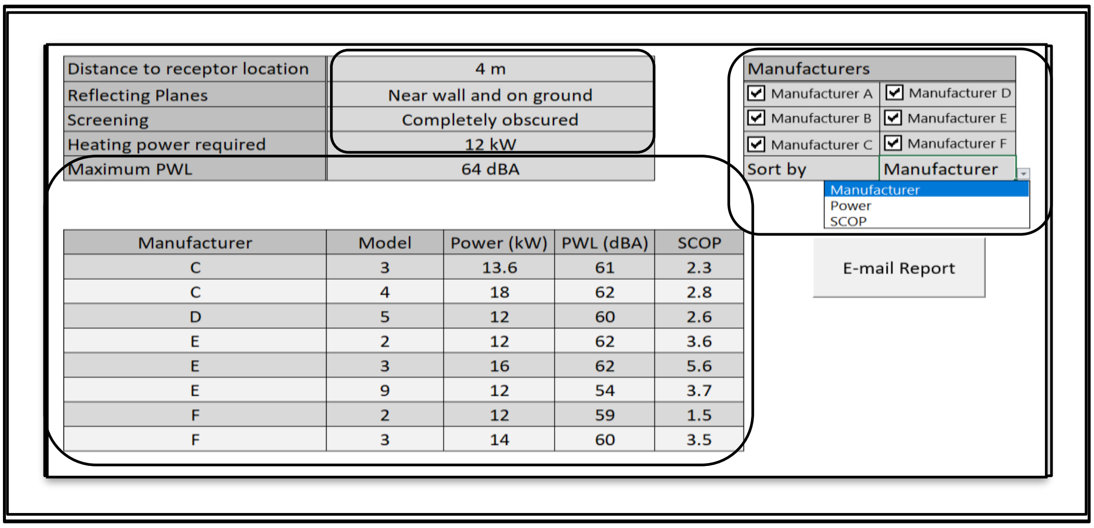
The first element of the tool takes the required inputs and performs a database lookup. The data in the database are currently real manufacturer's data, but anonymised. This portion of the tool answers the question:

- For a given distance to receptor location (the user's or neighbouring residents) and installation arrangement (i.e. knowing the number of reflecting planes around the ASHP, and the presence of a barrier or otherwise), what is the limit on sound power?

Which is followed with a filtered question:

- Given these environmental constraints, and knowing the heating power required, which ASHPs are available in the MCS database?

In this iteration, the user has the opportunity to limit the search to particular manufacturers. Other search constraints could also be implemented. For the purposes of this prototype tool, the data for monobloc units from the top five manufacturers on the MCS MID Database is used, along with one manufacturer's data for a split system external unit. These systems are used by one installer when there are noise constraints for the monobloc units.



User data input required, user control of extent and sorting, and outputs produced. When implemented as a web tool, there is an opportunity for the server to email a report of the results displayed on screen.

Figure 1: Database lookup tool based on ASHP location and heating power requirements

Given that there are over 2000 certified ASHPs on the MCS database (at the time of July 2023), it may be helpful to provide easier ways to limit the range of data considered, such as actively including selected manufacturers, rather than all being automatically included. This presentation of the MCS 020 calculation is similar to the calculators available on other countries' heat pump noise compliance websites, but with a significant difference: all those calculators simply check compliance, it is necessary to identify a manufacturer's make and model, advise the distances and arrangement, and the calculation tool simply advises if the ASHP passes or fails the test.

The tool proposed here enables the user to discover if there is a unit that is feasible in the context of the specific circumstances encountered in that location, and show which quieter units are available to provide an incentive to select from what is available on the market: this is design information which is otherwise very difficult to discern. An illustrative “button” is included to demonstrate that the report could be emailed to the user; alternatively, the calculation could be submitted directly as part of the submission and held on public record in case of need of future audit in the event of a complaint (for instance).

This tool could be extended with additional inputs, such as:

- Other receptor locations that have different barrier screening conditions (currently the tool must be used successively as point-to-point checks to determine the limiting constraint). This may allow cumulative impact to be incorporated, based on an assumption of future allowances for the archetype classification (see further works);
- An option to include a tonal / sound character penalty in the noise calculation (currently outside the scope of the MCS calculation);
- A user option to have another noise target at a different location, which may be the home owner’s own dwelling, quiet part of the garden or patio for example. This noise target could be more onerous or more relaxed, at the user’s discretion.

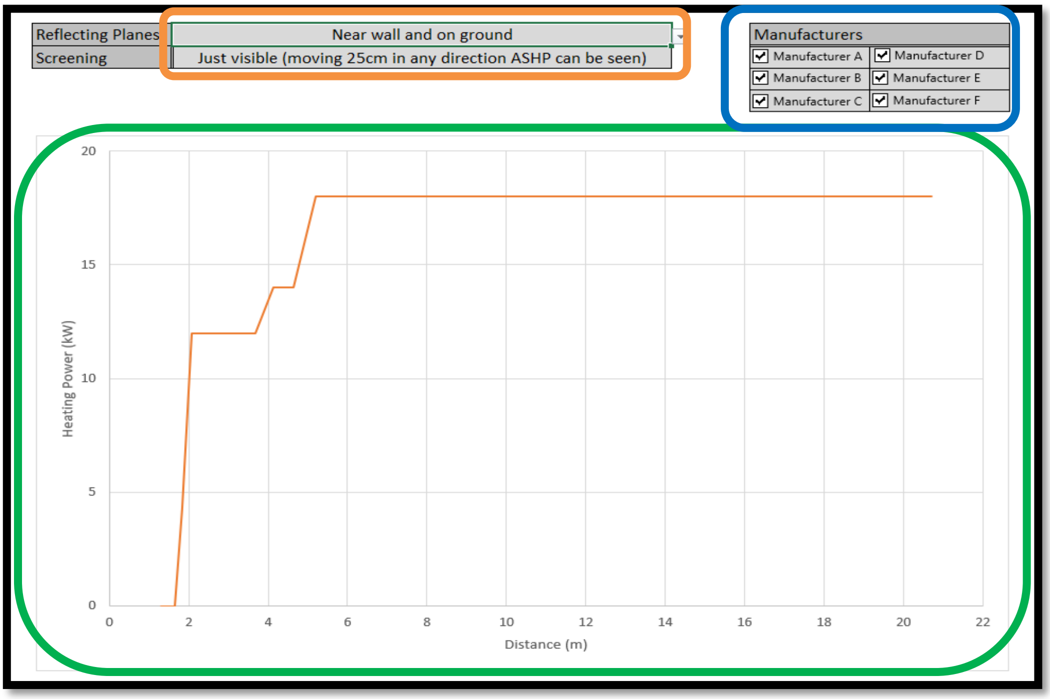
A further benefit of the tool is that, by using the location of the ASHP user’s window as the receptor, potential users can identify likely noise levels at their own windows. Potential users may then pick and position a sufficiently quiet unit to meet their own well-being requirements as well as planning requirements at their neighbour’s property, which could improve uptake of and support for such a tool by the general public.

The second element of the tool enables users to ask the question:

- If I site an ASHP in a particular arrangement (i.e. knowing the reflecting surfaces around it and any barriers, partial or full), what level of heating power is available and at what distance can it be located from noise sensitive windows (whether the user’s or neighbouring residents)?

This question has filters on the results, by manufacturer, although a deeper level of filters may be appropriate with a larger dataset to refine it further.

For the purposes of this prototype tool, a selected dataset has been used. This is based on real data from monobloc units of the top five manufacturers’, according to MCS database installs at the time of writing. In addition, the external unit of one manufacturer’s split system is considered, to demonstrate the significance of a higher heating power with a limited sound power rating. This demonstrates what can be achieved with existing data.



User data input required, user control of extent, and outputs produced.

Figure 2: Tool to determine available heating power based on ASHP distance

This portion of the tool enables users to get a simple visual indication of the availability of an ASHP to provide a certain level of heat output as well as the noise constraint (i.e. the current MCS permitted noise level) expressed as a distance. This removes the requirement to understand technically challenging acoustic information by the user by embedding it in the tool. The extent of data considered is then controllable by the user, for example if they know that they want to use a particular manufacturer that profile can be presented. This chart therefore uses the noise constraint to identify the envelope of heating power and distances that comply with the MCS 020 current calculation. Note this chart is based on the theoretical calculation of sound level with distance, NOT the table of distances and attenuations printed in the MCS 020 calculation tool. Therefore the precise numbers in this presentation differ from the values from the acoustic design tool table output.

Figure 2 example shows that for a 12 kW unit (which would satisfy most archetypes (see Table 2)) near a wall on the ground, just visible that it would need to be at least 2 m from a window. This is feasible for optimal locations for energy efficiency criteria and shows that this option could work in terms of noise constraints for most archetypes. The current 3 m restriction would prevent it currently being located as close to the boundary as it could be to benefit that neighbour with screening from a fence for example.

This approach could be extended with other inputs as noted above for the first element of the tool. The significance of this presentation of the data is demonstrated following the case studies.

3.2. WP2: Template Example Solutions

A summary of the building archetypes listed in (2) is reproduced in Appendix 1. This list has been condensed, for the purposes of this assessment, into the categories of:

- Mid-terrace;
- Semi-detached;
- Detached; and
- Purpose built flats, low rise.

Using these classifications, and splitting the categories in (2) for "bungalows" equally between mid-terrace, semi-detached and detached, the proportions of the whole of the UK housing stock are shown in Table 1.

Housing archetype	Percent of overall housing stock
Mid-terrace	31.0
Semi-detached	28.9
Detached	20.9
Low-rise flats	16.4

Table 1: Fractions of overall housing stock falling into different categories

The cumulative total of the above is 97.2 %. The remainder are purpose-built high-rise flats, and converted flats. It is not intended to characterise potential individual ASHP installations for these archetypes. Representative examples in each archetype are considered for example solutions.

It is also necessary to take a view on the heating capacity required, to determine the thermal size of heat pump to consider. Outline guidance from boilerguide.co.uk indicates the following, as shown in Table 2.

House type	ASHP recommended heating output (kW)
2 bed house / flat	5
Poorly-insulated 3 bed house	9
Well-insulated 4 bed house	9
Poorly-insulated 4 bed house	16
Well insulated 5 bed house	16

Table 2: Typical heating requirement for different housing archetypes

Hence it can be seen a range between 5 – 16 kW is likely to be required for terraced, semi-detached and detached dwellings that have not undergone a deep retrofit, depending on their size and thermal performance.

3.2.1. Mid-Terrace Archetype

Within the mid-terrace category, the single largest archetype is properties built pre-1919, which comprise 8% of the overall housing stock in the UK. 50% of these properties have a floor area between 67 and 100 m^2, with a mean floor area of 89 m^2. The archetypal image is reproduced in Figure 3.

Figure 3: An example of a mid-terrace archetype, this pre-1919, from (2)

Although these types are either with or without bays to the front elevation, 70% of these dwellings have "additional parts", which means that they have a non-rectangular dwelling shape. The additional parts are typically at the rear, and may comprise a later-addition or as-built extension. These additional parts may complicate the location for an ASHP. A typical dimension across the front is between 4.5 and 5.5 m for each property footprint. Typical views are shown in Figure 4 and Figure 5. Depending on the construction details, it is likely that a heating capacity somewhere between 9 and 16 kW is likely to be required, due to the size of these dwellings.

Using the tool it can be seen from the illustrated example in Figure 2 that for the 16 kW upper part of this range that distances of approximately 5 m would be needed to noise sensitive receptors, which would be very challenging for this archetype, unless additional mitigation or quieter options were selected to reduce the required distance.

Figure 4: Example view of terraced properties, Cardiff, 4.5 m property width, potential location of unit indicated by red arrow.

In the example of Figure 4, these are considered as the relevant distances:

- Distance of 4.0 m to an upper window on the left-hand side, with no barrier. Although the off-shoot part of terraced houses often accommodates a bathroom and kitchen, this is not always the case, and this could be a habitable room such as a bedroom.
- Distance of 2.0 m to the right-hand side, where this is a complete barrier formed by the boundary fence.

The acoustic design tool, output illustrated in Figure 5, shows that at 4 m and visible, the sound power level limit is 54 dBA; at 2 m and fully obscured, the limit is 58 dBA.

Distance to receptor location	4.0 m
Reflecting Planes	Near wall and on ground
Screening	Visible from receiver
Heating power required	5 kW
Maximum PWL	54 dBA

Manufacturer	Model	Power (kW)	PWL (dBA)
D	2	5	54
E	7	10	54
E	8	11	54
E	9	12	54

Figure 5: Tool output showing restricted heating power options with a monobloc system (5 kW), the E manufacturer units being split systems.

There may be only a very few manufacturers' units that currently could comply with the existing sound power level constraint, with sufficient heating power output. None of the top five manufacturers offer a monobloc system that can provide more than 5 kW with a sound power level not exceeding 54 dBA. At least one of the top five manufacturers offers a split system that can provide up to 12 kW heating with 54 dBA sound power level, but this illustrates the challenge to provide equality of access to the technology available for all archetypes with noise being a main constraint currently.

Therefore, careful acoustic selection should be the first step for a householder to aim to control noise at source, before they engage with an installer, as installers typically only use the manufacturer's units with which they are familiar with and which could otherwise limit the options to those which would be not suitable.

However, if mitigation is used as a second step (such as a barrier that completely obscures the line of sight between the ASHP and receptor) then all manufacturers have a monobloc unit that can provide more than 8 kW of heat, as shown in Figure 6 (note that the other constraint – 2 m and fully obscured meaning a sound power limit of 58 dBA – is disregarded here). Thus, having the option of a system to create a barrier could be fundamental to meeting the MCS noise requirements for monobloc units for this archetype, until quieter units become available.

Distance to receptor location	4.0 m
Reflecting Planes	Near wall and on ground
Screening	Completely obscured
Heating power required	8 kW
Maximum PWL	64 dBA

Manufacturer	Model	Power (kW)	PWL (dBA)
A	4	8.5	58
A	5	11.2	60
B	4	9	59
C	2	11.1	64
C	3	13.6	61
C	4	18	62
D	4	10	60
D	5	12	60
E	1	11	62
E	2	12	62
E	3	16	62

Figure 6: Different manufacturer's options at 4 m when there is a barrier completely obscuring the line of sight.

For the image in Figure 7, a location on the side of the off-shoot portion is considered. This would not comply with the current 3 m rule in Wales so would be disregarded as a site for potential deployment currently. It may not also be compliant with the current English 1 m from the boundary rule, due to the allowable space, presenting a problem for this example in terms of feasibility without a different approach.

Figure 7: Example view of terraced properties, Cardiff, 5.0 m property width, potential location indicated by red arrow at side of property near accessway

The relevant distances and associated sound power level limits are:

- Distance of 2.5 m to a lower window, with a full barrier: sound power level up to 58 dBA L_{wA};
- Distance of 3.5 m to an upper window, where this is a partial barrier formed by the boundary fence: sound power level up to 56 dBA L_{wA}.

Using the acoustic design tool, Figure 8 shows limited options for ASHP units that can comply with these sound power constraints. From the top five suppliers, a monobloc system can only supply up to 7 kW of heat at this sound power level constraint. A higher heat output requires a split system. This again illustrates how a different simplified approach could unlock the feasibility of this example.

Distance to receptor location	3.5 m
Reflecting Planes	Near wall and on ground
Screening	(moving 25cm in any direction ASHP ca
Heating power required	5 kW
Maximum PWL	56 dBA

Manufacturer	Model	Power (kW)	PWL (dBA)
B	2	5	55
D	2	5	54
D	3	7	55
E	7	10	54
E	8	11	54
E	9	12	54

Figure 8: Output for this limiting configuration. NB these options from manufacturer E are split systems (which have other constraints)

3.2.2. Semi-Detached Archetype

Semi-detached properties come in a wide range of configurations. The most prevalent type in the UK identified in (2) is constructed between 1945 and 1964, as illustrated by examples in Figure 9 and Figure 10. Half the properties in the later date range have floor areas between 74 and 96 m^2, with a mean area of 88 m^2. 62% have no additional parts beyond the rectangular dwelling footprint. The semi-detached category built between 1945-64 comprises 8% of the total UK stock, and the archetype built between 1919-44 comprises a further 7%. Typical views of semi-detached properties in Wales are shown in Figure 11 and Figure 12. Depending on the size and construction details, it is likely that a heating capacity somewhere between 5 and 16 kW is likely to be required.

Figure 9: Archetypal semi-detached, 1945 – 64, comprising 8% of the UK housing stock (2)

Figure 10: Archetypal semi-detached, 1919 - 44, comprising 7% of the UK housing stock (2)

Figure 11: Example view of semi-detached properties, Swansea (likely pre-1945)

For the image in Figure 11, a location on the side of the property is considered. This may not be compliant with the 3 m in Wales or the 1 m in England boundary rule, due to the allowable space, but is considered as in some cases it could be. It can be seen that there are windows on the side of the property (of the hypothetical customer), which are considered as habitable rooms. Often layouts for this archetype may have windows to circulation areas (e.g. top of the stairs) and bathrooms internally on such an elevation. In that case there could be no line of sight to those more sensitive windows, and the noise constraints would be reduced to potentially be irrelevant. For this example, those windows are considered relevant to the noise constraint.

These are considered as the relevant distances and associated sound power level limits:

- Distance of 5 m to a first floor window on the property opposite, with a clear line of sight: sound power level up to 56 dBA L_{WA}.

The acoustic design tool shows that two of the top five manufacturers offer a monobloc ASHP that can comply with this sound power constraint, up to a maximum of 7 kW, which is unlikely to be adequate. At least one manufacturer offers a split system that can provide up to 12 kW and complies with the sound power constraint.

The main issue here is about the suitability of a location between the properties, and whether there are any habitable rooms on that aspect. This again shows that a simple different approach would unlock this example of the semi-detached archetype.

Figure 12: Example view of semi-detached properties, Swansea.

For the image in Figure 12, a location on the rear of the property is considered. These pairs of semi-detached houses can be seen to have a larger distance between them than the previous example, or those dwellings in the top of the image of Figure 12. This is a critical aspect of these particular dwellings that may enable a suitable acoustic position, if that is practically possible (e.g. on the far right side of dwelling indicated in Figure 12, there is already a building extension at this location).

These are considered as the relevant distances and associated sound power limits:

- Distance of 7 m to a window on adjacent property to the left, with a visible line of sight; location has two reflecting planes, with the rear of the house and the fence to adjacent property: sound power level up to 57 dBA L_{WA}.
- Distance of 6 m to a window on adjacent property to the right, with visible line of sight: sound power level up to 57 dBA L_{WA} .

The acoustic design tool shows that two of the top five manufacturers can provide 5 kW of heating with this sound power constraint, and one can provide 7 kW, with monobloc systems. A split system is required to provide more than 7 kW of heating with this sound power constraint.

This example also illustrates the anomaly with the MCS calculation, which does not distinguish between 6 and 7 m distances.

3.2.3. Detached Archetype

Detached properties also come in a wide range of configurations. The most prevalent type in the UK identified in (2) is constructed post 1980, as illustrated by example in Figure 13.

Half the properties in this classification have floor areas between 100 and 159 m^2, with a mean area of 138 m^2. Around a third have bays, and just over half have additional parts beyond a rectangular floor plate. A typical view of more modern dwellings is shown in *Figure 14*.

Depending on the construction details, it is likely that a heating capacity somewhere between 9 and 16 kW may be required as an estimate, certainly for the dwellings that were built to less stringent thermal insulation requirements (i.e. early versions of the Building Regulations).

Figure 13: Example of post-1980s detached dwelling from (2)

Figure 14: Example view of detached properties, Swansea.

For the image in Figure 14, a location on the rear of the property is considered.

Note that the houses seen in front elevation at the bottom of the image have different garage arrangements from those dwellings seen in rear-aspect towards the top of the image, and the rows of houses have a different separation distance between them. For the location proposed, there is no direct line of sight to windows of the closest adjacent residential house.

The closest window with a line of sight is to the right-hand side, an upper window of the assumed customer's house.

These are considered as the relevant distances and associated sound power limits, based on the location being in a corner with two reflecting walls and the ground:

- Distance of 7 m to window on property to the left, with no line of sight: sound power level up to 64 dBA L_{WA}.
- Distance of 11 m to a window on property to the right, with clear line of sight: sound power level up to 59 dBA L_{WA}.

The acoustic design tool shows that of the top five manufacturers who can provide a monobloc system, only two offer a unit with at least 8 kW with the 59 dBA sound power level constraint.

In the absence of the garages to the rear, it may be much more difficult to find a suitable position, which means either accepting a more onerous sound power constraint, or constructing barriers to provide mitigation that would make this a viable option.

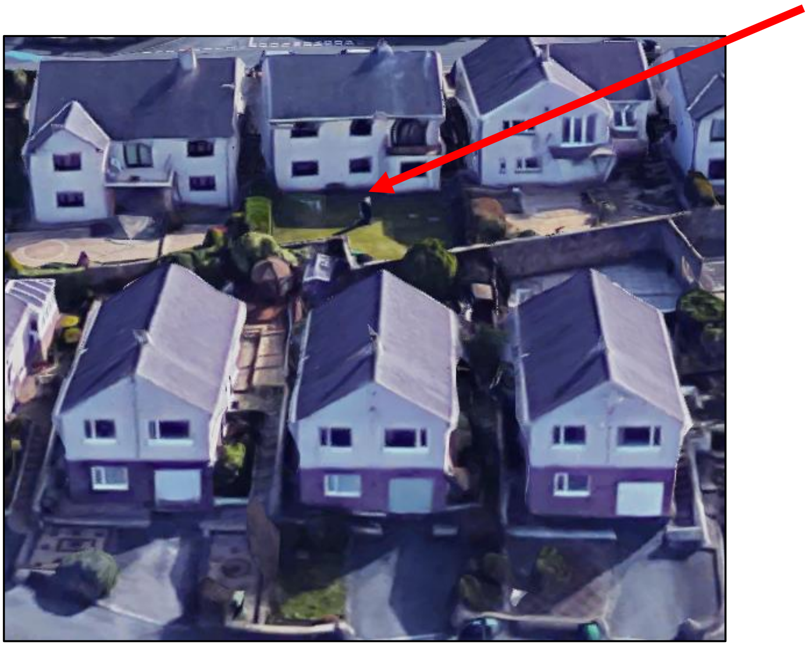


Figure 15: Example view of detached properties in Caernarfon

In the example in Figure 15, a location on the rear of the property is considered, optimised for noise in the middle of the plot. With these separation distances between dwellings a location between plots may be more appropriate, if the 3 m (and 1 m) rule are relaxed. For the location indicated, it is 9 m to a window on either side of the property:

These are considered as the relevant distances and associated sound power limits, based on the location being against a wall and the ground (two reflecting planes):

- Distance of 9 m to window on adjacent property, with clear line of sight: sound power level up to 60 dBA L_{WA}.

Note that as the assessment location is 1 m in front of a window or door of a habitable room, where the house on the left of the example location is slightly in front of the proposed ASHP location, so that the window itself may not be visible. The assessment point at 1 m in front of the window would be clearly visible however. As the assessment position is 1 m in front of the façade, it may be visible even when the actual window is obscured by the edge of the building.

The acoustic design tool, Figure 16, shows that three of the top five manufacturers offer a monobloc unit that can provide more than 8 kW of heating with this sound power constraint, with one offering 12 kW.

Distance to receptor location	9.0 m
Reflecting Planes	Near wall and on ground
Screening	Visible from receiver
Heating power required	8 kW
Maximum PWL	60 dBA

Manufacturer	Model	Power (kW)	PWL (dBA)	SCOP
A	4	8.5	58	4.4
A	5	11.2	60	4.4
B	4	9	59	5.9
D	4	10	60	5.3
D	5	12	60	2.6

Figure 16: Range of top manufacturers offering monobloc systems meeting a 60 dB sound power level limit using the prototype acoustic design tool.

3.2.4. Application of Acoustic Design Tool

The prototype acoustic design tool for a heating power capability of 9 kW and a direct line of sight assumption to the receptor location (1 m in front of a habitable room) shows that only one manufacturer has a split system product that requires a minimum of 4 m distance, as illustrated in Figure 17 (providing up to 12 kW output) whereas all the top manufacturers' monobloc units require a minimum of 8 m distance for acoustic compliance with MCS 020, as illustrated in Figure 18. Note that the sloping lines are an artefact that we have not overcome in this prototype graphing arrangement, and that the distance calculation for the chart is different from the table (see section 3.1), so that the numbers are different.

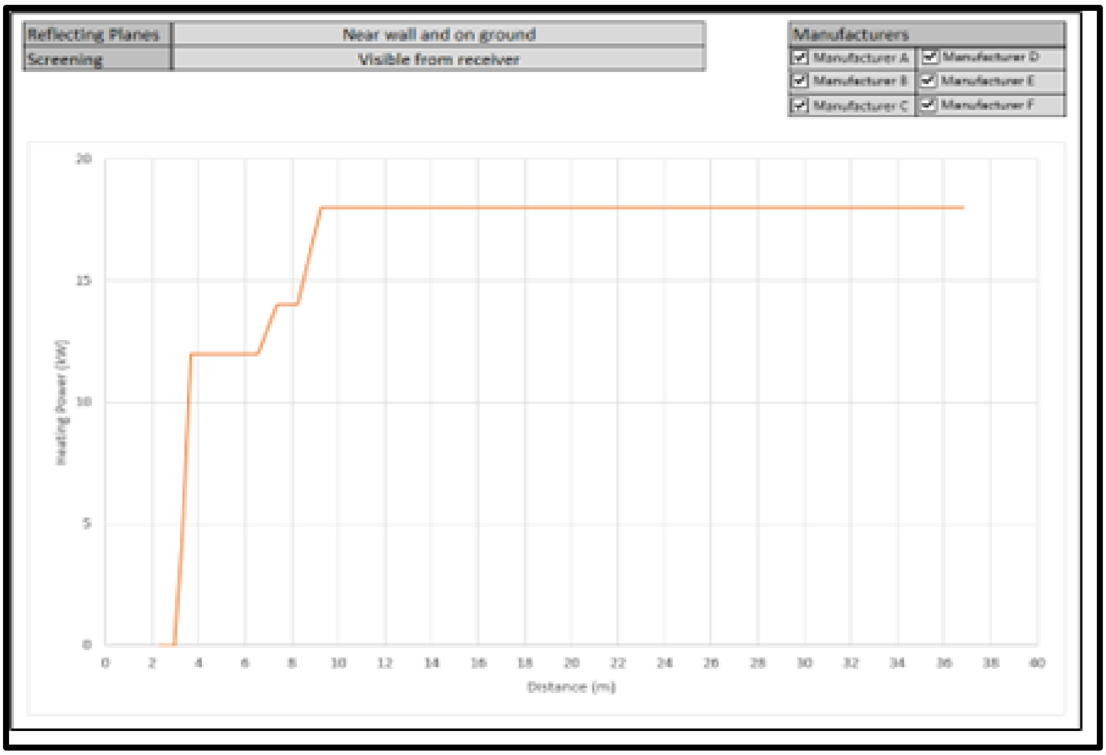


Figure 17: Constraints for all manufacturers in this sample data set (inc. sample split system)

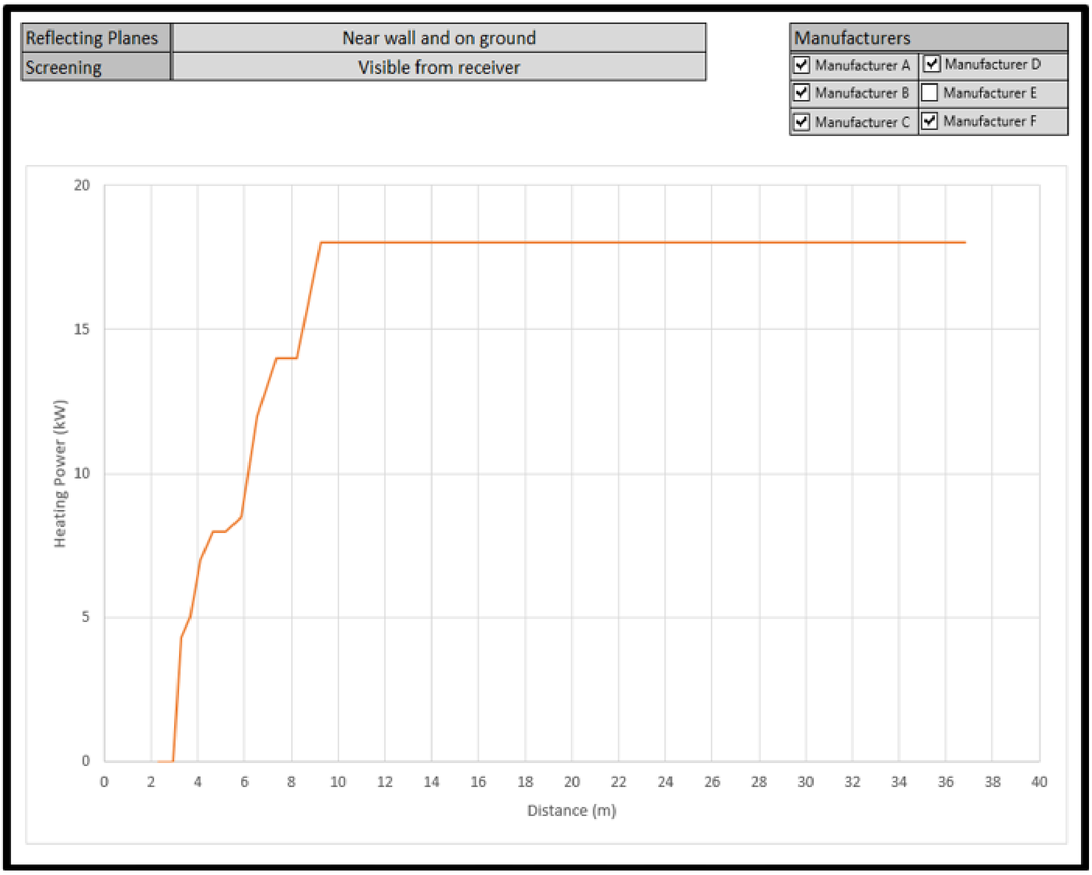


Figure 18: Distance constraints for top five manufacturers' monobloc systems in this sample data set using the prototype acoustic design tool.

The overall distance constraints for all manufacturers (i.e. limited by the single most effective unit, that provides the highest heating power for any given sound power) are shown in Figure 18. However, excluding the split systems reveals that the minimum distance is over 7 m, as illustrated in Figure 17 and Figure 19.

Distance to receptor location	8.0 m
Reflecting Planes	Near wall and on ground
Screening	Visible from receiver
Heating power required	8 kW
Maximum PWL	60 dBA

Manufacturer	Model	Power (kW)	PWL (dBA)
A	4	8.5	58
A	5	11.2	60
B	4	9	59
D	4	10	60
D	5	12	60

Figure 19: Use of acoustic design tool with 8 kW heating power, 8 m line of sight to receptor location

Given the dimensions and available locations, it is clear that the inclusion of a barrier in the noise assessment calculation is going to be essential. Including a full barrier, the minimum distance to enable a range of manufacturer's units to qualify is 3 m, as illustrated in Figure 20.

Distance to receptor location	3.0 m
Reflecting Planes	Near wall and on ground
Screening	Completely obscured
Heating power required	8 kW
Maximum PWL	61 dBA

Manufacturer	Model	Power (kW)	PWL (dBA)
A	4	8.5	58
A	5	11.2	60
B	4	9	59
C	3	13.6	61
D	4	10	60
D	5	12	60

Figure 20: Minimum 8 kW heating, 3 m completely obscured line of sight to receptor location

Similarly, the quietest manufacturer's split system unit can qualify with a distance of 1.5 m when the line of sight is completely obscured, as illustrated in Figure 21.

Distance to receptor location	1.5 m
Reflecting Planes	Near wall and on ground
Screening	Completely obscured
Heating power required	9 kW
Maximum PWL	55 dBA

Manufacturer	Model	Power (kW)	PWL (dBA)
E	7	10	54
E	8	11	54
E	9	12	54

Figure 21: Minimum 9 kW heating, 1.5 m completely obscured line of sight to receptor location

The above analyses demonstrate the challenges of finding a compliant location for an ASHP anywhere around terraced or semi-detached properties without the use of a barrier. This is problematic for the installation industry at present, because it is understood from WP5 and WP6 that it is not currently standard practice to include barriers with potential installations. If a barrier is required, an installer may decline to install, and indicate to the homeowner that they would need to install a barrier before the installer could reconsider an installation.

It is also evident that the quietest units are of a great advantage when installing with limited distances to neighbouring properties. However, the range of noise levels from different manufacturer's units is not well-known, as this information is not easy to extract from manufacturers at present, which presents an obstacle to deployment.

It is instructive to consider a sound power level that is likely to be acceptable for most terrace house installations, which would likely cater for the most challenging 30% of housing stock. Based on potential dimensions observed in the samples of terraced properties, it is considered that limiting the distance to 2.0 metres, and having a barrier that partially obscures the ASHP unit – i.e. moving 25 cm from the unit reveals the receptor location – the limiting sound power level is 53 dBA.

With a full barrier, the sound power level limit is increased to 58 dBA. Only one of the top five manufacturers offers a monobloc unit providing more than 8 kW limited to 58 dBA – rated at 8.5 kW.

There is a very limited choice of units with a sound power level not exceeding 53 dBA, and with very limited heating outputs.

A summary of sound power level limits that may be desirable for manufacturers to avoid noise constraints in terraced house installations is provided in Table 3.

Proposed installation arrangement	ASHP sound power level limit to achieve installation within 2.0 m
Partial barrier arrangement	53
Full barrier arrangement	58

Table 3: Sound power level limits that may be desirable for manufacturers to avoid noise constraints in terraced house installations. Ideally, a heating power of 12 kW, or even up to 16 kW, would be desirable.

An arrangement of acoustic barriers/ screens could be developed to illustrate installation details that are compatible with manufacturer's specifications for free space around the machines. Such an exercise requires understanding of manufacturer's spatial constraints, as well as potentially suitable locations for terraced and semi-detached houses, as there are many other constraints to installation as well as the sound emission.

It is also understood from a planning perspective and PDR that noise barriers are not a preferred solution, because the PDR relies on the barrier for the life of the ASHP. A modification to the barrier might not concern a homeowner, as it will not interfere with the provision of their heating, but it may change the noise impact on them or their neighbours. A further consideration in the use of noise barriers to reduce noise to neighbouring properties is that an ASHP that requires a noise barrier to protect a neighbour is likely to be a high noise risk to the owner of the ASHP, who will not necessarily be protected by such a barrier (depending on the extent and positioning of the barrier).

3.3. WP3: Ready Reckoner Design Charts

It is understood from WP5 and WP6 that installers have determined their own distance constraints for the units that they install. The overall intended relationship between sound power and distance, for a unit on the ground near one wall with different barrier configurations, is shown in Figure 22.

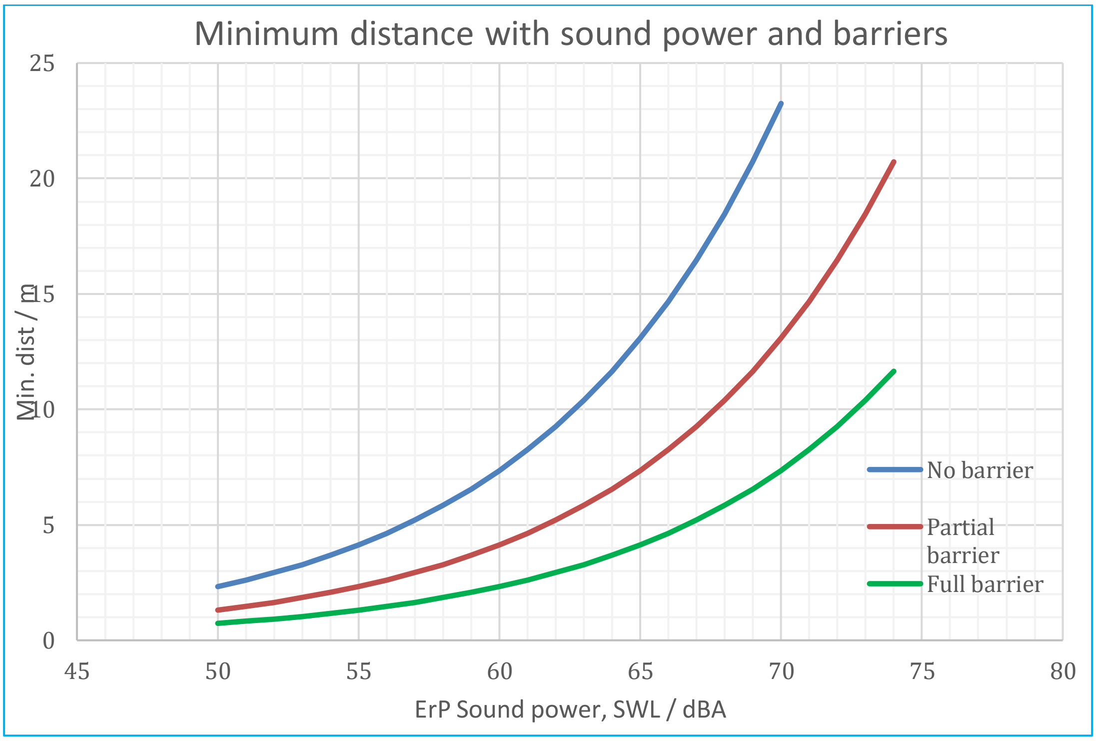


Figure 22: Theoretical calculation for minimum distances based on sound power and barrier configurations, for a unit mounted at a junction between two planes – e.g. the ground and a single wall

However, the actual relationship between distance and sound power is given in look-up tables rather than an equation; this means that the actual requirements, as stated in MCS 020, change in a step-wise fashion, as indicated in Note 4 in MCS 020, as reproduced in Figure 23.

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	-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.

Figure 23: Note 4 from MCS 020 for distance attenuation

The actual sound power level constraints of the MCS are plotted in Figure 24 (solid lines), along with the theoretical calculated limits, shown dotted, for an installation on the ground and against a wall (Q = 4). This illustrates how the MCS constraints change in a step-wise fashion; most significantly, many of these steps are 3 dB between 4 and 8 m, which are likely to be common distances encountered in practice. This means that the MCS calculation has an additional layer of prudence due to the lumpiness of the calculation procedure – e.g. if the distance is 7.9 m, the constraint is nearly 4 dB more onerous than the theoretical calculation indicates.

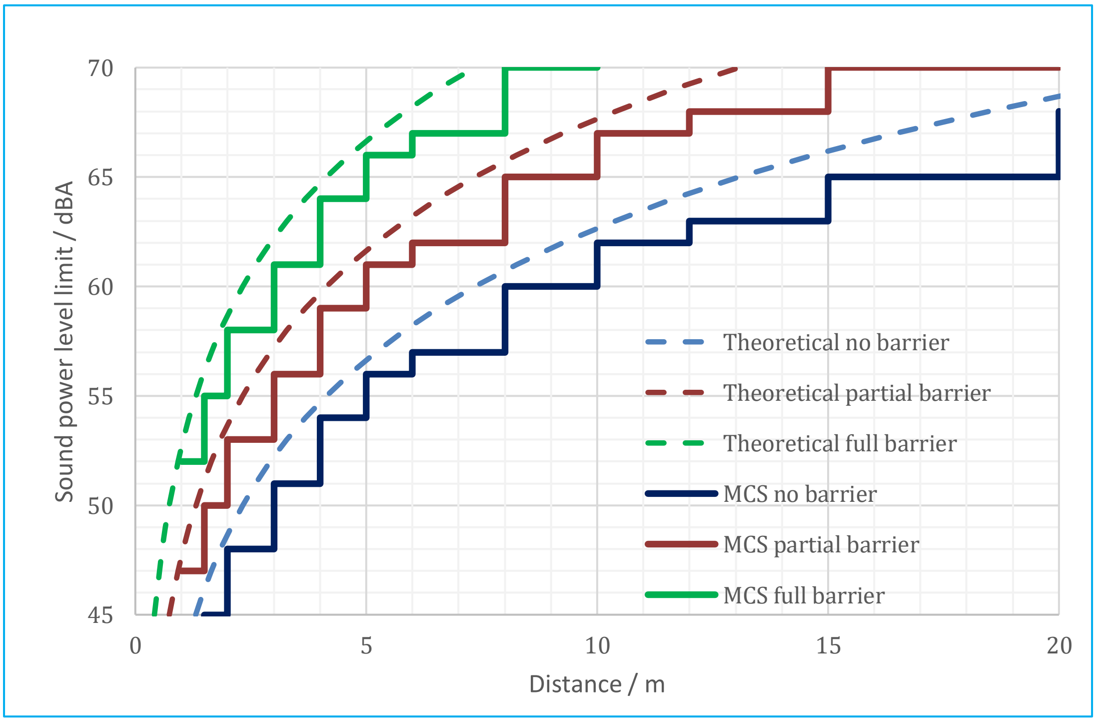


Figure 24: Actual sound power constraints from the MCS calculation, for Q = 4

3.4. WP4: Deeper Investigation with the Local Authority that Approached Welsh Government with the Noise Problem Originally

The South Wales Local Authority Environmental Health Officer was contacted again and discussion lasting over two hours followed. The specific example that was referred to as part of the initial interview related to early 2021: a large social housing application was received in a rural area that the officer provided technical services to, including advice on noise.

The application site was near a bus interchange project as a geographical feature but was not affected by the noise from it. An ASHP was included for every property of the development. This was the first time this issue had been encountered by the officer, and as it was a Local Authority project it was a concern to get the approach right in relation to noise grounds.

BS 4142 was considered the most appropriate way to deal with the potential impact of noise from the proposed ASHPs on properties within the scheme, and the cumulative impact of multiple units was a concern on the noise climate of the area. Planning officers appeared to be less supportive of requiring a full planning application, in favour of directing through the MCS calculation approach for each property and treating the ASHPs installations as PDR. This is understood to have been the approach taken, and it is not clear if this project is now complete and operational, but complaints have not been forthcoming so far. This may provide a useful basis for a case study (see further works).

3.5. WP5: Deeper Investigation with Energy Providers and Installers

The energy providers advised that they respond to customer queries about installing ASHPs, they do not search for potential installation sites. A triage process is the first step to determining suitability of the site for an ASHP installation, then an on-site survey by a RICS surveyor is undertaken to investigate more thoroughly if it is possible to install an ASHP. One of the installers advised that they use an in-house app, focussed on one manufacturer's units, that will identify if installation under PDR is possible. After the survey, the ASHP installation is designed and completed.

One of the installers could not think of anything that would help them comply with MCS 020, but the other installer suggested that greater clarity in the MCS process and inclusion of options for noise mitigation, such as barriers or enclosures, would be helpful to tackle the more difficult sites (e.g. terraced housing). They also identified that automation of the process would help, although they acknowledged that this would be difficult due to the variation in site specific scenarios. In addition, they identified that the visual aspects of

ASHP installations need to be consistently applied and aligned with the objectives of the roll out.

As identified in Phase 1 of this work, the '3 m rule' (and even the '1 m rule' as required in England) is by far the most common reason for turning down a site. However, one of the energy providers advised that they would not want to see installation of an ASHP within 1 m of a window or door. Both energy providers advised that installation at terraced housing and some semi-detached housing is not possible due to the requirement for 3 m from the boundary of the property.

One of the energy providers suggested including orientation of the ASHP and the directivity of the sound emissions in the MCS 020 calculation, but the authors of this report acknowledge that this is not currently possible as the current test procedures do not enable the directivity characteristics to be determined, let alone calculated for a prospective location.

Neither of the energy providers currently install an ASHP where noise mitigation (a noise barrier) will be required - the customer must find a separate contractor to install the noise barrier first. However, where there are noise issues, one of them installs a split system, which has a lower sound power than that installer's monobloc systems, despite that requiring a Category 1 gas installer.

Upon being shown the tools developed in WP1 and WP3, the energy providers advised that they already have their own calculation sheets or app, with both suggesting they may be more helpful for independent installers.

One of the energy providers highlighted other issues restricting roll-out of ASHPs, including: difficulty connecting to Distribution Network Operators (DNOs); the fact that many houses still have 6A fuses; and the fact that the approach and requirements differ between the different planning authorities.

One of the energy providers advised that only 3% - 5% of the calculations fail on noise grounds, but the authors of this report suspect that this will be much higher if the '3 m rule' was removed and more sites were opened up for ASHP installation with PDR.

Finally, one of the energy providers commented that in order to increase the number of ASHPs being installed to meet the target numbers, the Welsh Government could reduce the design burden and standardise design as much as possible.

3.6. WP6: Interview Independent ASHP Consultants

The independent ASHP installer's responses agreed closely with those of the large energy providers. The installer advised that desktop assessments are completed first, then site visits are conducted for survey, design and a quote for viable sites. Over the past two years or so, the installer has received more enquiries about ASHPs from people in towns and cities, whereas previously the enquiries were from people living off-grid in rural areas.

The installer is largely happy with the MCS 020 calculation method, but did highlight that the background sound level is not considered in the calculation, which they thought might cause issues in quiet locations.

The installer reported that noise is not typically a restricting factor for ASHP installation, particularly as "the ASHP works hardest in winter when people are indoors with windows closed". However, they advised that noise is an issue for terraced housing, suggesting that the best location for ASHPs on terraced houses would be "back-to-back on boundary fences", noting that this would mean even a PDR rule requiring a minimum distance of 1 m to the boundary "would not work". The installer suggested that as long as the ASHP meets the MCS 020 standard then there should not be a minimum distance from the boundary of the property.

Regarding the PDR requirements, the installer noted that:

- Large houses can require more than one unit (rather than a larger unit due to the electricity supply), therefore the requirement for no more than one ASHP could be restrictive.
- The requirement that a wind turbine cannot also be installed at the property is not considered to be restrictive.
- The installer said that none of the units they install exceed 1 cubic metre, so it is not considered to be restrictive.
- The requirement that no part of the ASHP can be installed within three metres of the boundary of the property is the most restrictive aspect of the PDR requirements.
- The installer does not consider the requirement for the ASHP to not be installed with PDR on a pitched roof is not restrictive as very few ASHPs are installed on pitched roofs for engineering and safety reasons. Likewise, the requirement to be 1 m from the edge of a flat roof is not considered restrictive.
- The requirement for an ASHP to not be installed on a listed building or scheduled monument with PDR is appreciated and is not considered to be restrictive.
- The requirement not to install an ASHP on a wall or roof fronting a highway is thought by the installer to be for visual reasons, and they thought it fine to keep the requirement. Likewise for the requirement that the ASHP must have a minimal effect on the external appearance of the building.
- The installer did not understand the requirement that the ASHP must have a minimal effect on the wider amenity of the area.

The outcomes of WP1 and WP3 were demonstrated to the installer, who thought they would be useful for their preliminary calculations.

4. DISCUSSION

4.1. The Noise Lottery - Democratising Access to Sound Data

Currently, the noise question is a lottery: there is no way to access the full range of units available on the market when using an installer. Installers have limited access to the market, as they are invested usually in one or maybe two different manufacturer's products.

ASHPs and their controls are sophisticated systems; it takes time and investment on the part of the installer to become familiar and confident with the physical components and the control systems. However, different manufacturers' systems vary in sound power level right around the levels that may be critical for compliance. Hence the current lottery: if the homeowner was fortunate enough to approach an installer who uses a manufacturer with sufficiently quiet products for their installation, they are in luck. Homeowner are in a position where they are entirely dependent on whether the installer has access to quiet units; they have no assurance that a different installer would have any better access to those which exist on the market.

Currently, it is very difficult for a member of the public, an installer or even an acoustic consultant to investigate alternative manufacturers' products and compare the sound power levels. Hence the proposal to democratise access to this information, which must legally be declared on the product labels and so is publicly published information - it is in no way a manufacturer's sensitive information.

The sound power level could be included in the publicly available MCS database of certified products. When this information is publicly available, an API (Application Programming Interface) can be developed to search that database as demonstrated in WP1. All interested parties can then compare the products that they are using with the others on the market. This democratising of access to publicly published data is likely to facilitate the market adopting products for which there are wider applications, such as the quieter machines. The benefit of controlling noise at source is that this would also reduce the potential for a cumulative noise impact.

Figure 25 shows coloured lines which each represent the upper envelope of heating power that a manufacturer's range of units can provide at a given distance with line of sight, and assuming Q = 4 (i.e. located with two reflective surfaces nearby, typically a floor and wall). The critical region for viability consideration for terraced and semi-detached houses is shown ringed in red. It can be seen that a large portion of heating power provision between 4 m and 6 m is only accommodated by a split system (i.e. lies under the green line only) which is available from one manufacturer only. That one manufacturer cannot meet this criteria whilst providing a level of heating power beyond 12 kW. Many properties might need higher energy output that this but even if this would achieve the requirements if the installer used does not have access to this manufacturer then the limited choice would place that prospective homeowners or installers in difficulty, even though there may be a solution available to certain installers.

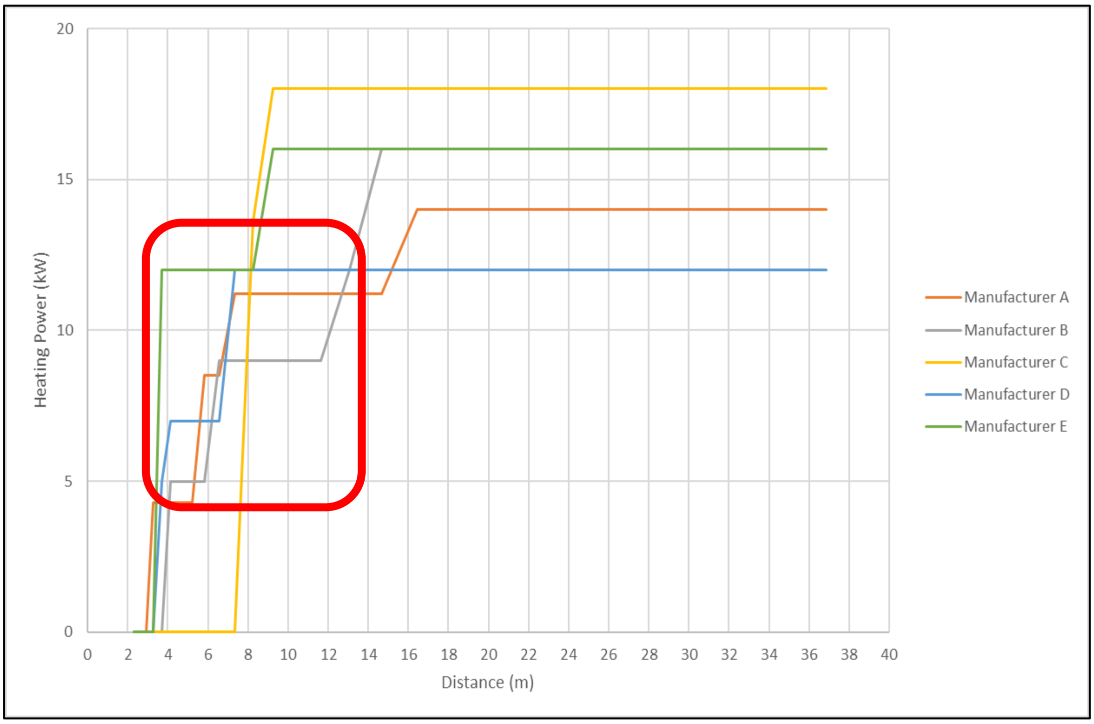


Figure 25: Top five manufacturers distance and heating power constraints for a clear line of sight, and where Q = 4 (i.e. installed on the ground against a wall). NB the Green line represents split system external units, all other data is for monobloc systems.

4.2. Terraced and Semi-Detached Properties: Case Studies and Exemplar Solutions

It is clear from the WP1 and WP2 calculations investigating potential installation locations that with the current technology noise is a significant factor to overcome in terraced and semi-detached property archetypes, for all manufacturers with monobloc units.

It is important to understand the other constraints that may arise for potential installation locations, not related to noise. Therefore, to develop more realistic case studies, it is suggested that further work is undertaken in collaboration with an installer. It is not considered that realistic template case studies can be developed if these are solely based on the noise constraints alone.

Realistic case studies will be of limited benefit without access to different manufacturer's noise data. A case study illustrating how an installation can be facilitated with a particular sound power level is of no use if the consumer - either the homeowner or installer - cannot then use that information to access which ASHP could comply with the noise constraints. Exemplar solutions would be of limited use if no-one can replicate them. These case studies can be most powerful in conveying useful information if the full process can be replicated by a homeowner or designer (installer). If the conclusion from a case study is that an ASHP with a particular sound power limit should be sought, it is imperative that a means to search for this is available.

4.3. MCS Procedure Multiplies Noise Constraints

As demonstrated in WP3 the procedure for the MCS calculation adds additional noise constraints that are not noted in the text describing the calculation or likely to be intended to be there. The process effectively adds a further noise constraint of up to 4 dB sound power level (buffer caused by rounding errors), which is a significant quantity to add simply to enable hand calculation of the result.

A manufacturer will potentially invest considerable time, effort and money to reduce the sound power by much less than this amount, which was a finding of Phase 1 work, so this appears to have introduced a careless and punitive approach to the calculation procedure, as illustrated in Figure 26, and should be addressed.

The solution to this would be straightforward: rather than define the calculation to enable its execution by hand, it could be carried out in an online calculation tool accurately, as demonstrated in the prototype ASHP acoustic design tool in WP1. The result could then be submitted directly for MCS 020 compliance, or emailed and then included as part of the submission package, including for the records of the customer.

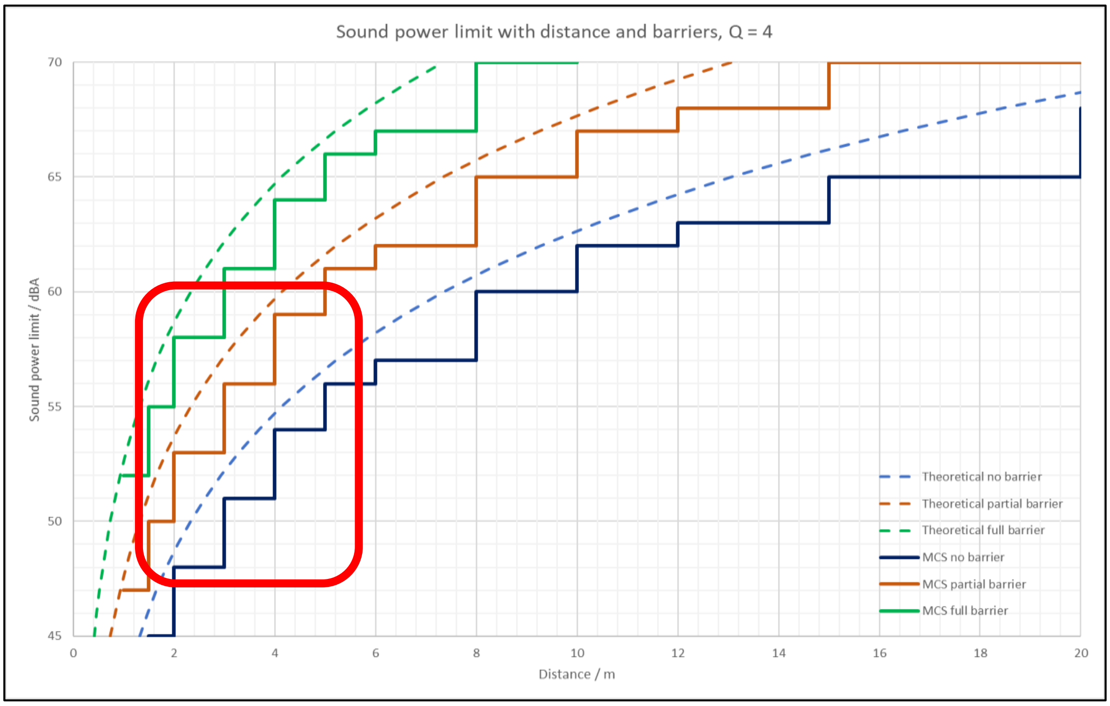


Figure 26: The MCS calculated constraint (solid lines), and the actual intended constraint (dashed lines)

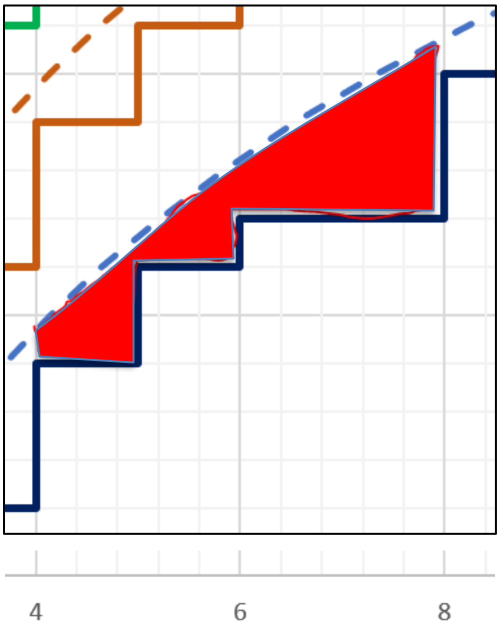


Figure 27: The critical area of the graph, between 4 and 8 m distance with clear line of sight, with error margins identified in red.

The distance between 4 and 8 m with a clear line of sight represents sound power level limits between 54 and 60 dBA, which is the critical range for terraced and semi-detached properties (as a barrier reduces the sound power level constraint at shorter distances). The average noise penalty introduced by the step function rounding error (shown as the area outlined in red in Figure 27) over this range is over 2 dB.

The calculation procedure also appears to consider 37.0 dB as the limiting sound power, rather than 37.8 dB (37 is the largest integer that can be logarithmically added to 40 without exceeding 42.0; but to one decimal place, the largest number is 37.8). This may have been a rounding procedure in the determination of the distances and levels - it is the reason that that the stepped graph never quite touches the theoretical curve of intended noise level limits.

4.4. Effective Current MCS Noise Constraint is 35.8 dBA

Considering the intended absolute noise constraint of 37.8 dB and the average additional constraint of 2 dB, the current MCS calculation can be considered to effectively constrain the noise impact to an absolute level of 35.8 dBA. This is a stringent level, comparable with some European countries' requirements at night-time only, although in the UK this limit applies at all times.

4.5. Noise Barriers/ Screening and Future Development

The screening of sensitive receptors provided by purpose-provided noise (or acoustic) barriers (as opposed to barriers formed by parts of a building) are potentially one of the 'elephants in the room'. None of the installers consulted during both phases of this work would install a noise barrier as part of an installation. A purpose-provided noise barrier is not desirable from a planning perspective as maintenance then needs to be taken into account, to maintain the permitted development rights. Therefore currently "noise barriers" as mitigation to enable use of noisier units in some of the denser archetypes are a complication and included in the assessment only if they happen to exist as part of the building massing or constructed elements. As there is little guidance, for example, on how effective a boundary fence may objectively perform as a noise barrier, it is treated crudely at best, and inaccurately at worst. The MCS currently states:

"*For a solid barrier (e.g. a brick wall or a fence) that completely obscures an MCS Contractor's vision of an assessment position…*"

If an element is assumed there is an obligation to make sure that is maintained for the lifetime of the units operation - this should be formally communicated to the homeowner.

One concern that adds complication is if a future residential extension may bring noise sensitive spaces closer to existing ASHP units and increase the noise impact at the new position. In this situation, the potential increase in noise impact should be a consideration of the planning application for the extension, to make sure sufficient noise mitigation is included for the new extension to reduce the noise impact so that amenity and quality of life is sufficiently protected. This could be the subject of guidance to Local Authorities as part of Best Practice in relation to ASHPs installed within their areas under PDR.

Whether a lightweight fence would qualify as a barrier if it completely obscures the visual path is not clear in the MCS, but it would not have as good acoustic performance where it is not continuous and the surface mass is below 10 kg/m^2. Noise barriers may be much less effective than the rather crude 5 or 10 dB attenuation correction that is attributed in the MCS calculation.

The reduction of sound due to barriers is not the same at each frequency, with low frequencies diffracting over the barrier more than high frequencies, which are therefore reduced more effectively. The spectral profile of the sound from the unit will therefore affect how much attenuation occurs in reality, and inclusion of a noise barrier may affect the tonality of the sound from the ASHP at the receptor location.

There are also other factors to consider, such as if sound reflections from a nearby wall mean that reflected sound from the unit can more easily propagate over the barrier via that reflected path. The effective screening will be degraded as a result.

The MCS assumptions and 020 calculation process currently use simple 'rules of thumb', which could lead to insufficient attenuation being in place, and higher noise levels occurring outside windows than are calculated. On the other hand, a more sophisticated treatment would be possible as part of an online tool which draws from information on the quality of the screening that is in place.

4.6. Directivity - Placement and Reflective Surfaces

The effect of placement of the units receives only very basic treatment in the MCS 020 calculation, with the number of surfaces within 1 m of the installation being required.

In practice, the effect of a reflecting surface is likely to depend not only on whether it is within the near field of 1 m proximity to the sound source (ASHP), but its overall size compared to the receptor distance, its distance from the source, and any other reflecting surfaces in proximity.

A more nuanced calculation may be considered, but is likely to add complication beyond what is necessary. The Annex 63 programme is covered in detail in Phase 1 report. It will focus on the acoustic effects of the placement of ASHPs - it is suggested that participation by providing Welsh Government representation in this programme will maintain the opportunity to adopt the most effective guidance in this regard, and inform the most appropriate and consistent approach to adopt.

The opportunity to include directivity information is considered to be an element of the calculation that requires attention to consider whether the customer or the neighbour would be adversely affected by directivity of sound.

4.7. Sound Power Level

In the Phase 1 report, the requirement in the MCS calculation requirement to use the “highest sound power level”, and manufacturer’s interpretation of this statement, was considered. The MCS 020 calculation indicates:

“*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).*”

From the interviews in Phase 1 with manufacturers, it is understood that the vast majority of manufacturers use the sound power level rating that is required to be declared as part of the ErP label. The sound power test for this label requirement is based on 40% of the heat load, with an air temperature of 7 degrees C and a water flow temperature of 55 C degrees (for medium temperature heat pumps). A higher thermal performance, and different environmental conditions, will lead to different sound power level emissions - which may be 3 to 6 dB higher, for example. The difference will depend on the physical characteristics of the ASHP and the control strategy, which can vary significantly between models. Annex 51 proposed a seasonal sound power coefficient, similar to a thermal Seasonal Coefficient of Performance (SCOP); in the evaluation of a sample machine, the seasonal sound power level was a few decibels higher than the ErP label sound power level rating. One consideration suggests that an ASHP will only be working at its higher capacity during the winter, when most people will have their windows substantially closed; this does not account for domestic hot water generation, which is required all year round and over simplifies the approach compared with the reality.

The MCS calculation qualifies "highest sound power level" by indicating that this does not mean in quiet mode, rather than suggesting it should be at full load, along with any particular environmental conditions. As manufacturers have to undertake a very wide range of tests of ASHPs in accredited laboratories, it is not considered appropriate or necessary to require a further sound power test, although this might be desirable for more robust sound power data that represents the performance more meaningfully. In any event, for standardisation purposes, this would require a new standard to be written to describe such a test.

At present, one manufacturer prefers to state their highest measured sound power level, rather than adopt the ErP label value, as discussed in the Phase 1 report. It is not known if other manufacturers measure the sound power level at any other operating points, as that information is not required to sell an ASHP in Europe.

4.8. 3 m Boundary Rule

It has been noted on multiple occasions that the 3 m to the boundary rule is the biggest constraint to ASHP installation in Wales, and also that it is unnecessary provided the MCS calculation target is achieved. Providing the MCS calculation is reflecting a level of impact that reasonably protects the acoustic amenity of the neighbours, this supplementary proxy rule is counter-productive as installers shy away from the Welsh market as a result.

It is also important to acknowledge as an aside that the 1 m rule in England is also an unnecessary constraint for the same reason. There are benefits from installing an ASHP up against the boundary fence because of the acoustic screening provided by it – with manufacturer's recommended clearances, typically only requiring 300 mm. In these scenarios, it may be prudent to comment on the efficacy of the boundary fence. An example of a brick wall is given in the MCS, but the number of holes or missing boards in a timber fence, for example, for it to qualify / be disqualified as a barrier is a matter for clarification and guidance.

It might also be argued that it is more socially equitable to place the units as close as possible to a solid boundary fence orientated toward the customers property so any noise burden is experienced by the persons benefiting from the service provided by the unit (see further works section in terms of quality of the sound). This may also provide an incentive to the occupant to select quieter units, and so support the drive for manufacturers and installers to offer access to quieter units to protect themselves, rather than directing the noise emissions towards neighbours. Examples have been experienced when considering potential case studies for this work where customers have opted to orientate units towards their neighbours windows rather than their own.

This approach may encourage a fairer concept of sharing any noise burden caused, assuming the acoustic capacity would be one ASHP for each property in time. Therefore, placing ASHP units back--to-back either side of a boundary fence, to maximise screening, together with selecting units to minimise the noise pollution experienced by residents on their own property means the person installing the ASHP receives the majority of the noise impact from their ASHP.

This is not possible currently, as directivity data is not available for ASHPs, beyond including it as part of best practice installation (see 7.2, 7.7 and 7.8 of Further Works)

4.9. Visual Constraint to Location and Size on Front Elevations – Enable Placement on Noisier Façades

Regarding the size of ASHP units quieter units are generally larger, because of the noise control incorporated in the body of the unit. Therefore, a tension does exist between the acoustic benefit provided to control noise at source and the potential visual impact of an ASHP. The size constraint of units is therefore an obstacle to the selection of the quietest units as it stands.

Managing the visual impact if placed in prominent positions, such as the front façade, can be mitigated with camouflaged “skins” such as matching brickwork or biophillic designs to match planting etc. It may be possible therefore to mitigate the visual impact to an extent that placing the unit on the noisier front facade might be a sensible planning balance to make so that the beneficial masking sound that this provides.

It should be noted that where road noise is largely caused by combustion engines currently the shift to electric vehicles, for low speed roads, may reduce the masking noise in time, so this may cause be a potential benefit to the soundscape in the medium term, provided that the noise form ASHP does not then become most the most prominent sound source. There is, however, a short-term advantage to gain whilst ASHP units are still in their first generation, with a wide range of noise emissions, and whilst low speed roads remain relatively noisy where traffic flow is constant. As the technology and design of ASHPs will be likely to improve, they are also likely to become quieter in following generations, as indicated by our findings during this work. Therefore they are likely to provide a wider range of solutions for more of the challenging archetypes and placements in time .

Using noisy facades would also provide a short-term noise mitigation to assist the early adoption of ASHP, with the visual aspects being a matter of planning balance.

4.10. Placement on Roofs Locations

Providing the permitted noise level of the MCS calculation is achieved it does not seem sensible to restrict units on roofs, provided the permitted noise levels can be achieved and that they can be sited so safe access can be achieved for installation and maintenance.

Some models are now designed to be located in the roof space, which would otherwise not be an option.

5. IMPROVEMENTS TO THE MCS CALCULATION

5.1. Simplify the MCS Calculation

The MCS calculation currently has more steps than are required. The same result is obtained if the calculation is stopped at Step 6, with a permitted target of 37.0 dBA. The subsequent steps are entirely unnecessary.

5.2. Digitalise the Calculation

The current calculation is presented as if it is going to be undertaken by hand, with look-up tables rather than equations representing the attenuation of sound with distance. The manual calculation method implies step changes in acceptability from one distance to another, embedding rounding errors in the result, whereas in reality there is a continuously changing calculated sound level with distance. This results in bigger safety margins for the noise impacts assumed, but correspondingly more onerous constraints for sound power levels, which are unnecessary.

The calculation could be made simpler by transferring to a digital form, with the distance input to the nearest 0.1 m. This would be measured from the centre of the ASHP to the assessment location. When digitalised, the output could then be logged directly on an application automatically and/ or the result of the calculation could be emailed to the user.

Digitalisation of this calculator would immediately reduce the noise constraint by an average of 2 dB for sound powers levels between 54 and 60 dBA, the critical range for terraced and semi-detached properties, providing a more realistic result (which could be presented in terms of potential adverse impact using the colour and text informatives discussed above).

There is an irony in the current provisions: the energy providers and installers with whom we have had discussions, as well as some of the manufacturers we talked to, currently provide digital design tools to their staff and customers. It is much more difficult to create a digital tool that replicates the hand calculation with look up tables, compared with one that calculates the answer directly from the formula.

5.3. Provide Acoustic Design Tool

The benefits and value to all parties of the prototype tool developed in WP1 are apparent – this tool is an essential element in overcoming the noise constraints to the large scale rollout of ASHPs. It is also likely to be of interest to practitioners in other countries, and attract an international audience.

As demonstrated, this tool could provide the digitalisation discussed above, and also act as a means to demonstrate compliance with the MCS standards.

5.4. Enhanced Acoustic Design Tool - Other Factors

As noted previously, there is a very large number of certified ASHPs on the MCS MID database already (circa 2000). Homeowners and installers may wish to search by other characteristics as well as heating power, SCOP and sound power. For example, people may be interested in factors such as:

- Monobloc or split system / DX unit,
- Refrigerant type,
- Length of warranty, etc.

Monobloc systems are likely to have less risk of refrigerant leaking compared to split systems, which may be a factor that is important to residents. Similarly, the range of refrigerant gases available in different systems varies widely, in terms of their refrigerant gases, people may be motivated to seek systems with lower Global Warming Potential (GWP) refrigerant gases. It is suggested that a piece of sociological research could be conducted to determine the range of factors that could optimally be included in the database. There is, of course, a cost associated with additional types of data due to the time required to produce it, review it, and record it.

5.5. Review Permitted Noise Impact and Level

The single figure value for sound power level that is required for ErP labelling has been shown to be a highly simplified characterisation of the sound emissions from a complex machine with variable operating states. However, until a great deal more work is undertaken at an international level, it is the most reliable and consistent single figure indicator that is available.

The single figure approach is an absolute standard applied nationally, where it is part of PDR. The lack of regard for variation in background noise level makes this a crude approach, which does not take into account the soundscape of the area or context in which it is located. Whilst this is undoubtedly a weakness in the approach, a test of how suitable the current permitted noise level is can be considered by the evidence of the number of complaints compared with the number of installations, although this does not provide a positive indication that quality of life has been protected adequately.

Phase 1 demonstrated a very small proportion of complaints at present, but the installations have so far been mainly in the detached archetypes where distance is likely not to present a noise constraint and there is a low risk of noise affecting neighbours. The risk therefore remains that the noise burden placed on neighbours may generate complaints for the denser property archetypes.

The conclusion that the permitted noise level is set at an appropriate level must therefore be treated with caution, requiring further work to monitor and evaluate it with a potential review period to consider the evidence to revise it, based on meeting the expectations of the planning test to adequately protect amenity and quality of life of neighbours as well as those people benefiting from the operation of the unit.

The two scenarios that therefore benefit from further work to inform whether refinements of the method to accurately assess the noise impact on the local soundscape and residents' quality of life are:

1) Whether the existing permitted noise level in MCS 020 adequately controls noise impact to a degree expected to meet the planning test to protect amenity and quality of life, taking seasonal variability of noise emissions, tonality and directivity and local soundscape into account; and
2) What are the main causes of complaints to Local Authorities, Installers or the MCS, to feed into a good practice guide for installers to minimise noise impact and the risk of significant adverse impacts being caused.

The burden of sound impact experienced from ASHPs is currently not widely known. Social surveys and objective noise impact assessments would be required to establish the range of impacts that are currently caused by the permitted noise level within MCS 020, under PDR.

The levels of complaints or dissatisfaction in other European countries, where the rollout has been faster than in Wales and the rest of the UK, would also provide valuable information on the extent of adverse impact associated with any particular noise impact limits.

5.6. Differential Daytime / Night-Time Noise Limits

Many other European countries adopt different daytime and night-time limits for noise impact. As the global manufacturers develop products for the European market, they already have control systems that are capable of being set with different operational constraints for daytime and night-time periods. This would therefore represent a relatively simple change that could permit higher noise impacts during the daytime, and hence reduce the noise constraint considerably. Adopting higher daytime noise impact limits is likely to be the single biggest change that would largely remove noise barriers to higher installation rates.

5.7. Add Background Survey Data for a Higher Noise Impact

The current sound pressure level limit of 37 dBA (from Step 6 of the MCS calculation) implies an internal level of 25 dBA, if 12 dB attenuation is considered for a partially open window. Although larger window openings may be required in summer to mitigate overheating, the ASHP is less likely to be working hard when windows are open to mitigate overheating.

Therefore, this absolute level would seem to be approximately appropriate, if no consideration is given to the impact on the quality of the local soundscape. Where that is important, the control of noise at source could make it desirable to select the quiet units (with sound quality ratings which could sit alongside or draw from the MCS sound power data) in a similar way to Defra approved wood burners in smoke free areas, for instance. This would provide the Welsh Government with a chance to identify a register of units suitable for use in for high quality soundscape areas, and guard against cumulative impact in quiet areas that are designated as such within Local Authority action plans. This in turn act as a stimulus to the marketplace to provide quiet units.

If the location is subject to higher sound levels, it would be appropriate to allow relaxation to apply to the permitted noise level (i.e. a higher sound level), following the principles and method of BS 4142. However, it is essential that a route remains through the MCS for this alternative noise calculation to be considered, as PDR and grant funding rely on MCS compliance. Therefore, it is suggested that a simplified process is enabled for noisier environments, if applicants so desire.

This could include the following:

- A minimum site survey duration - e.g. between 18:00 hrs and 08:00 hrs;
- Data recorded in accordance with BS 7445 by a suitably qualified acoustician;
- The prevailing background sound level determined in accordance with BS 4142;
- The calculated ASHP sound level not to exceed the background, $L_{A90, T}$, level; and
- Consideration of cumulative impact.

As a first step, the Welsh road and railway noise maps, published at 10-metre resolution, could be used to determine the likelihood of the proposed ASHP location being in an area with a good quality soundscape, where noise from the ASHP may have more of an impact, or a poor quality soundscape, where a relaxation of the permitted noise level may be acceptable. It should be noted, however, that these noise maps only illustrate noise from road and rail sources, and not sources such as industrial estates or commercial premises, for example, therefore using them has a high likelihood of resulting in an overestimate of the quality of the existing soundscape.

5.8. Reconsider Acoustic Screening Efficacy

Preliminary work by the University of Salford and iKoustic (3) suggests that the 5 and 10 dB attenuation assumed by partial and full barriers in the current MCS calculation may be optimistic. A more robust consideration needs to be included within any amendments to the calculation, which draws on information about the screening that is on offer, and the conditions in which it is located and maintained.

5.9. Account for Absorptive Panels Behind the ASHP

A question is asked in Annex 51 if an absorptive panel can be used behind the ASHP to negate the effect of that reflective surface by transforming it into an absorptive surface. If 100% of the sound incident on it was absorbed it may reduce the sound pressure level at a distance by up to 3 dB, which is a significant decrease in terms of energy (half in fact). However, absorption is very unlikely to be this effective in practice, due to the directivity of the sound emissions from the ASHP, the frequency range of absorption, and the extent of coverage of the wall. It is suggested that further laboratory tests are undertaken to determine an appropriate sound power level allowance that this mitigation is equivalent to, with a correction between 0 and 3 dB expected.

5.10. Consider Tonality, Intermittency and Directivity

It is clear from the complaints reported in Phase 1 of this work that the tonal and intermittent characteristics of ASHPs can contribute significantly to the annoyance of neighbours. It is also documented that these features are not recorded during the acoustics tests carried out for ErP product labelling.

To assess tonality, intermittency and directionality new laboratory standards are required to define and measure these characteristics. New calculation methods are necessary to determine the in-situ sound propagation, and new assessment methods are necessary to determine the presence of tones in variable background noise. There is a large amount of work that would require global cooperation within the industry to define the standards for laboratory tests, calculation methodologies and the most objective human response to these characteristics.

The assessment of characteristics that attract attention and are prominent are likely to be even more heavily influenced by non-acoustic factors. It is well established that for sound from aircraft and road traffic, one third of the variance in annoyance reactions can be explained by acoustic factors, leaving two thirds to be explained by non-acoustic factors. For ASHPs, it is likely that an even lower proportion of the annoyance may be explainable by acoustic factors. This emphasises the urgent need for the UK governments to invest in shaping the public perception of sound from ASHPs (discussed further in Sections 7.6 to 7.8).

6. CONCLUSIONS

This report presents the outcome of the work undertaken for Phase 2 of this project. There are limited options for changes to PDR to remove obstacles to large scale ASHP rollout – the distance to the boundary rule is one possible change that has been considered. However, a wide range of options for updating the MCS calculation procedure and tools are proposed, as well as other supporting work that can all contribute to reducing noise constraints for the rollout of ASHPs across Wales, and managing and controlling the environment noise burden that may result as part of a strategic approach using PDR.

This report identifies the following eight areas where conclusions can be summarised from the Phase 2 works:

1) The 3 m boundary distance rule is the biggest obstacle to ASHP installation in Wales and should be removed if permitted noise levels are met. Interviews found general support for requirements to meet permitted noise levels at receptors rather than fixed boundary distances providing proxy buffer zones.
2) Allowing installations on roof locations where the permitted noise level can be achieved, provided that safe access can be assured and maintained.
3) Easily accessible noise data on ASHPs would allow homeowners and installers to find and select suitable low-noise units. The sound power level could be incorporated into the MCS MID database. This would allow a simple digital web-based tool (proposed as the Acoustic Design Tool) to be able to draw from this database to identify suitable low-noise units. A prototype demonstration sheet has been created to show how this could work, allowing selection of appropriate units to meet the permitted noise level using visual charts that incorporate the noise constraint, rather than by manual calculation methods, removing the 2 dB rounding error.
4) Noise barriers are not typically installed by ASHP installers because of maintenance implications, but demonstrating their use through case studies could facilitate more suitable units to be appropriate for installations in terraced/semi-detached houses under certain circumstances.
5) Detached rural houses present the easiest ASHP installations from a noise impact perspective. Additional assistance is needed to facilitate installations for terraced and semi-detached houses, which represent the majority of the housing stock, with consideration for guidance on addressing the noise burden in a socially equitable way, also creating an incentive to select the quietest units to protect customers quality of life.
6) It has been demonstrated how the current noise constraints can be achieved for the most dense archetypes with a combination of selecting appropriate units using the acoustic design tool proposed, access to better design information, case studies examples, some additional mitigation. This will facilitate ASHP viable deployment across all residential archetypes.
7) Further work is recommended (see Section 7) to test whether the current MCS 020 permitted noise level is appropriate to protect amenity and quality of life,

considering temporal, tonality, directivity factors and follow up investigations into case studies and complaints received.

8) Further work is recommended (see Section 7) to develop additional case studies, improve public perceptions of ASHP noise, and promote the selection of ASHPs on sound quality grounds in a way that can address cumulative impacts on soundscapes in Wales.

The overall conclusion that can be drawn is that noise is an important and critical consideration in the selection of ASHP and the rollout of ASHPs as part of renewable technology deployment across all property types in Wales.

The constraints currently encountered as a result of noise with PDR can be addressed by implementing the findings of this report, and simplifying PDR requirements as recommended.

The approach suggested is a strategic one requiring a number of steps, but which will provide an evidence-based approach to support the widespread deployment of ASHPs across all residential archetypes in Wales, whilst minimising the risk of widespread noise annoyance and complaints. This is contingent to the further works that are recommended being completed with a degree of urgency to prepare the public, raise awareness around noise and the choices available and perhaps most importantly to test the validity of the existing permitted noise levels within MCS 020 for the factors identified as important.

7. FURTHER WORK

This section considers further work outside MCS 020 updates, which are considered separately.

7.1. Is the MCS 020 permitted noise level correct ?

The current level is a rather crude absolute limit which does not take account of a number of factors, considered important to the degree of adverse impact cause by the noise emissions of units on residents and the quality local soundscape.

It is considered that urgent work to consider the implications of the tonality and character, diurnal temporal and seasonal temporal variation of the sound emissions, directionality on the permitted noise level adopted as the point of compliance for noise impact.

It is necessary that this adequately controls noise impact to a degree expected to meet the planning test to protect amenity and quality of life. It is also important to consider the impact on the local soundscape (see also 7.5)

7.2. Complaints and Best Practice Guidance /Advice note

Work to follow-up on large scale installations (in social housing projects for example, or the most dense archetypes) to proactively investigate the impacts caused by noise, including the acoustic and non-acoustic factors affecting the level of annoyance caused to communities, is considered valuable.

Where there are complaints it is important that these are taken seriously and investigated. It is suggested that creation of a specialist task force would enable complaints received by Local Authorities, Installers and the MCS to be gathered and reviewed to determine what the main causes of complaint are. This would enable the creation of a Good Practice Guide that can be used to refine the approaches taken by installers to minimise the risk of adverse noise impact and prevent significant adverse impacts to residents being caused as a result of PDR.

7.3. Provide exemplar case studies with installers

Identify real examples of installations in different archetypes and provide post-commissioning evaluation of the impact of noise from the units on the occupier and the neighbouring properties, would provide advice on successful placements of units that can be used for training of installers, by consumers when considering their own choices and to raise the standard of installations through shared learning. Case studies could be identified by consultation with installers - either through the social landlord route, or by direct collaboration with installers. These could form part of the Best Practice guidance suggested in 7.2.

7.4. Annex 63

Annex 63 is looking at the acoustic placement of heat pumps. No doubt there will be much useful experience to be gained from full engagement with this Annex, not least because most countries in Europe have installed more ASHPs than Wales and the UK, and are therefore at a more advanced stage of noise issues that may arise. The expertise within the Annex 63 collaboration is likely to be at the forefront of global knowledge. This is likely to take some time, and may be too late to influence or inform the measures taken in the first wave of deployment of ASHPs to all building archetypes in Wales.

7.5. Investigate potential for cumulative sound impact

To implement the soundscape approach in Wales, Local Authorities need to set strategic acoustic allowances for existing and proposed schemes that involve installing ASHPs in standardised positions. These allowances should reflect the cumulative noise impact on every property affected by the ASHPs.

The cumulative noise impact should consider the factors such as geometry, distances and archetypes of the properties and the ASHPs, as well as the quality of the soundscape. This is perhaps most important to better understand for the early rollout phase across all archetypes, when the technology is likely to be at its noisiest. The indications from manufacturers from the Phase 1 work is that units are being designed to be quieter, but it is relevant that these can often result in larger units, so size constraints are a disincentive for use of quiet units.

Developers of new schemes that require planning permission should conduct a scheme noise impact assessment to demonstrate compliance with the quota. For PDR schemes, a model for each archetype should be used to estimate the noise impact (see further works).

The ASHP sound power tool from WP1 could be used within the context of the archetype of an area to test the potential for cumulative impact. This would be a much simpler approach than using full acoustic modelling, although full acoustic modelling is probably a more appropriate method, and would offer greater insight into the risks of cumulative impact.

7.6. Gauging public perception of sound from ASHPs

The recent evidence sessions held by the Science and Technology Committee of the House of Lords into the effects of noise on human health heard the Defra Minister of the time, Rebecca Pow MP, recognised that noise from air source heat pumps in particular was a concern of the public. This was picked up by the Telegraph and Daily Mail raising noise as an obstacle to rollout in recent articles, and it is clear that some public awareness now exists that noise is a potential obstacle to widespread adoption, as a perception at the very least.

It is considered important to test the reality of annoyance and complaints caused against the perception and fear of the impact that could result. Building an evidence that provides confidence that this is a perception and not a reality is necessary. The evidence on complaint numbers from Phase 1 suggests that this may be a perception rather than reality, but there are examples where a small number of installations which have resulted in actionable nuisance. The reason for this requires investigation to examine the reason.

We are aware of work being completed for the UK Government Department for Energy Security and Net Zero (DESNZ). The social survey undertaken for that project targeted areas of high ASHP deployment in order to identify if the neighbours proximal to ASHP installations are identifying ASHP noise as an issue, or identifying it at all. In addition, follow up interviews are being conducted with those who have identified ASHP noise as an issue to understand the factors that contribute to this. This work compliments use of complaint numbers as a measure of the success of the MCS permitted noise emissions target. The results of the DESNZ project can inform the speed of deployment, which would otherwise leave a high risk of noise becoming an issue in the more challenging archetypes, especially the terraces which comprise a third of all housing stock.

It is considered that social survey techniques should also be used to conduct qualitative research in areas where low levels of ASHP deployment using PDR have occurred for comparison with areas of high deployment to test the perception of those living with the noise ASHPs generate.

The results should be then combined with objective noise assessments for a range of ASHP installations referred as having complied with the target, but for whom MCS or the Local Authority have received complaints in relation to the noise generated by them. These case studies can inform further refinements, but have some urgency to be completed early in the development process.

7.7. Promoting public awareness - the purring sounds of renewable heat

The public perception of sound from ASHPs may initially seem a superficial aspect compared with the objective acoustic impact, but it is of great importance for their general acceptance, given a large proportion of an annoyance response is likely to be linked to non-acoustic factors. In order to avoid unnecessary obstacles to widespread uptake, and to actually reduce annoyance, there is a real public health benefit to identify what can help create a positive public reaction to sound generated by ASHPs. A positive public view of sound from ASHPs should not be left to chance, the vagaries of the press or as a political football; this requires proactive management. Currently it is largely omitted from public discourse, but media attention is raising it to the public's awareness (4). The sound generated by ASHPs should be actively addressed and embraced in terms of public information and education. This requires a lot more work to determine appropriate strategies, and their implementation ahead of widespread deployment. Some type of sound quality mark (see 7.8) may yet be an area to explore further, which could be awarded via the MCS database.

7.8. Promote sound quality

Sound quality is a well-used product design tool in the automotive industry and also for white goods markets such as for dishwashers, vacuum cleaners or washing machines. While Quiet Mark provides a certification scheme, the judgement of the qualification is opaque. If the sound power data for all units becomes identifiable and searchable in the MCS MID database, as proposed in this report, a transparent process could be used to identify the quietest units in any particular class at any particular time.

However, there is still an opportunity to champion the sound quality of an ASHP. No doubt some ASHP manufacturers are already deeply involved in considering the sound quality of their products, most likely in confidence. The promotion of sound quality by government sources or agencies may assist those manufacturers who have products that have been engineered with considerations of sound quality to promote those characteristics and provide a market opportunity to such units.

8. LIMITATIONS

The findings and conclusions of this work have limitations, which should be considered as part of decisions of what degree of weight can be attributed.

The main area of limitation is the lack of response from installers, which means the 'deep dive' into the challenges faced by them as part of Phase 2 was only possible for one example. It is felt that there may be some reluctance to engage for competition reasons, as the energy providers who use installers from a closed supply chain were happy to engage.

A further limitation is the evidence of complaints associated with installations that have already occurred. It maybe that some follow-up case studies are needed for the examples identified (e.g. the large social housing installation that was identified as part of WP5) to see whether complaints result and if so to explore why (see further works section).

Another area of limitation or potential uncertainty is the archetypes in Wales, and any variation from the sources assumed in terms of proportion of property archetypes. It is expected they would be broadly similar to the UK data however.

9. ACKNOWLEDGEMENTS

The authors would like to thank:

- The Institute of Acoustics
- The Chartered Institute of Environmental Health
- Matt Torjussen of ANV Measurement Systems for sharing IOA survey data
- All the participants who provided their time without recompense

10. ABBREVIATIONS

The following abbreviations are used throughout this document and also the Phase 1 report.

Abbreviation	Full Phrase
ASHP	Air Source Heat Pump
dB	Decibel
dBA	A-weighted decibel
ErP	Energy-Related Product
GHC	Greenhouse Gas
GWP	Global Warming Potential
IOA	Institute of Acoustics
MCS	Microgeneration Certification Scheme
MID	Microgeneration Certification Scheme Installations Database
PDR	Permitted Development Rights
RICS	Royal Institution of Chartered Surveyors
SCOP	Seasonal Coefficient of Performance

11. REFERENCES

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APPENDIX 1

Extract from (2), 40 archetypes in UK:

Frequency Rank		Frequency	Percent	Cumulative Percent	Proportion of whole stock (notional SAP) CO_2 emissions	Page
1	Pre-1919, mid terrace	2,090,000	8.0	8.0	7.9	7
2	1945-1964,semi detached	2,040,000	7.8	15.9	7.6	12
3	1919-1944, semi detached	1,920,000	7.4	23.2	8.1	17
4	Post 1980, detached	1,840,000	7.1	30.3	7.5	22
5	1965-1980, semi detached	1,200,000	4.6	34.9	4.1	27
6	1965-1980, detached	1,050,000	4.0	38.9	5.5	32
7	1965-1980, purpose built flat, low rise	1,050,000	4.0	43.0	2.1	37
8	Post 1980, purpose built flat, low rise	1,040,000	4.0	47.0	1.7	42
9	Pre-1919, semi detached	830,000	3.2	50.1	5.4	47
10	1965-1980, mid terrace	810,000	3.1	53.3	2.1	52
11	Post 1980, semi detached	800,000	3.1	56.3	2.0	57
12	1965-1980, bungalow	780,000	3.0	59.3	2.9	62
13	Pre-1919, detached	780,000	3.0	62.3	8.2	-
14	1945-1964, purpose built flat, low rise	720,000	2.8	65.1	1.6	-
15	1919-1944, mid terrace	690,000	2.6	67.7	2.1	-
16	Pre-1919, converted flat	690,000	2.6	70.4	2.5	-
17	Pre-1919, end terrace	670,000	2.6	73.0	3.6	-
18	1945-1964, mid terrace	670,000	2.6	75.5	1.9	-
19	1945-1964, bungalow	640,000	2.5	78.0	2.4	-
20	Post-1980, Bungalow	560,000	2.2	80.1	1.7	-
21	Post 1980, mid terrace	540,000	2.1	82.2	1.0	-
22	1945-1964, detached	520,000	2.0	84.2	3.1	-
23	1945-1964, end terrace	510,000	2.0	86.2	1.8	-
24	1965-1980, end terrace	510,000	2.0	88.2	1.7	-
25	1919-1944, detached	500,000	1.9	90.1	3.5	-
26	Post 1980, end terrace	420,000	1.6	91.7	1.0	-
27	1919-1944, end terrace	400,000	1.5	93.2	1.5	-
28	Pre-1919, purpose built flat, low rise	400,000	1.5	94.7	1.2	-
29	1919-1944, purpose built flat, low rise	390,000	1.5	96.2	1.0	-
30	1919-1944, Bungalow	240,000	0.9	97.1	1.0	-
31	1965-1980, purpose built flat, high rise	190,000	0.7	97.9	0.4	-
32	1945-1964, purpose built flat, high rise	130,000	0.5	98.3	0.3	-
33	Pre 1919, bungalow	110,000	0.4	98.8	0.6	-
34	1919-1944, converted flat	70,000	0.3	99.1	0.2	-
35	1945-1964, converted flat	60,000	0.2	99.3	0.2	-
36	Post-1980, converted flat	50,000	0.2	99.5	0.1	-
37	1965-1980,converted flat	50,000	0.2	99.7	0.1	-
38	Post 1980, purpose built flat, high rise	40,000	0.2	99.8	0.1	-
39	Pre 1944, purpose built flat, high rise	30,000	0.1	100	0.1	-
40	All temporary dwellings & All non residential flats	< 10,000	< 0.1	100	0.03	-
	Total	*26,030,000*	*100*	*100*	*100*	-

Table A: The 40 archetypes identified in U.K.