Towards Modelling Guidelines for Domestic Air Source Heat Pumps

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Abstract

The joint IOA / CIEH practitioner note refers to "appropriate sound propagation modelling carried out by an SQA". The industry and international standard model for outdoor sound propagation modelling is ISO 9613-2, despite not being proven to be suited to modelling complex urban morphologies. Variability in how practitioners build and configure these models can lead to materially different predicted sound levels for a specific scenario. This paper outlines the modelling features that may be useful to include in modelling guidelines for ISO 9613-2 based predictions of sound from domestic air source heat pumps (ASHP), developed in the context of planning for domestic ASHPs.

Guidelines are recommended for ground absorption, spectral data, reflection order, and building geometry to work towards establishing a consistent, robust framework. The advantages and constraints of point source or box sources are also discussed. Practical guidance is proposed for corner placements, partial barriers, and receiver positioning.

Keywords: *acoustic modelling, ASHPs, building decarboniasation, ISO 9613*

1. Introduction

The acoustic community would benefit from establishing a consistent, evidence-based approach to modelling sound transmission from a proposed air source heat pump (ASHP) to a receptor location. Developing clear and repeatable acoustic frameworks supports broader environmental policy by facilitating the transition from fossil-fuel heating to electrified systems, a key component of decarbonisation strategies aimed at mitigating global climate change.

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In the UK, Permitted Development Rights (PDR) enable domestic ASHP installations without requiring a full planning application, provided noise emissions meet particular criteria. Under the Microgeneration Certification Scheme standard MCS 020a [1], the sound pressure level L_p at 1m from a neighbouring habitable room window or door must not exceed 37 dB(A). When an installation fails the simplified MCS 020a calculation by a small margin, or where PDR does not apply, planning barriers frequently delay or stall ASHP installations. To address this, the Domestic Air Source Heat Pumps Professional Advice Note (2026) [2], produced by the Institute of Acoustics (IOA) and the Chartered Institute of Environmental Health (CIEH) introduced a Level 1 assessment pathway. This pathway allows a Suitably Qualified Acoustician (SQA) to conduct desktop sound propagation modelling using ISO 9613-2 [3], as an alternative between the MCS 020a calculation - which has been shown to be conservative - and a full BS 4142 [4] assessment, which requires background sound measurements.

However, because ISO 9613-2 contains numerous configurable parameters, variability in how SQAs construct and configure software models can yield inconsistent predictions for identical scenarios. This paper proposes standardised modelling guidelines for domestic ASHPs to establish a robust, repeatable framework.

2. ISO 9613-2 Implementation

ISO 9613-2 is a widely used standard that defines a calculation for outdoor noise propagation. It has been proven to be accurate for mid-range distances evaluating industrial sources; yet is adopted for a wide range of outdoor propagation modelling, including domestic ASHPs.

This calculation model is implemented in many software applications; in this research, CadnaA by Datakustik [5] has been used in the modelling exercises. As such, some proposed recommendations may be limited in being relevant exclusively to this software, however it is understood that other software most likely have different ways of accessing the same settings and implementations that are discussed in this paper.

Software variations are inevitable, which is why this research is working towards guidelines for modelling ASHPs, with the desire for input from a range of users as part of its development.

3. Modelling Investigation Method

The modelling exercises that inform this document were part of Work Package 3 associated with the 'Reducing acoustic barriers to ASHP installations' project [6], funded by the MCS Foundation and Nesta. This firstly considered theoretical modelling, to probe how the software implemented the ISO-9613 calculation, including the understanding of ground absorption, reflections and source properties; which are discussed in later sections of this paper. The influence of each setting was investigated over a range of distances up to 15m, with receivers spaced every 0.5m, to investigate the effect across a small distance, as relevant to domestic properties. Real-world scenarios were then considered using the knowledge from the theoretical modelling. The modelling was completed for a variety of sites, including where complaints had been made about noise levels. Over 7,500 separate ISO 9613-2 calculations were made.

4. Baseline Environmental & Software Settings

When considering the baseline software settings within the creation of a model, due diligence of the SQA to check their model is implementing the requirements appropriately is of great importance. This section discusses baseline model design mechanisms to form part of a checklist when creating a model for a domestic ASHP.

4.1 Ground Absorption

Models should utilise an acoustically hard ground setting (G=0). This setting provides a prudent sound propagation scenario and avoids relying on ground conditions as part of the sound attenuation; ground conditions may change during the life of the ASHP, and the calculation should not rely on the landscape. Due to the context of domestic ASHPs being present in homeowner's gardens, using the soft ground attenuation in the assessment can restrict the homeowner from developing their garden in future use, as such hard ground should be assumed.

4.2 Ground Absorption Calculation

Beyond setting the ground absorption, there are options for how the ground absorption is calculated. These are defined in ISO 9613-2 (2024) [3], method 7.3.1 and method 7.3.2. CadnaA provides multiple options, which are described in the CadnaA documentation [7], including the two ISO methods mentioned previously, no ground attenuation (other than that accounted for using equation 15 from ISO 9613-2), and a fixed value of -3 dB from LAI-2015, [8]. Changing these calculation methods was investigated as part of the theoretical modelling. Considering the above recommendation of modelling with hard ground, the simplified method is not appropriate, as 7.3.2 is stated to be considered under specific conditions including that 'the sound propagation occurs over porous ground or mixed ground most of which is porous'. Therefore, the default 'Spectral, all sources' option using the method defined in 7.3.1 is considered most appropriate.

4.3 Building Geometries

The topographical modelling of buildings should assume flat surfaces without intricate modelling. Features such as window reveals for example should not be used to reduce calculated sound level impacts. This is standard practice when considering environmental modelling and should be maintained in these scenarios, despite focusing on small distances of calculation.

5. Source Characterisation

5.1 Data Input

The availability of input data can vary – for example, it may be available as broadband (i.e. A-weighted sound power level) only, and there may or may not be directivity data available for a particular installation. In most cases this is sufficient to proceed with modelling. If there is additional data, the modeller will need to determine if it is advantageous to try and use it.

5.1.1 Considering Spectral / Single Octave Band Data

Within the modelling investigations, with hard ground absorption and implementing the ground absorption reflection method in 7.3.1 [3], in over 50 % of the scenarios, no difference was found between broadband (implemented at 500Hz in the model) and octave-band calculations considering the predicted A-weighted sound pressure level, L_p . Single-band modelling is therefore sufficient for most scenarios, though octave-band data may be preferable when detailed barrier attenuation is evaluated.

5.1.2 Directivity

Information regarding the spatial variations and directivity of ASHPs is available from a limited number of sources, including the AIT / CETIAT sound intensity database [9] and other reports [10] [11], detailing individual ASHP directivity. To understand how this data translates into prediction software, the AIT database directivities were modelled in two different ways:

- By applying the sound intensities on different faces to area sources on a box source, using K_0=3.
- By using the intensities as ordinal directivities for a point source, and interpolating between the axes.

While both approaches are considered to be reasonable implementations of the directivity data, they result in opposite effects within the model. The application of area sources to different faces does not result in greater sound emissions perpendicular to the larger faces: because the area sources are composed of point sources that act omnidirectionally in the model, the resulting effect is greater sound propagation on the axes where the model itself is largest (i.e., along the horizontal axis in Figure 3.) Conversely, where directivity is applied directly to the point source, higher sound emissions are observed on the vertical axis.
Modelling directivity, and acquiring suitable source directivity data to implement, is a complex area. Field evidence strongly supports a simplified approach; the 2011 Building Performance Centre (BPC) report [11] demonstrates that the domestic ASHPs measured in-situ were not particularly directional. An analysis of the available data within the CETIAT database suggests that an emission profile close to omnidirectional is likely typical for these units.
Consequently, it is considered appropriate and sufficient to model domestic ASHPs as being omnidirectional.

5.2 Source Implementation Choice

The appropriate source representation in an acoustic model can be a choice that affects outcomes; the potential application of different options is discussed below and summarised in Table 1.

5.2.1 Point Source

Where the sound propagation is of a distance that is at least several (e.g. two) times the largest dimension of the ASHP, and there are no partial barriers (e.g. barriers that block a line of sight to some parts of the ASHP but not others) using a point source is usually considered to be most appropriate. Placing the point source at the geometric centre of the unit is considered best practice.

5.2.2 Box Of Area Sources

Creating a box of area sources to the dimensions of the ASHP can be used when evaluating noise impact in close proximity, or where there are geometrical features that would result in the sound transmission being sensitive to the precise source location. For example, if an ASHP is partially screened by a barrier, or if there are reflection paths that are very sensitive to the precise location of the source. In these cases the detail of the physical dimensions and spatial distribution of the sound energy may be important, and can be captured by effectively distributing the sound sources over the area of the box.
The sound power of the unit should be distributed across the area sources of each side of the unit. A practical recommendation is to draw the dimensions as accurately as possible into the model, and then use the exact dimensions of what is in the model to calculate the specific sound power (dB/m^2) and assign to each source area accordingly.

5.2.3 Box Of Area Sources With Building

Area sources with a building inside have also been considered as a modelling method. This can be an appropriate method if the object may realistically act as a barrier to other sound sources. Although it may appear to be more intuitive in embodying physical reality, caution is required when implementing this method. The use of K_0=3 doubles the sound power of the area sources to account for the screening of the sound power in any one direction. This method also introduces a model artefact along the axes of a box source, where the sound level is lower due to the line of sight to less than half the source sound power, see Figure 3.
Within CadnaA, this implementation can be achieved by drawing an area source to the dimensions of the ASHP, and then converting this into a building. This creates a building with an area source on each of the faces. A correction feature of k_0=3 must be applied to the sources.

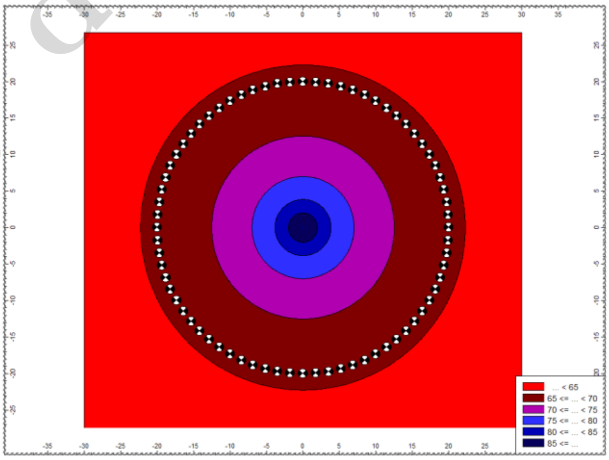

Figure 1. Point Source Radiation

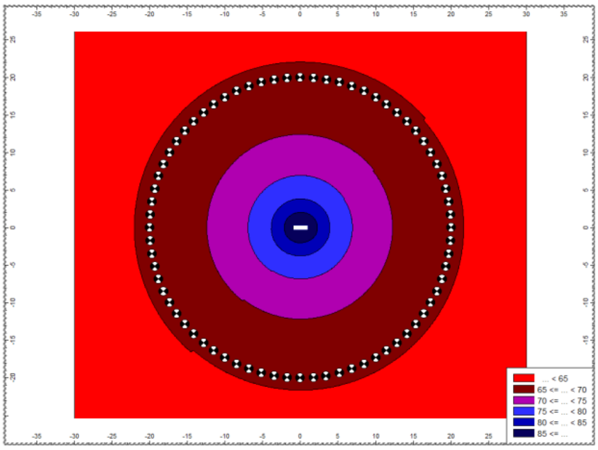

Figure 2. Empty Box Radiation

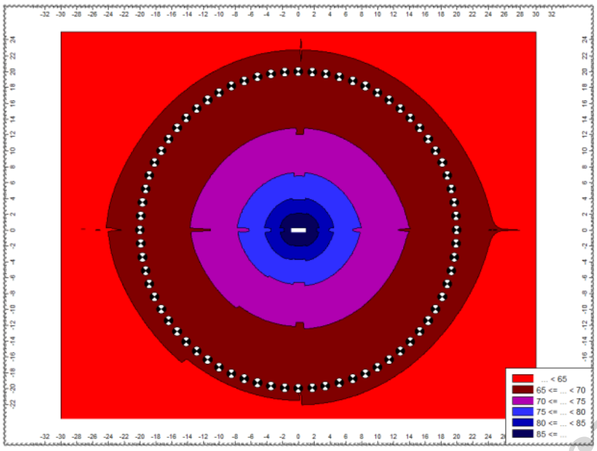

Figure 3. Building Box Source Radiation

Table 1. ASHP Source Implementation Summary

Source Type	**Usage Example**	**How to Model**
Point Source	Mid-Long range assessments	Omni-directional at geometric centre
Empty Box	Short range assessments, or for partial screening	Area source to represent each face of an ASHP. Ensure $k_0=0$
Box Source	Short range assessments, where barrier of unit is important	Area source to represent each face of an ASHP, with a building inside. Ensure $k_0=3$

6. Reflection Settings

6.1 Number Of Reflections

Previous research [12] has indicated that modelling with three reflections is typically sufficient within most common modelling scenarios. To understand the appropriate number of reflections required in a model, the number of reflections can be increased until the result does not vary significantly. Models for domestic ASHPs are unlikely to be computationally intensive, and a greater number of reflections is unlikely to be a practical constraint.

6.2 Assessment Position

MCS 020a [1], indicates an assessment position at 1 m in front of the centre of a window or door to a habitable room. The calculation model in MCS 020a does not take account of any reflections from the facade; the sound level may therefore be interpreted as a free-field incident level. There is also an (unstated) implication that the purpose of the MCS 020a standard is to protect people in their bedrooms at night; by extrapolation this would also protect people in living rooms during the daytime.

When considering the calculation with modelling software, results from receptor points at a particular distance from a facade can be inconsistent, depending on some key settings.

In CadnaA there are user-controllable settings for minimum distances (thresholds) between source and reflector, and also reflector and receiver. Beyond these thresholds, there are user-configurable settings for the interpolation of results. The interpolation setting between receiver and reflector controls the interpolation between a region having been calculated with and without reflections. This interpolation can cause a level jump at a certain distance (with the default being at 1m from the facade). This creates variability with step changes in sound levels created by the thresholds for including or excluding reflections under different model conditions.

The above variability is avoided if the model is used to calculate sound level incident on the facade. To this end, it is suggested that the receiver positions are located on the facade to evaluate the free-field incident sound level, excluding the effect of reflections from the facade in question.

6.3 Reflection Behaviour

Within ISO 9613 [3], section 7.5, conditions are defined to determine when reflections occur from a surface. This is based on variables including the:

- Distance between surface and source
- Distance between surface and receiver
- Extent of surface beyond the point of potential reflection and frequency of the sound
- Angle of incidence

The presence or absence of reflections in the model is not necessarily intuitive; it is strongly recommended that ray tracing is observed as part of the modelling exercise undertaken. Observing the ray paths that are included in the model enables the user to confirm their expectations are reflected in the model behaviour. An example of where this could be important is illustrated below in Figure 4.

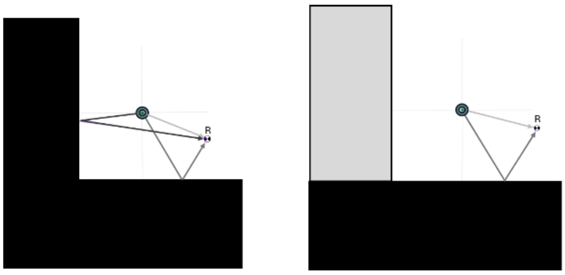

Figure 4. Modelling example where building implementation affects reflections.

When modelling a source located in the corner of a building, the construction of the modelled building can affect whether or not reflections are included from a surface, as seen in Figure 1. On the left, it is constructed as a continuous building, and a reflection is evident. On the right, the two parts are constructed as separate elements: no reflection is calculated, despite the geometry appearing to the eye as being equivalent. This is because the building element on the right does not extend sufficiently past the source. Note that this extension is frequency-dependent, and if a full spectrum source is used, some frequency bands may include a reflection but not others. This highlights the importance of checking that the model is implementing the calculation in the manner expected.

7. Barriers

One final aspect to highlight is the inclusion of barriers. Modellers should be careful to include barriers that do not physically intercept the direct line of sight between source and receiver, as these still have an attenuating effect on the sound transmission. For example, a boundary fence that sits below the line of sight to a neighbour's upper-floor window can still affect the propagation path and should be included in the model. Barrier attenuation is frequency dependent, so there may be different results from modelling with a frequency spectrum rather than using single figure calculations.

8. Summary of Proposed Guidelines

Table 2. ASHP Source Implementation Summary

Parameter	Proposed Setting	Technical Justification
Ground Absorption	Hard ground	Avoids reliance on soft ground that may be hard-paved in future
Ground Calculation	ISO 9613-2 clause 7.3.1	Mandatory for hard ground, ISO 9613-2 Clause 7.3.2 is invalid over hard ground
Source Type	Point source (geometric centre)	Sufficient accuracy for typical domestic PDR distances
Spectral Data	Broadband or Octave-band	Difference in L_p output is < 1 dB over hard ground
Receiver Location	Snapped to façade (free-field)	Standardises output to incident free-field sound pressure level
Reflections	Order >=3, Ray-tracing checked	Ensures computational accuracy and catches building polygon artefacts

9. Conclusion

As the UK transitions towards electrified systems and decarbonisation, mitigating planning delays for domestic Air Source Heat Pumps (ASHPs) is increasingly critical. The IOA/CIEH Level 1 assessment pathway [2], offers a valuable alternative to the conservative MCS 020a [1], calculation by permitting ISO 9613-2 [3], desktop modelling. However, the extensive configurable parameters within ISO 9613-2 software mean that standardisation is required to prevent varying predicted sound levels for identical scenarios from different modellers.

The considerations discussed in this paper aim to offer a starting point towards unifying practitioner approaches and establish a repeatable, reproducible framework. By adhering to baseline recommendations, such as the proposed hard ground settings, assessing free-field levels snapped to the façade, using a point source at the geometric centre, and ensuring appropriate reflection and barrier geometries, uncertainty between modellers can be reduced.

While these proposed guidelines offer a foundational checklist, they are not exhaustive; Suitably Qualified Acousticians (SQAs) undertaking modelling must continue to exercise professional judgement to ensure appropriate model implementation. Moving forward, collaboration between users of different software will be vital to refine and agree appropriate standards and protocols.

10. ACKNOWLEDGMENTS

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