NOISE AND VIBRATION FROM AIR SOURCE HEAT PUMPS

Richard Mackenzie
RMP Acoustics
Edinburgh Napier University
Team lead DECC (now DESNZ) ASHP noise project (EE0214)

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Presentation content

- Introduction to ASHP
- Planning and Permitted development rights
- Microgeneration Certification Scheme
- REHIS guidance and Local Authority criteria
- Noise from ASHP
- Predictions of noise from ASHP
- Mitigation options
- Vibration

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Introduction to ASHP

- Along with wind turbines and solar panels, heat pumps have an important role to play in achieving Government's strategy to reach net zero carbon emission by 2050. ***'Air source heat pumps get £409 million government boost'.***
- ASHP will largely replace gas boilers which will be banned in new housing from 2025.
- However this is introducing an external noise source which has its roots as commercial plant into residential areas.

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What is an Air Source Heat Pump?

An ASHP takes latent heat from outside air and concentrates it to a higher temperature, high enough to provide heating to, for example, a domestic central heating system.

ASHPs work much like a domestic refrigerator whereby heat energy is transferred from one place to another using heat exchangers and a refrigerant fluid going through a process of compression and expansion.

In addition to the main refrigeration components, ASHPs also include a fan, to push a greater amount of air through the external heat exchanger, in order to accelerate the heat transfer process.

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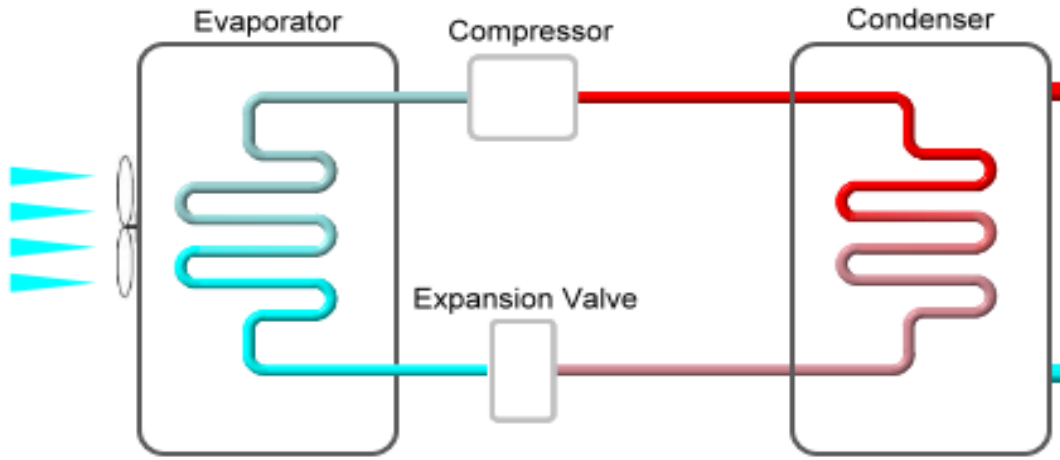
Compression

The gas is compressed which raises its temperature and pressure.



Evaporation

Outside air is drawn in to the unit. It warms the refrigerant which turns to gas at very low temperature.

Condensation

The gas releases heat to the system and condenses back to a liquid state.

Expansion

Liquid refrigerant passes through an expansion valve, reducing its pressure and temperature.

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Introduction to ASHP

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- The main components of the ASHP in terms of noise generation are the compressor and the fan, with slight noise also provided by the expansion valve and any electrical transformers associated with the system.

- A variety of compressor types could be used within an ASHP system such as reciprocating, scroll or screw types. However, the **scroll type is generally favoured** by ASHP manufacturers on account of its higher efficiency, lower maintenance and lower noise level.

- Fans used in ASHPs are typically of the axial type, with four blades, although centrifugal fans are sometimes used.

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Introduction to ASHP

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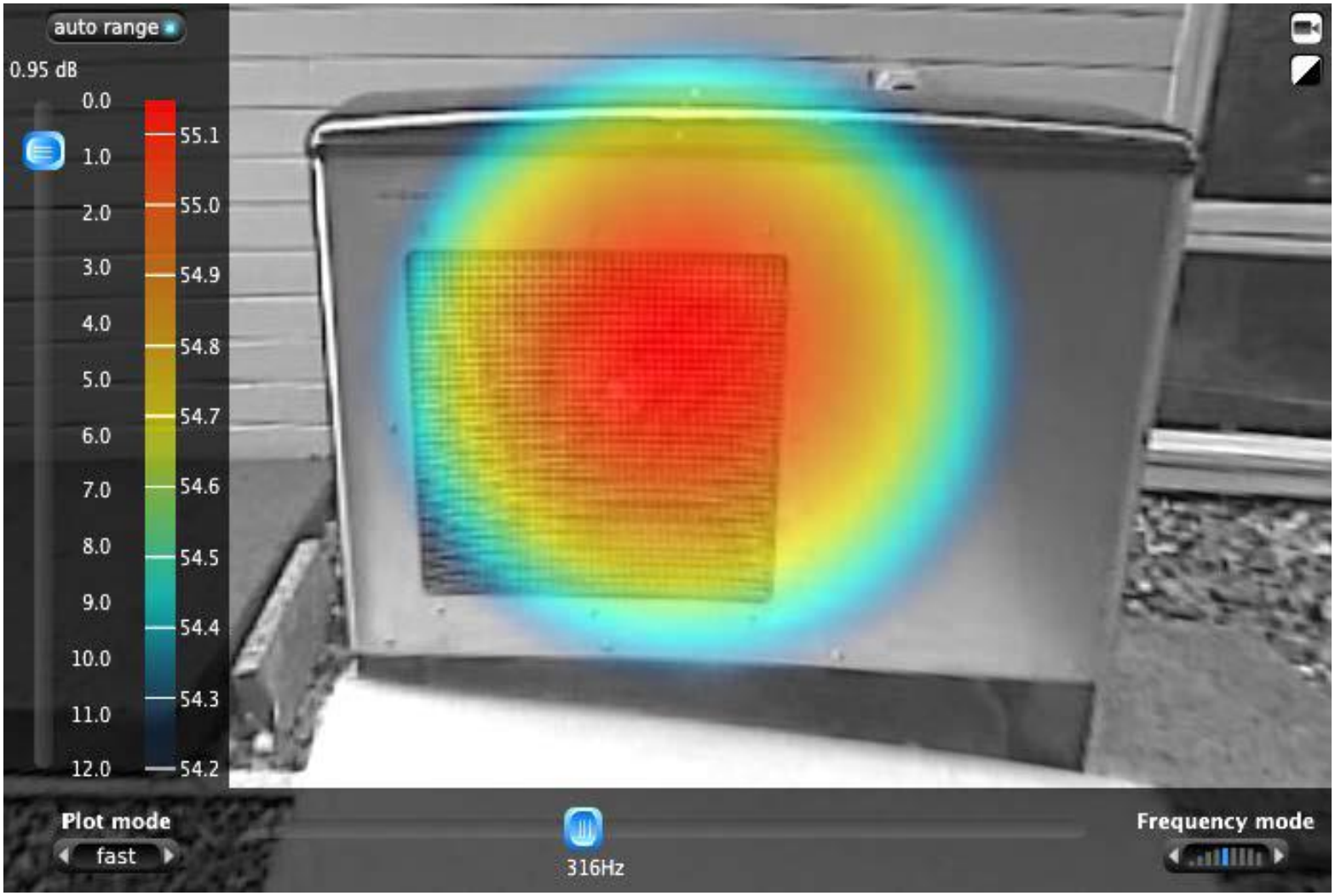

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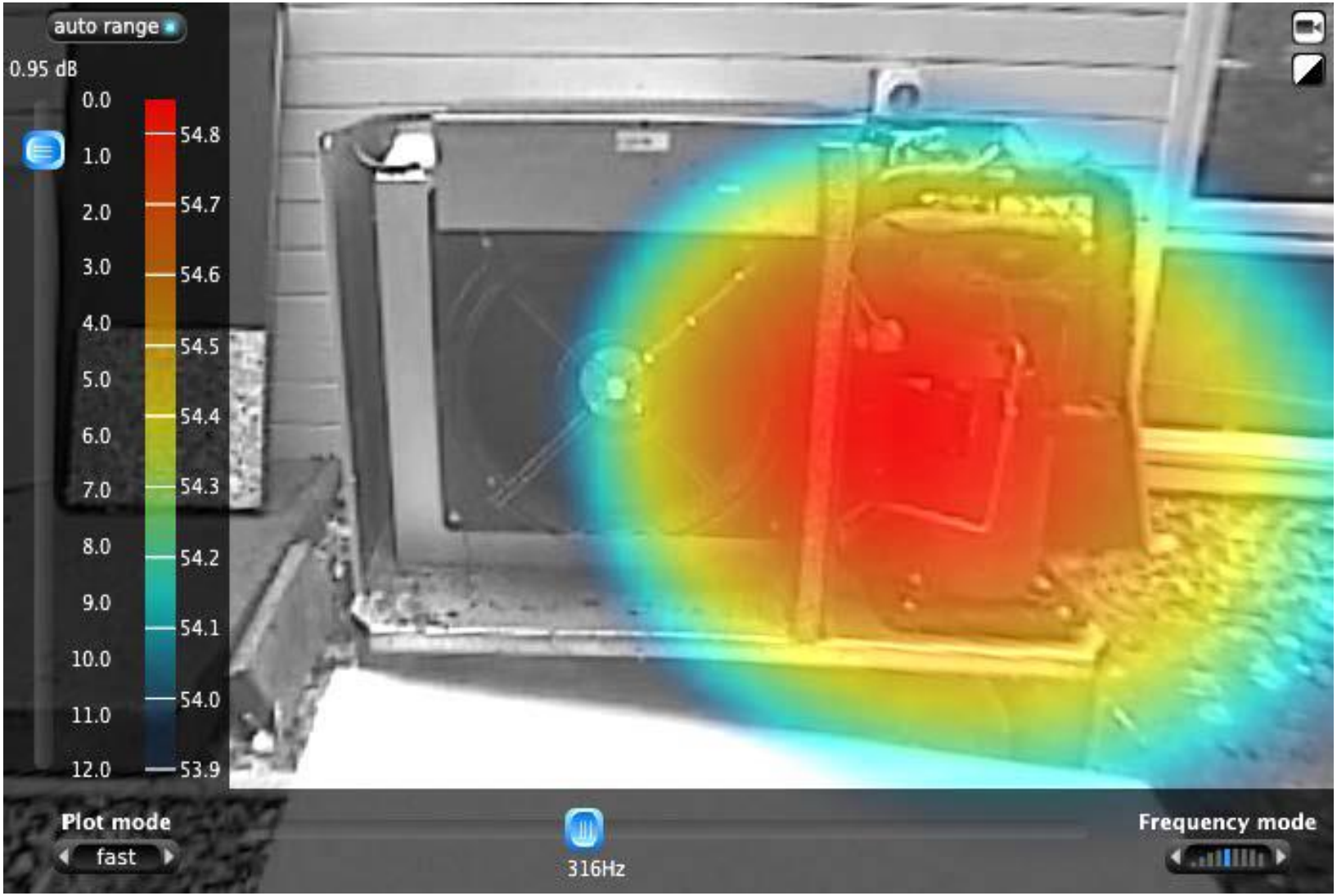

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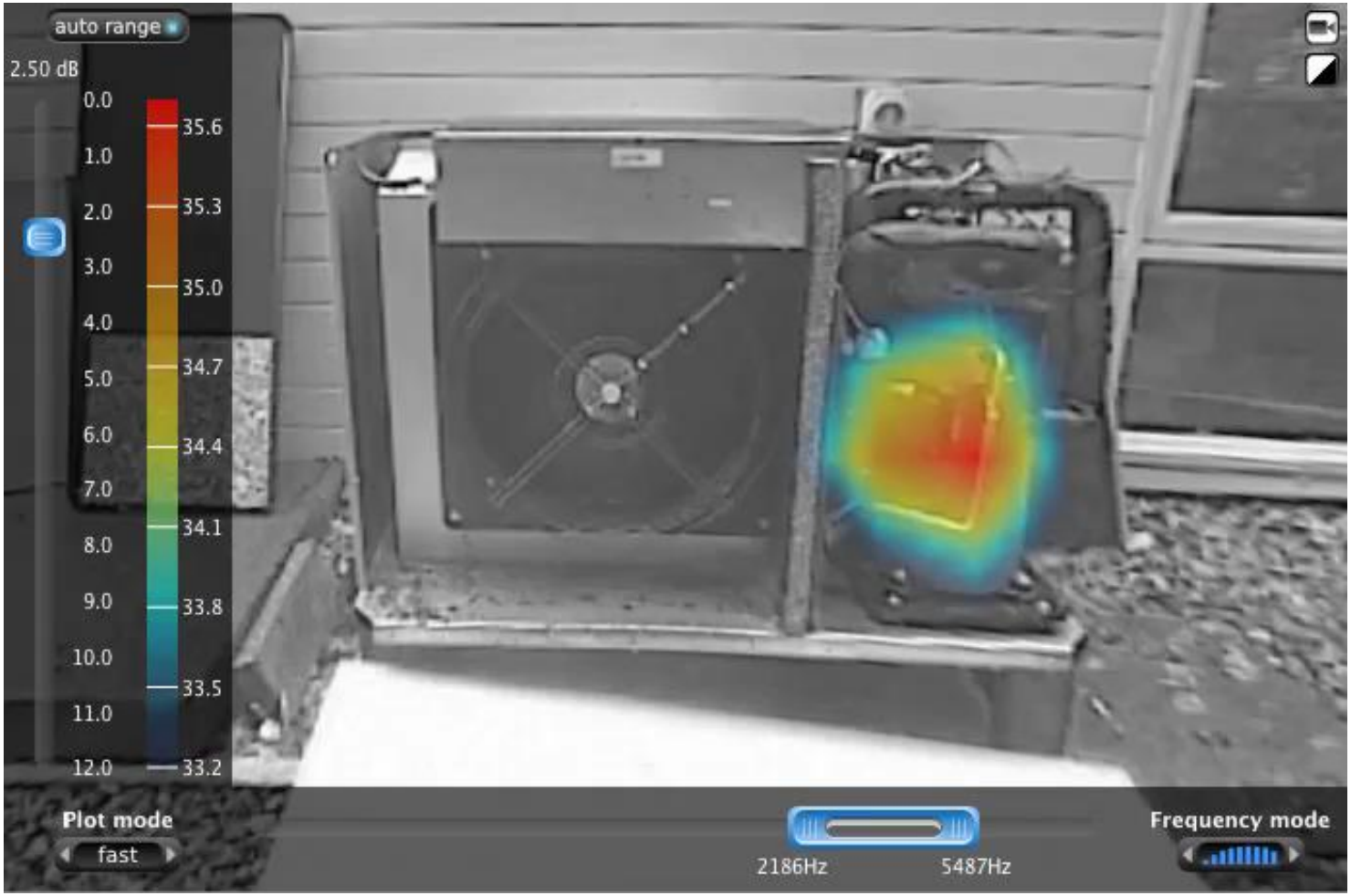

Defrost cycle

As the refrigerant expands and cools during the refrigeration cycle, it is at a lower temperature than the ambient air. This can cause water in the air to condense and freeze on the heat exchanger. The frozen water reduces the efficiency of the heat exchange process and therefore ASHPs run a defrost cycle.

During this cycle, the compressor will run in reverse for a short time at its maximum power. This increases the temperature at the heat exchanger and melts any ice which has collected. However, the process can produce a different noise signature, and with the absence of any masking noise provided by the fan, any tones can be more prominent than during normal operation.

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Planning and Permitted development rights

Is planning permission required for ASHP ?

- Yes, for all new residential and non-residential developments such as commercial properties, schools, hospitals, offices etc
- For new ASHP in existing residential properties, The Town and Country Planning (General Permitted Development) (Scotland) Amendment Order 2016 sets out strict criteria which if satisfied results in no planning application being required.
- If the PD criteria is not met a planning application is required.

Planning and Permitted development rights

Some Council's have provided checklists for residents to determine if planning permission is required, such as this example from Perth and Kinross Council

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CHECKLIST
DO I NEED PLANNING PERMISSION FOR THE INSTALLATION, ALTERATION OR REPLACEMENT OF AN AIR SOURCE HEAT PUMP?

If you answer **NO** to **ALL** of the following questions then please read the conditions on page 2

If you answer **YES** to **ANY** of the following questions you **NEED PLANNING PERMISSION:**

	Tick answer	
• Will there be more than one air source heat pump on the building or within the curtilage of the dwelling?	**Yes**	**No**
• If the air source heat pump is attached to the dwelling: i. Will any part of it protrude more than 1 metre from the external wall, roof plane, roof ridge or chimney? Or; ii. If located within a conservation area, will the ASHP be located on the principal or side elevations and be above ground floor level?	**Yes** **Yes**	**No** **No**
• If the air source heat pump is to be located within the curtilage of a dwelling: i. Will any part of it be forward of a wall forming part of the principal elevation or side elevation where that elevation fronts a road? Or; ii. Will it exceed 3 metres in height?	**Yes** **Yes**	**No** **No**
• Will the air source heat pump be located within the curtilage of a listed building*or a World Heritage Site**? *A search of Listed Buildings can be carried out on Historic Scotland's website at https://www.historicenvironment.scot/ ** A search of World Heritage Sites can be carried out on the UNESCO website at http://whc.unesco.org/en/list/	**Yes**	**No**

• Have 'permitted development' rights been removed? You will need to check the original planning permission for the development. Permissions from 2007 onwards can be found on Public Access. Use the map search to find your plot. Please be aware that the map function on public access is not available when using tablets or mobile phones *You can check the planning history of the property on PublicAccess via our website http://www.pkc.gov.uk/publicaccess. For help on how to search on public access please see our 'How to use Public Access' guidance note	**Yes**	**No**

Conditions

If you have answered no to all of the above questions then you should not require planning permission. Class 6H of the Town and Country Planning (General Permitted Development) (Scotland) Order (as amended) provides conditions to the permitted installation of an air source heat pump.

1. **The air source heat pump must be used only for the purpose of providing domestic heating or hot water.**

2. **Where the air source heat pump is no longer needed for, or capable or, providing domestic heating or hot water it must be removed as soon as reasonably practicable.**

3. **The air source heat pump must comply with MCS Planning Standards or equivalent standards.**

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Microgeneration Certification Scheme

ISSUE 1.3

MICROGENERATION INSTALLATION STANDARD: MCS 020

MCS Planning Standards for Permitted Development Installations of Wind Turbines and Air Source Heat Pumps on Domestic Premises

Microgeneration Certification Scheme

- Sets a maximum ASHP level noise limit of 42dB $L_{Aeq,\ 5\ mins}$ at the façade of the nearest residential property. The limit is likely derived to achieve the BS 8233:2014 night time internal noise level allowing for the window of the receiving property to be open.
- 42dBA + 3dBA (façade correction) -15dBA (open window) = 30dBA (inside) (About ~NR 24).

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Microgeneration Certification Scheme

MCS sets out a simplified calculation method for predicting the noise level at the nearest neighbouring residential properties

Step	Instructions	MCS contractor results / notes
1.	From manufacturer's data, obtain the A-weighted sound power level of the heat pump. See 'Note 1: Sound power level'. The highest sound power level specified should be used (the power in "low noise mode" should not be used). *Example: Manufacturer's data states the sound power level of the heat pump is 55 dB(A).*	STEP 1 RESULT =
2.	Use 'Note 2: Sound pressure level' and 'Note 3: Determination of directivity' below to establish the directivity 'Q' of the heat pump noise. *Example: The heat pump is to be installed on the ground and against a single wall hence the directivity (Q) of the heat pump noise is Q4.*	STEP 2 RESULT =
3.	Measure the distance from the heat pump to the assessment position in metres. *Example: Distance between heat pump and assessment position is 4 metres.*	STEP 3 RESULT =
4.	Use table in 'Note 4: dB distance reduction' below to obtain a dB reduction. *Example: 4metres @ Q4 = -17 db.*	STEP 4 RESULT =

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Microgeneration Certification Scheme

Some local authorities provide calculation sheets to assist residents, see Shetland Council

https://www.shetland.gov.uk/downloads/download/388/air-source-heat-pump-noise-calculator

The Institute of Acoustics also provides general advice sheet and a calculation sheet. This goes one step further than the MCS procedure by giving the option of adding a tonal correction to the calculation

https://www.ioa.org.uk/heat-pump-briefing-notes-calculation-sheet-ioa-cieh

MCS Microgeneration Installation Standard: MIS 3005

2.5 MIS 3005 Issue 5.0 (2017) provides guidance on installation of heat pump systems. Subsection 6.3 SITE SPECIFIC ISSUES the following has been recommended.

6.3 SITE SPECIFIC ISSUES

6.3.1 Heat pumps should be located according to the manufacturer's instructions.

Note: For air source heat pumps, these will include consideration of factors that may detrimentally affect the performance of the heat pump system such as recirculation of chilled air.

6.3.2 Heat pumps should not be located adjacent to sleeping areas or on floors that can transmit vibration.

6.3.3 Anti-vibration pads/mats/mounts and flexible hose connections should be installed according to the manufacturer's instructions to reduce the effects of vibration on the building structure.

6.3.4 The location of external fans and heat pump compressors should be chosen to avoid nuisance to neighbours and comply with planning requirements. Note: See MCS 020

6.3.5 Internal fans and ducts should be fitted with sound attenuation devices where required to meet recommended or required sound levels.

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REHIS guidance and Local Authority criteria

If you need to get planning permission, it is likely that you will be asked by the local authority to demonstrate that the noise from your ASHP will not cause disturbance to adjacent properties. This is normally achieved by submitting a **Noise Impact Assessment,** undertaken by a competent acoustic engineer.

https://www.association-of-noise-consultants.co.uk/

ANC ACOUSTICS & NOISE CONSULTANTS

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REHIS guidance and Local Authority criteria

Guidelines on acceptable environmental noise levels are provided in the REHIS guidance document, Briefing Note 017

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REHIS guidance for plant noise

Noise Sources	Relevant Standard for Assessment	External Target Levels	Standard from which target levels are derived
Fan, air conditioning units, ventilation systems etc.	Noise Rating Curves	Internal Noise levels: NR25	BS8223:2014 Sound insulation and noise reduction for buildings

Inside with window open, except for exceptional circumstances.

Typical Local Authority criteria

- **East Lothian Council -** 'shall not exceed Noise Rating curve **NR 20** at any octave band frequency between the hours of 2300-0700 and Noise Rating curve **NR 25** at any octave band frequency between the hours of 0700-2300 within any neighbouring residential property. **All measurements to be made with windows open at least 50mm**.'

- **Angus Council – '**Noise from any or all mechanical and electrical plant or equipment associated with the development hereby permitted shall not give rise to a noise level assessed with windows open within any dwelling or noise sensitive building in excess of that equivalent to **NR 25** between 2200 and 0700 hours and **NR 35** at all other times.'

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Local Authority criteria

- **City Of Edinburgh Council -** will use the NR 25 criteria with windows open, but will no longer apply a suspensive condition. Will request a worked design and mitigation to NR 25 and will condition specifications and drawings. Difficult to do at planning stage as plant not specified and also not flexible post planning.
- **Glasgow City Council -** criteria for plant noise are typically based on a noise rating of **NR 35** daytime (0700hrs – 2200hrs) and **NR 25** night-time (2200hrs – 0700hrs) not to be exceeded with noise sensitive receptors with windows closed.
- **Aberdeen City Council -** NR 25 is generally used as the design criteria for protection in bedrooms from the noise from fans, air conditioning units, ventilation systems etc. at night.

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Local Authority criteria

North Lanarkshire Council

Noise Rating (NR) Curve	Time of day
NR 30	07:00-23:00
NR 25	23:00 – 07:00
NR20 (quieter areas)	23:00 – 07:00

<u>Dundee</u> - noise generated by the external plant should be assessed in accordance with the guidance given in BS 4142 (2014): *"Methods for rating and assessing industrial and commercial sound".*

In addition to the BS 4142: 2014 assessment, the impact of plant noise should make reference to maximum external NR criteria levels of NR 45 during the daytime period and NR 35 during the night-time period **outside** the nearest residential properties.

Local Authority criteria

West Lothian - Commercial noise sources such as shop fans and ventilation systems for example require to achieve Noise Rating Curve NR 25 during the night when measured within any living room or bedroom within a noise sensitive property with windows open for ventilation.

A lower Noise Rating Curve may be applicable depending on the nature and characteristics of the noise source, for example where a discernible tone is obvious or where the existing background noise environment is low (less than LA90 30dBA) NR 20 may be more appropriate.

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What are NR's ?

Noise Rating Curves are defined in BS 8233:2014 Annex B. The NR curves are unweighted spectrum based criteria which requires that the maximum noise level at a range of octave band frequencies should not be exceeded.

NR 25 is shown in the chart on the next slide as the light blue line. The test signal in the chart would be rated at NR 50, as this is the highest curve not exceeded.

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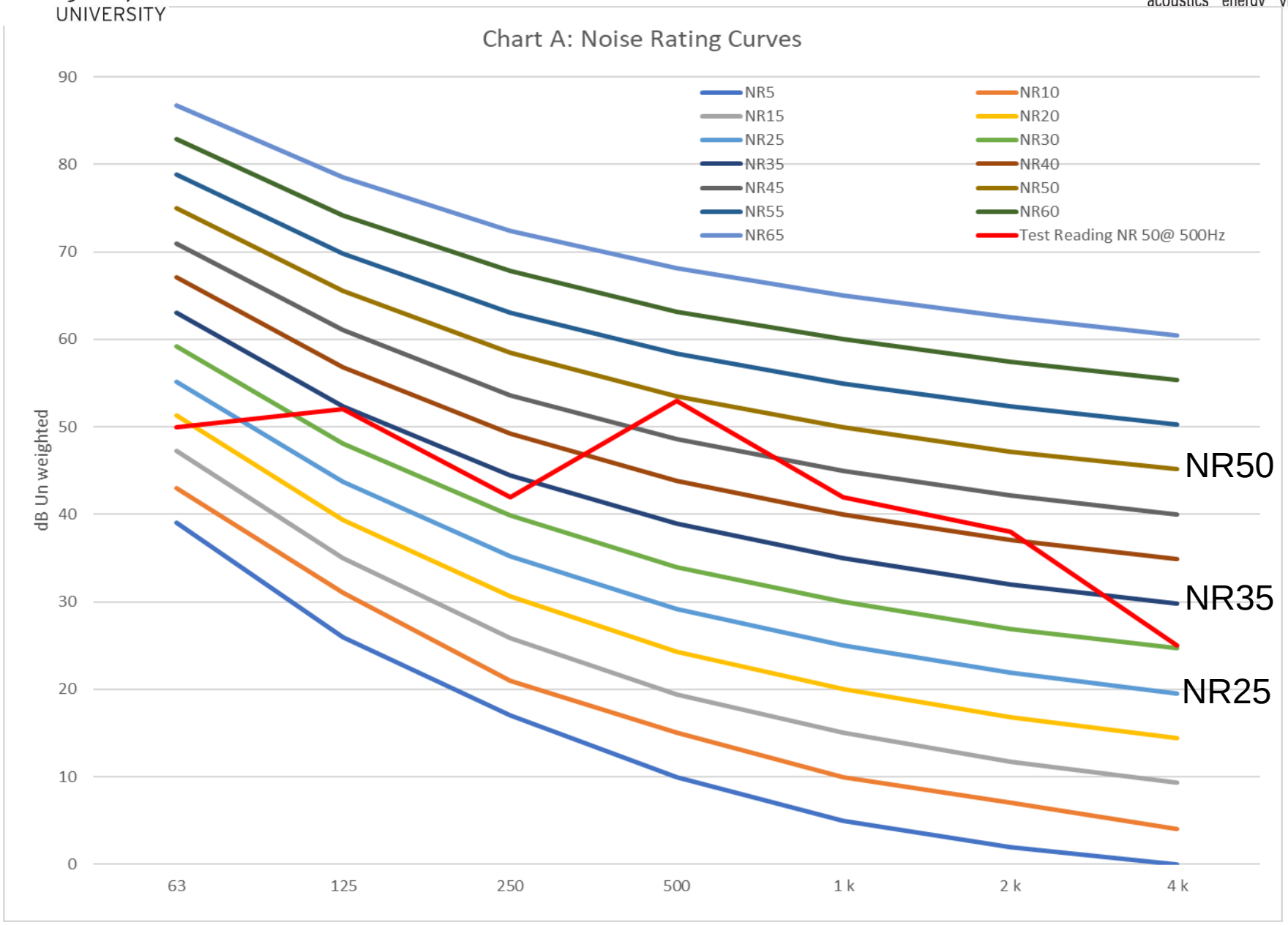

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Noise levels from ASHP

In product literature and specifications, manufacturers present the A-weighted **sound power level** as required by the Microgeneration Certification Scheme(MCS). Some manufacturers additionally provide sound pressure level data at defined distances, although sometimes it is not stated under which conditions measurements were made.

It is not common for manufacturers to provide frequency information on their ASHPs, but can often provide when pushed. Manufacturers generally do not provide information on tonal/character adjustment that may be appropriate.

		5.20
OPERATING AMBIENT TEMPERATURE (°C DB)		-20 ~ +35
SOUND DATA*3	Pressure Level at 1m (dBA)	45
	Power Level (dBA)*4	58
WATER DATA	Pipework Size (mm)	22
	Flow Rate (l/min)	17

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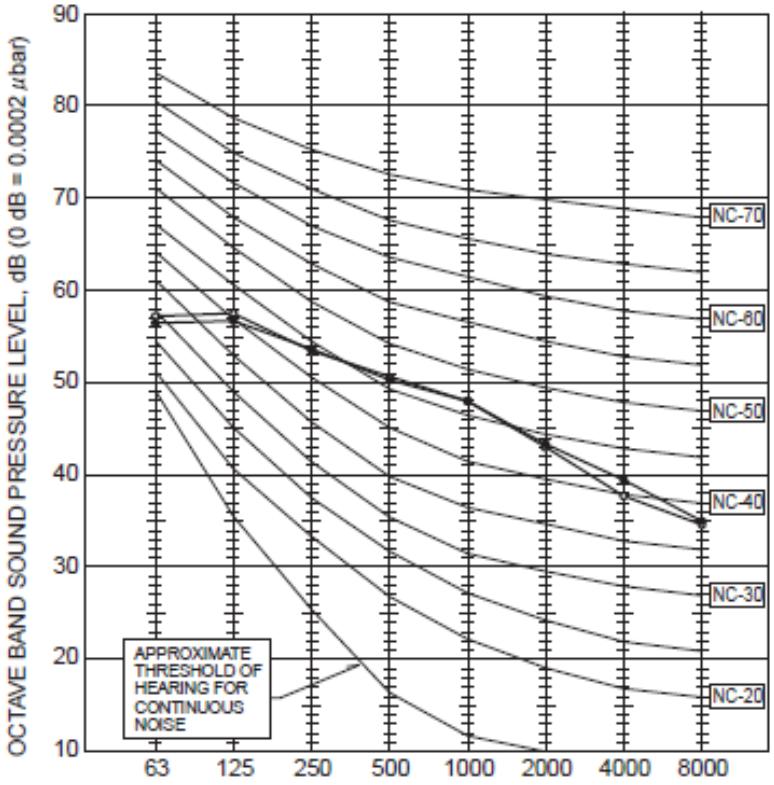
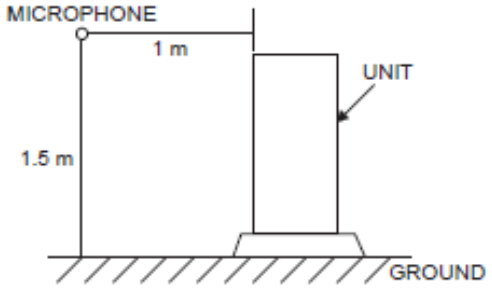
■ PUZ-HWM140VHA(-BS)
PUZ-HWM140YHA(-BS)

MODE	SPL(dB)	LINE
COOLING	53	○——○
HEATING	53	●——●





LEV operates.

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Circulating water volume range *5			25 l/min-250 l/min
Sound pressure level (measured 1m below the unit in an anechoic room) *1*4		dB (A)	64
Sound pressure level (measured 1m below the unit in an anechoic room) *3*4		dB (A)	72
Water pipe diameter and type	Inlet	mm (in)	38.1 (1 1/2"), housing type joint
	Outlet	mm (in)	38.1 (1 1/2"), housing type joint
External finish			Acrylic painted steel sheet

CAHV-R450YA-HPB

Ecodan Air Source Heat Pump

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Noise from ASHP

Some examples and outcomes from the DECC Study

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North Pitblae, Fraserburgh

Start up

Defrost

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Wilson Close, Compton

Start up

Defrost

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Manufacturer data vs site measurements

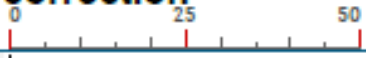
Table 4-1: Typical Sound Pressure Level Results $L_{Aeq(1min)}$ dB @ 1m from unit (in line with fan)

Site Code	ASHP Description	Manufacturers' SPL Data	Typical Site Measured L_{Aeq} level	Difference
		20 50 80	20 50 80	-5 0 5
478	8.5 kW Manufacturer A	53	55	+2
479	8.5 kW Manufacturer A	53	56	+3
422	8.0 kW Manufacturer B	58	56	0
422	6.0 kW Manufacturer B	51	47	-4
418	8.0 kW Manufacturer B	58	57	0
443	8.2 kW Manufacturer C	64	64	0
440	9.0 kW Manufacturer D	-	61	0
474	9.1 kW Manufacturer E	57	60	+3
475	5.5 kW Manufacturer E	57	62	+5
486	8.0 kW Manufacturer F	49	54	+5

Distance to meet MCS $L_{Aeq\ 42\ dB}$

Table 4-3: Distance from unit at which noise level would be L_{Aeq} 42 dB (m) (free field)

Site Code	ASHP Description	Without tonal correction
478	8.5 kW Manufacturer A	9
479	8.5 kW Manufacturer A	10
422	8.0 kW Manufacturer B	10
422	6.0 kW Manufacturer B	4
418	8.0 kW Manufacturer B	11
443	8.2 kW Manufacturer C	28
440	9.0 kW Manufacturer D	16
474	9.1 kW Manufacturer E	16
475	5.5 kW Manufacturer E	20
486	8.0 kW Manufacturer F	8



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Defrost Cycle

Table 4-5: ASHP defrost cycle occurrence and duration			
Site Code	**ASHP Description**	**Approx. occurrence**	**Approx. duration**
478	8.5 kW Manufacturer A	-	-
479	8.5 kW Manufacturer A	-	-
422	8.0 kW Manufacturer B	~8 hours	3-4 mins
422	6.0 kW Manufacturer B	~4 hours	1-2 mins
418	8.0 kW Manufacturer B	~3 hours	3-4 mins
443	8.2 kW Manufacturer C	~2 hours	2-3 mins
440	9.0 kW Manufacturer D	~8 hours	3-4 mins
474	9.1 kW Manufacturer E	~2 hours	1-2 mins
475	5.5 kW Manufacturer E	~8 hours	2-3 mins
486	8.0 kW Manufacturer F	-	-

For the majority of ASHPs the defrost cycle noise level is lower than the normal operating noise level, but on some have a tonal characteristic.

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Predictions of noise from ASHP

We have already see the MCS simplified method using single dBA

Now look at basic calculations to a Noise Rating criteria for single source and receivers

plus

3D modelling of complex situations

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Predictions of noise from ASHP
Basic calculation for single source and receiver to NR 25

Table 1. Predicted ASHP unit noise level within neighbouring dwelling, dB re 2 x 10^{-5} Pa									
Frequency (Hz)	63	125	250	500	1k	2k	4k	8k	L_{Aeq}
Manufacturer SPL data at 1m from unit (L_{eq})	54	54	55	53	50	46	41	39	53
Distance attenuation (1m/10m), point source	-20	-20	-20	-20	-20	-20	-20	-20	
Angle of view correction	-3	-3	-3	-3	-3	-3	-3	-3	
Façade corrections, at source and receiver	+9	+9	+9	+9	+9	+9	+9	+9	
Open window attenuation	-15	-15	-15	-15	-15	-15	-15	-15	
Predicted Internal Levels	25	25	26	24	21	17	12	10	25
NR 25	55	44	35	29	25	22	20	18	
Exceedance	-	-	-	-	-	-	-	-	

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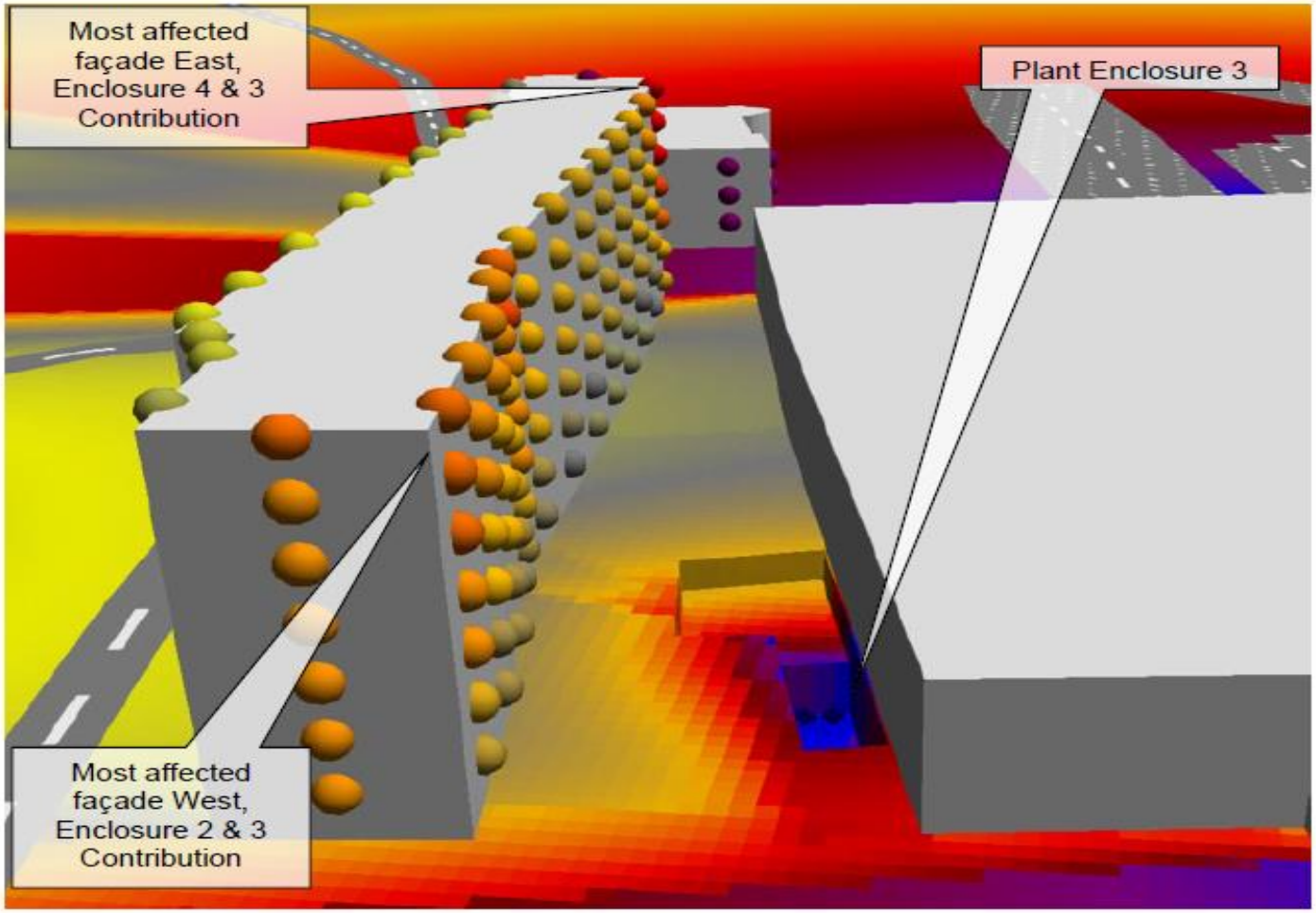
Cadna A 3D Noise Model for single source and multiple receivers



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3D Noise Model for multiple ASHP sources and receivers

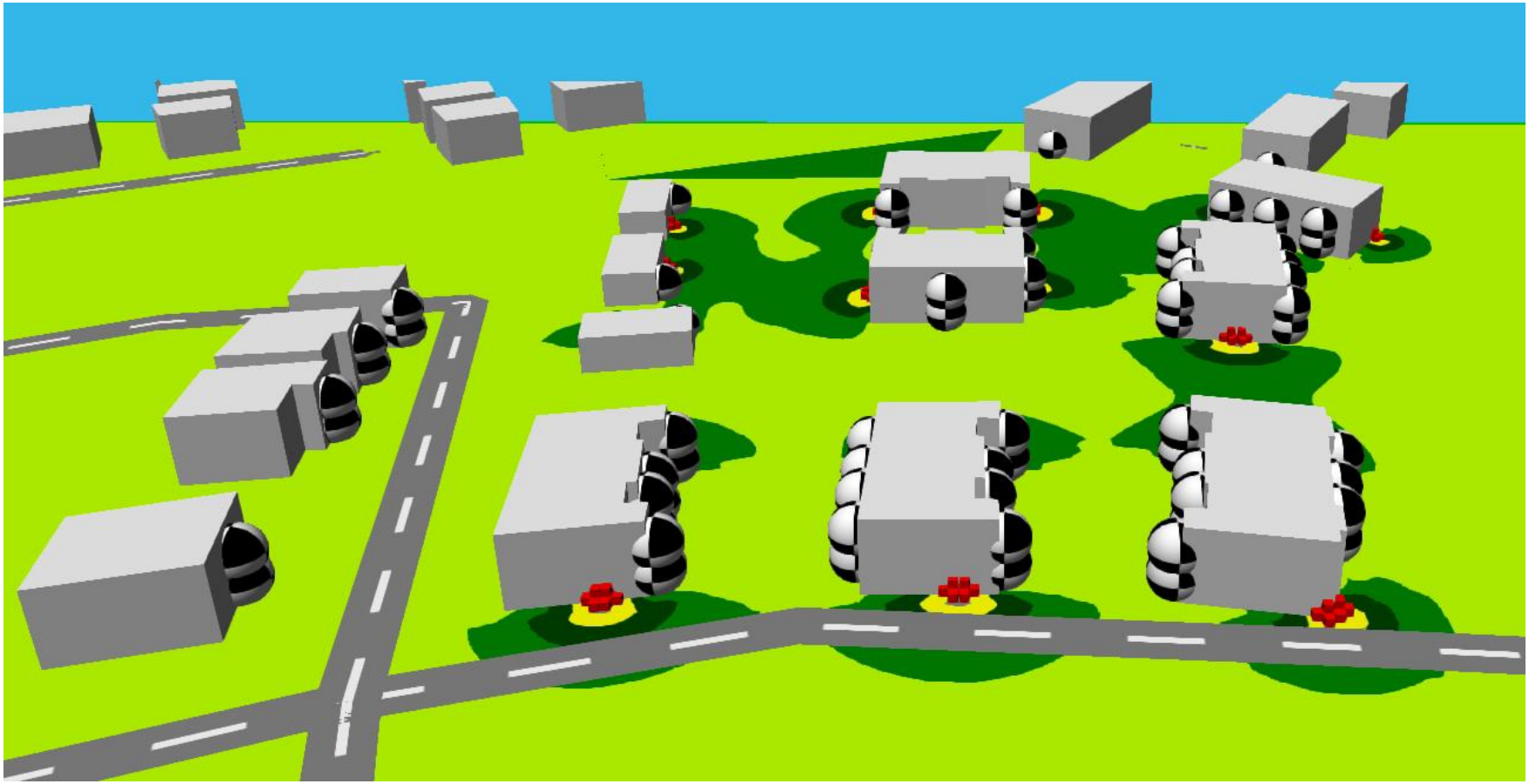

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Table 2 - CadnA Plot/Receiver External Results – Whole Site								
		Octave Band Centre Frequency						
Receiver Height (m)	Plot/Receiver	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
1.5	Offsite NSR2 ground (1-storey NSR)	42	36	25	23	26	23	15
3.5	Offsite NSR3 1st	41	35	26	24	25	22	15
1.5	Offsite NSR3 ground	41	36	25	23	25	22	15
3.5	Offsite NSR4 1st	42	37	28	26	28	24	17
1.5	Offsite NSR4 ground	43	37	26	24	27	24	17
3.5	Offsite NSR5 1st	36	30	22	21	23	19	12
1.5	Offsite NSR5 ground	36	30	20	18	23	19	12
3.5	Offsite NSR6 1st	41	35	26	25	27	23	16
1.5	Offsite NSR6 ground	41	36	25	23	26	23	16

Models only as good as input data and selected options. Façade absorption/reflection, source spectrum, source size and height all need confirmed

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Mitigation Options

Not just to protect the neighbours !

‘The noisy heat pump in our new home is keeping us awake at night. What can we do ?’

https://www.irishtimes.com/life-and-style/homes-and-property/the-noisy-heat-pump-in-our-new-home-is-keeping-us-awake-at-night-what-can-we-do-1.4603397

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Acoustic barriers

Reflective

Absorbent

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Acoustic barrier example

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Acoustic barriers

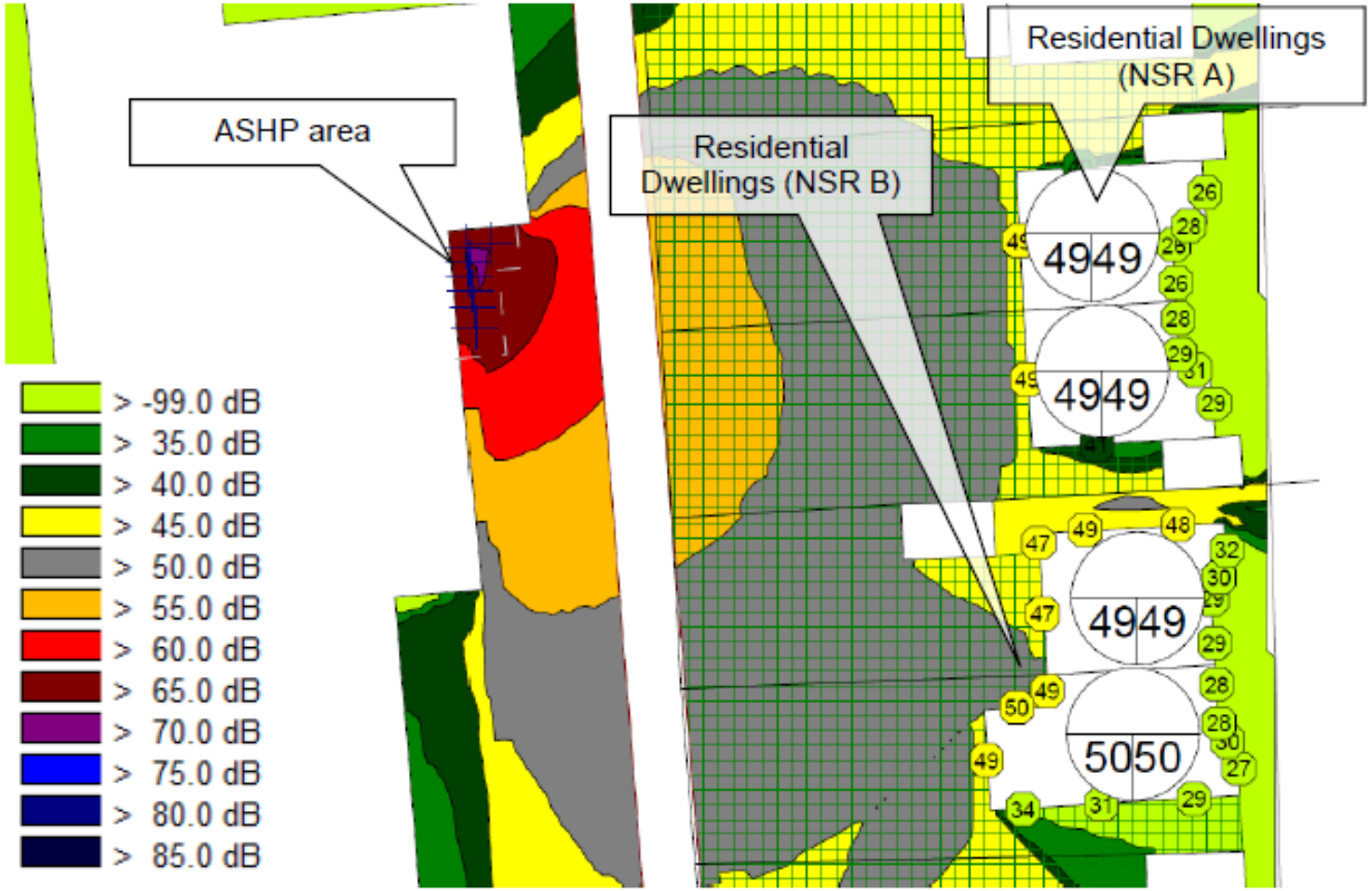

Figure 4: CADNA A model output, birds' eye, no mitigation

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Acoustic barriers

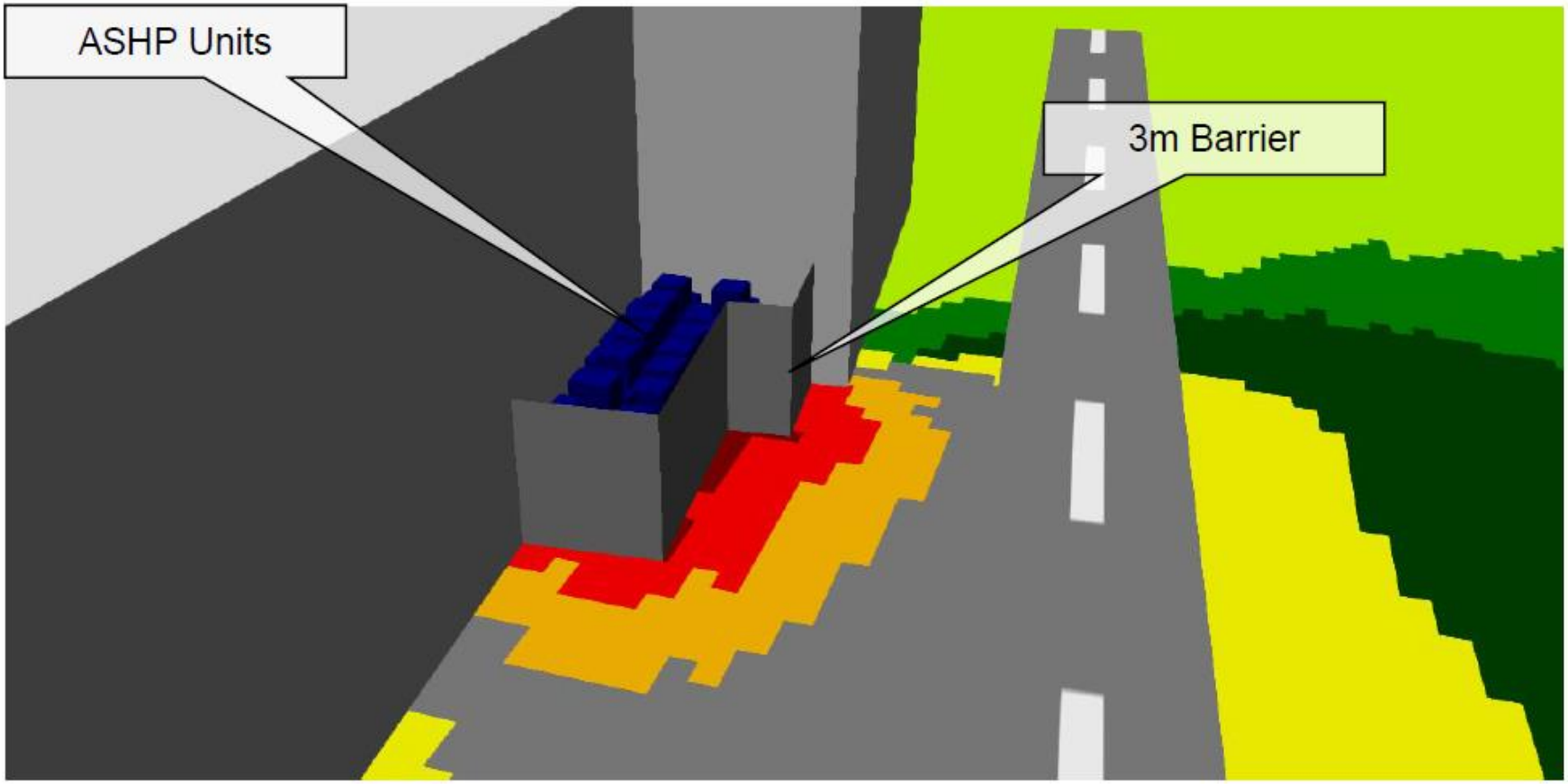

Figure 7: CADNA A model barrier implementation, 3D

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Acoustic barrier

With 3m high absorbent acoustic barrier should meet NR 25

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Acoustic Enclosures

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Acoustic Enclosures

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Acoustic Enclosures

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Acoustic Screens and Louvers

Innovation

https://www.linkedin.com/posts/taylor-wimpey_twfuturehomes-activity-7039567585696186368-UmCl/?utm_source=share&utm_medium=member_ios

Taylor Wimpey trial of ASHP mounted in roof space of new houses

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Vibration Criteria

•Criteria are typically adopted from Table 2 of BS 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings

•The operation of the air handling units shall not result in vibration dose values which exceed those stated for a low probability of adverse impact.

Vibration dose values above which might result in various degrees of adverse comment within residential buildings, m/s $^{1.75}$.			
Place	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Residential buildings 16 hr day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential building 8 hr night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

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During the DECC study, vibration was measured at each location on the ground and adjacent walls. Vibration was found not to be a significant issue for ground based units. The project recommended that anti-0vibration mounts be fitted to any building mounted units.

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Wall mounted unit with AV mounts

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Ground mounted unit with AV mounts

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Thank you for listening ☺

This paper & more research available at

https://www.rmp.biz/research/

Including DECC ASHP Research

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Any Questions?