ACOUSTIC IMPLICATIONS OF LOW CARBON HOUSING

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1 INTRODUCTION

Against the backdrop of high energy prices, unsolved supply chain disruptions and the ongoing climate emergency, consumer interest in living in more energy efficient homes with lower operating costs has never been so high. The development of low carbon technologies coupled with Government backed grants and incentives to retrofit existing housing stock along with the prospect of new legislation to build low carbon housing acts as a catalyst for the built environment to play its role in the UK meeting its legally binding net zero targets.

The term net zero refers to achieving a balance between the amount of greenhouse gases emitted into the atmosphere and the amount removed from it. Emissions reduction can be achieved by replacing fossil fuels with renewable energy sources, improving energy efficiency and adopting sustainable practices. This paper only considers operational carbon and carbon reduction and does not consider embodied carbon or carbon capturing.

Buildings contribute approximately 30% of the UK's greenhouse gas emissions, primarily through energy used for space heating and hot water. From 2022 interim Building Regulations legislated that all new build homes in England must emit 30% less carbon than previous regulations. As part of the next set of Building Regulations due in 2025 connecting new build homes to the gas grid will be banned. Whilst the implementation of the new Building Regulations stops the growing number of homes that need to be retrofitted, new build homes represent a small percentage of the UK housing stock (approximately 150,000 completions annually). Greater emphasis is required on retrofitting the 28 million homes across the UK by implementing energy efficiency measures and low carbon heating solutions to meet the 2050 net zero targets.

The integration of low carbon solutions in buildings presents a range of acoustic implications from the construction materials used, the incorporation of heating, ventilation, air conditioning, and refrigeration (HVAC&R) systems, and the wellbeing and comfort of occupants.

This paper provides an overview of relevant legislation and industry schemes in England, including Building Regulations, the Boiler Upgrade Scheme, the Future Homes Standard, and Permitted Development Rights. The acoustic provision within recent updates and consultations will be discussed, along with the differences between retrofit and new build housing.

The shift towards low carbon, energy efficient buildings and construction practises should not only promote sustainability but also foster improved occupant wellbeing. The relationship between good acoustic design, other indoor environmental design factors, and low carbon, energy efficient buildings will be discussed, with example case studies.

Finally, this paper will summarise the acoustic implications of future low carbon housing, the challenges that need to be quantified and addressed, and the pivotal role acoustic professionals can play on the UK's pathway to net zero.

2 LEGISLATION AND INDUSTRY SCHEMES

2.1 Overview

In April 2021 the Government enshrined in UK law targets to reduce greenhouse gas emissions by 78% by 2035 on 1990 levels and focus on the UK's trajectory towards net zero by 2050. In October 2021 the UK government published their "Heat and Buildings Strategy"[1] to explain key activities

proposed to achieve the move to net zero, including building performance and energy efficiency measures, wider deployment of renewable technologies, and the introduction and delivery of heat networks. While some strategic topics, such as the use of hydrogen, are unlikely to be utilised at scale in a residential setting; others such as heat pump deployment and increasing the mandatory minimum standards to improve building performance are already making progress.

In England there are currently several regulations and schemes linked to promoting low carbon housing, with the key points of each outlined below. Proposed regulatory changes likely to become a requirement in 2024 and 2025 around Permitted Development Rights and the Future Homes and Buildings Standards are also discussed.

2.2 Approved Document F Volume 1

Approved Document F Volume 1 is part of the Building Regulations in England and is entitled "Ventilation – Dwellings"[2] It is often abbreviated to simply "Part F" and will be referred as such in this paper. The purpose of Part F is to ensure good indoor air quality for occupants of dwellings by means of appropriate ventilation. Correctly sizing, installing and commissioning a ventilation system continues to become increasingly critical as new versions of the Building Regulations require the building envelope to become more airtight. Various types of ventilation strategies are permitted for new build and retrofit housing including natural or mechanical ventilation or a combination of both. Ventilation may operate continuously or intermittently and can be centralised or decentralised.

Part F states as far as is reasonably practicable ventilation provision should produce low levels of noise and several noise control measures are recommended throughout Part F, such as correctly sizing ductwork and minimising external noise ingress. During the commissioning phase of new dwellings, it is a legal requirement to carry out ventilation testing in terms of measuring and complying with minimum airflow rates, detailed in Table 1.2 of Part F.

Section 1.7 of Part F states that good acoustic conditions would be achieved by following the maximum sound pressure levels:

- 30dB $L_{Aeq,T}$ for noise-sensitive rooms (e.g. bedrooms and living rooms) when a continuous mechanical ventilation system is running on its minimum low rate.
- 45 dB $L_{Aeq,T}$ in less noise-sensitive rooms (e.g. kitchens and bathrooms) when a continuous operation system is running at the minimum high rate or an intermittent operation system is running.

There is however a rather large caveat in that there is no requirement to undertake noise testing of an installed system.

2.3 Approved Document L Volume 1

Approved Document L Volume 1 is part of the Building Regulations in England and is entitled "Conservation of fuel and power – Dwellings"[3] It is often abbreviated to simply "Part L" and will be referred as such in this paper. Recent revisions of Part L have placed a greater focus on climate change mitigation as technology has evolved. The most current version of Part L was updated in 2021 and introduced a primary energy target, acknowledging that while CO_2 is an important issue, energy itself is an important resource.

For a new dwelling to comply with Part L, the following criteria must be met:

- The design must meet CO_2, primary energy targets, and fabric energy efficiency targets.
- Elements of the design must meet worst allowable standards; for example minimum efficiencies for building services plant and maximum U-values for building fabric.
- Commissioning of the building services systems and airtightness testing.

The same criteria are applicable to retrofit of existing dwellings, except for the requirement to carry out airtightness testing. Instead, guidance is provided on good practise to reduce unwanted heat loss such as draft-proofing and well-fitting windows and doors.

Although explicit references to noise are limited in Part L, there are a few acoustic implications. Firstly, in Section 0.21 of Part L the interaction with Approved Document E "Resistance to the passage of sound"[4] is noted and the importance of construction junctions not only limiting thermal bridging but also noise transfer. Secondly in Section 6.42 and 6.43, refer to heat pump heating system design, the siting of heat pumps to minimise transmission of vibration, away from bedrooms to avoid sleep disturbance, and at a location to minimise disturbance to neighbours, whilst remaining in compliance with planning requirements.

2.4 Passivhaus

The Passivhaus Standard[5] has some of the strictest criteria in terms of energy efficiency and low carbon housing. The principle of Passivhaus is to provide new build and retrofit housing with a high level of occupant comfort and low energy usage to deliver net zero ready houses. Criteria includes minimum standards of airtightness, ventilation, heating and cooling systems, and building controls. There are slightly more relaxed criteria for retrofit rather than new build. Within the standard there are several references to noise control practises to avoid occupant disturbance, as well as maximum sound pressure levels of 25dB(A) in residential rooms with mechanical ventilation system supply air paths. Compliance is determined through inspection and testing by an accredited Passivhaus certifier.

2.5 Boiler Upgrade Scheme (BUS)

The Boiler Upgrade Scheme (BUS)[6] was introduced in March 2022 and superseded the Renewal Heat Incentive (RHI). The scheme provides grants to homeowners covering part of the cost of replacing fossil fuel heating systems with a heat pump. The BUS is valid for individual systems up to a maximum capacity of 45 kWth and shared ground loops up to a maximum capacity of 300 kWth. The scheme is aimed at the retrofit market and is not applicable to new build dwellings or social housing.

To promote good quality, high performing installations, the BUS stipulates qualifying heat pumps must have a minimum SCOP (Seasonal Coefficient of Performance) of 2.8 and the heat pump installation must be carried out by an MCS certified installer. Installers must therefore comply with MIS 3005-I[7], which details installation requirements, including consideration of the potential impact of noise and vibration.

2.6 Permitted Development Rights (PDR)

The Town and Country Planning (General Permitted Development) (England) Order 2015[8] outlines permitted development rights for extensions and renovations to existing dwellings. Section G covers permitted development rights for the installation, alteration or replacement of an air source heat pump. Homeowners do not have to go through planning permission if they comply with certain conditions, such as meeting the MCS or equivalent (noting there is not currently an equivalent) Planning Standards, being 1m from the boundary of the curtilage of the dwelling, and not being installed on a pitched roof.

In February 2024 the Department for Levelling Up, Housing and Communities launched a consultation on proposed changes to permitted development rights in England[9]. Many of the changes proposed are designed to ease the burden of installing low carbon technologies within homes. With the General Election in July 2024 and the subsequent new government, the outcome of the consultation and a revised version of permitted development rights are yet to be published. The acoustic implications of the proposed changes to heat pump installation are discussed below.

It is proposed to remove the requirement to install a heat pump 1m from the boundary, allow physically larger units (although any new dimensions restrictions are not yet known), and permit two units to be installed on one property. Air source heat pump installations will still need to comply with MCS (or equivalent) Planning Standards. Whilst blanket relaxations have the potential to cause a noise impact to residential areas, the proposed changes were based on evidence in the 2023 DESNZ "Review of air source heat pump noise emissions, permitted development guidance and regulations"[10]. Due to the design and operation of air source heat pumps, physically larger air source heat pumps with the same heating capacity have the potential to be quieter, because they can have a larger evaporator and therefore slower speed fan. There would also be space for increased sound absorption materials and anti-vibration design solutions.

2.7 Future Homes and Buildings Standards

In December 2023 the Government launched a 15 week consultation on "The Future Homes and Buildings Standards"[11]. The consultation includes changes to Part 6, Part F, and Part L of the Building Regulations for dwellings and non-domestic buildings and sought evidence on previous changes to Part O of the Building Regulations. It is currently expected that the new version will be published in 2025. Relevant proposed changes to Part F and Part L for dwellings are outlined below.

The major change within Part F is around the installation and commissioning of ventilation systems and includes:

- A competent person must carry out ventilation system installation and commissioning.
- Flexible ductwork is banned in almost all situations.
- Requirements have been added for the maximum static pressure in systems.

In the consultation document, the reason given for these changes is the ongoing concern that the poor design and installation of ventilation systems has led to fans having to operate at maximum fan speeds to achieve the design airflow rates, which causes increased noise nuisance to occupants. Whilst ventilation testing requirements have been tightened, the recommended noise limits remain unchanged, and acoustic testing during commissioning is still optional.

The major theme around changes within Part L is improved system efficiencies and includes:

- Clearer design and installation guidance for building elements.
- Reduction in system heat losses through improved insulation requirements.
- Additional design criteria, minimum system efficiencies, and installation guidance for low carbon technologies such as MVHR, heat pumps and heat networks.

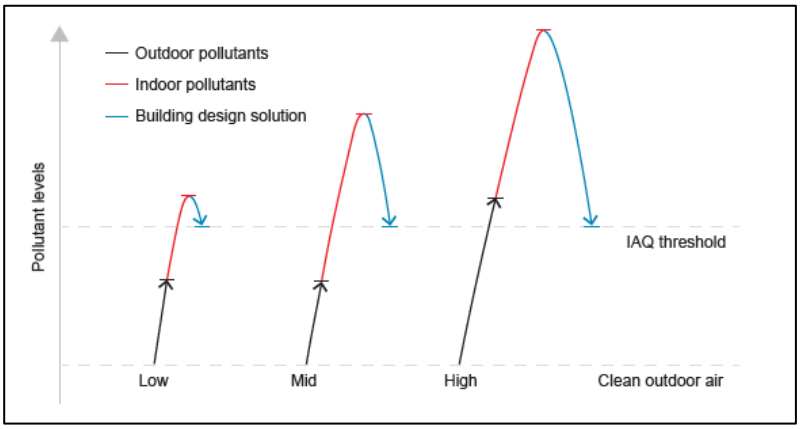
Whilst there are still limited references to noise and vibration control within Part L, improved system efficiencies and reduced building heat losses, may enable quieter system operation.

3 IEQ AND LOW CARBON HOUSING

Occupant wellbeing is segmented into functional, psychological, and physical conditions. Physical conditions are encompassed by indoor environmental quality (IEQ), which includes air quality, thermal comfort, acoustics, odours, and lighting. To effectively understand the IEQ in a dwelling, measurements can be carried out of the individual parameters, but it is important the components of IEQ are considered holistically.

The level of outdoor and indoor pollutants will determine the scale and nature of the building design solution required, to meet a good level of indoor air quality (IAQ), as demonstrated in Figure 1. For example, if both outdoor and indoor pollutants are minimised, then there will be flexibility in what design solutions can be implemented, including natural ventilation. The higher the levels of outdoor pollutants, the more likely design solutions will require mechanical ventilation with filtration, which in turn has the potential to increase noise levels in the dwelling if not correctly managed.

Figure 1 Building design solution requirements based on pollutant levels



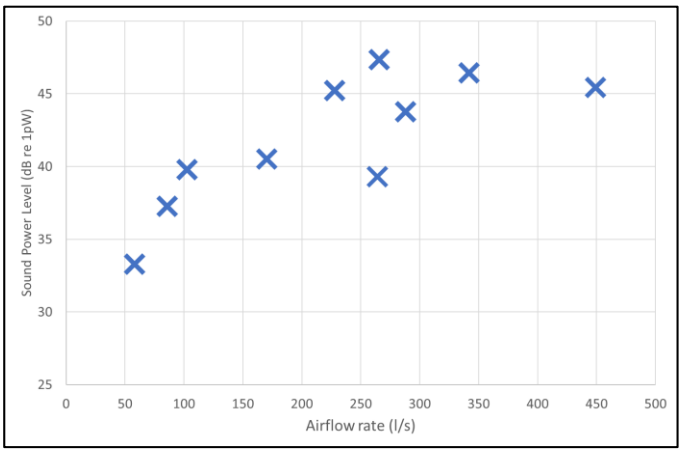
Post occupancy evaluation can be carried out using the BSRIA Occupancy Wellbeing (BOW) survey, which determines occupant satisfaction for wellbeing parameters including IEQ. If an occupant of a house is dissatisfied with the noise from their ventilation system, they will turn it down or even off. This can lead to issues of reduced indoor air quality, mould, and poor health. If over time maintenance, such as cleaning filters, is not carried out the building occupant may need to increase the fan speed of the ventilation system to overcome the increased pressure drop, which can lead to increased noise levels, occupant disturbance and reduced wellbeing. Low carbon homes promote airtightness but must be ventilated correctly to ensure good IEQ.

4 CASE STUDIES OF LOW CARBON HOUSING PRACTISES

4.1 Product Development

When a manufacturer is developing a product there are a variety of performance criteria that are trying to be met, which can include thermal, airflow and acoustic performance. Figure 2 shows the sound power level against airflow rate for several residential supply air systems, as tested in the BSRIA laboratory. Whilst there is a general trend of increased sound power levels with increased airflow, there are some noticeable exceptions. For example, two products both delivering about 260 l/s but with sound power levels about 8 dB different. This demonstrates when selecting products for low carbon houses it is important to consider all performance criteria to select the optimum design solution.

Figure 2 Sound power level against airflow rate for household air supply devices



4.2 Installation

Often space and logistical considerations (e.g. ductwork pathways and electrical connections) dictate where products are installed, especially during retrofit, which can have acoustic implications. Table 1 details sound pressure level measurements in the bedroom of a dwelling where an exhaust air heat pump (EAHP) was retrofitted into a property and located in a cupboard in a bedroom. The sound pressure levels were compared against recommended daytime and nighttime noise levels in bedrooms stated in BS 8233:2014[12]. The EAHP only complied when operating at low fan speed. To achieve correct ventilation rates and system performance it was necessary to operate the EAHP at high fan speed, which has the potential to lead to occupant disturbance.

Table 1 Bedroom sound pressure levels from EAHP operating

Fan speed	Sound Pressure Level dB(A) L_{Aeq}	Complies with BS 8233 noise criteria	
		Daytime	Nighttime
Low	28	Yes	Yes
High	39	No	No

Figure 3 shows images from an acoustic camera for two air source heat pumps installed on new build properties. The heat pump in the middle image was emitting a distinct noise compared to the heat pump in the left image. Further inspection found the heat pump casing had been incorrectly installed and was the source of the noise, as shown in the right image. Once the casing issue was rectified the sound quality emitted by the heat pump improved.

Figure 3 Acoustic camera images of air source heat pumps

4.3 Commissioning

Part F and Part L of the Building Regulations require commissioning tests for ventilation airflow (Part F) and building airtightness (Part L). Over the past year BSRIA has carried out hundreds of ventilation airflow tests and tens of thousands of airtightness tests. Analysing the results of testing demonstrates a 90% pass rate for airtightness tests but an 80% fail rate for airflow tests. To pass the requirements of an airflow test, fan speeds are typically increased, resulting in faster spinning blades pushing more air and creating more turbulence, which can lead to increased vibrations.

The Future Homes Standard is expected to drive house builders to use centralised ventilation systems. Decentralised fans whether this be intermittent or continuous extract are predominantly used based on cost, ease of installation and, in the case of intermittent, the occupant's tolerance to a short period of increased noise from the fan. In fact, this has even led to some developers selecting intermittent solutions over continuous ones. The proposed regulation changes, whilst giving limits for system noise fails to mandate testing for compliance with these levels. Given the historical installation issues it is unlikely that noise limits will be consistently achieved, resulting in the isolation of installed systems by the occupants and the deterioration of IAQ.

5 FUTURE CHALLENGES/OPPORTUNITIES

5.1 New Build v Retrofit

80% of buildings that will exist in 2050 have been built. The drive towards low carbon energy efficient housing must therefore not only consider stricter legislative requirements for new build houses, but also how to retrofit existing homes, to not only improve airtightness and reduce heating demand, but also provide adequate ventilation to enable good indoor environmental quality and occupant comfort.

One of the biggest steps to decarbonising houses it to install a renewable heating system, such as a heat pump. BSRIA Market Intelligence data shows that for the last four years approximately 40% of heat pumps sold in the UK were installed in new build houses, with the remaining 60% attributed to retrofit projects. The data also shows the average heating capacity of heat pumps has reduced over the last 8 years, with a greater proportion of the units being less than <6kW across all property types. Correctly sized smaller capacity heat pumps can generally operate more quietly and cause less disturbance to occupants and neighbours. If the heating demand of a building has not been correctly determined through heat loss calculations, a heating system may be undersized and a heat pump would have to operate at its maximum capacity for longer, thus increasing noise levels.

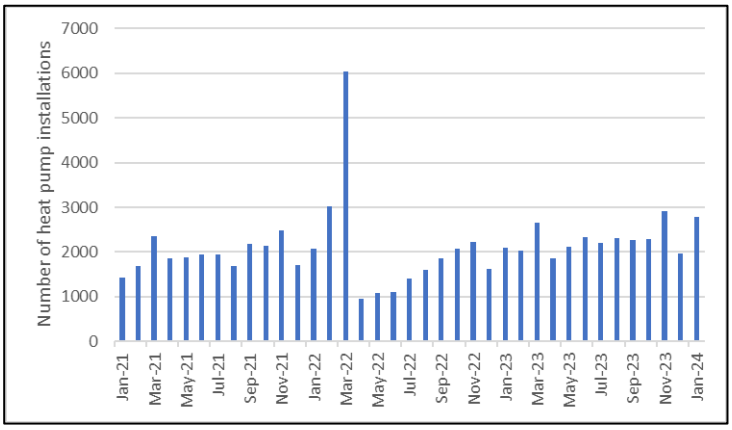
5.2 Operational Factors

Historically heating and hot water systems in homes were operated by a simple on/off thermostat or a basic timer. Control strategies for low carbon homes have become more elaborate, with each technology having sophisticated operational controls based on environmental monitoring, system feedback and occupant behavioural patterns. There are also whole house control systems, where inputs from all systems (heating, hot water and ventilation) are combined to provide optimum overall building performance and energy efficiency.

The move towards a sustainable, zero-emissions electricity grid is fundamentally changing how to generate and use power. The evolution of a smarter, more flexible, and secure electricity grid requires the use of demand-side response (DSR). DSR represents a shift in how building services manage electricity use and store energy offering occupants the flexibility to adjust consumption patterns, leading to cost savings. Many utility companies incentivise consumers to use electricity during off-peak hours.

Government backed incentive schemes have been used in many different forms over the years to stimulate the uptake of low carbon technologies. One example is the Renewable Heat Incentive (RHI) which operated in England until March 2022. In the month before the RHI closed prior to being superseded by the BUS, there was a large spike in MCS certified heat pump installations[13], as shown in Figure 4. There was a smaller market response when the BUS increased payments from £5000 to £7500 in November 2023.

Figure 4 Number of MCS certified heat pump installations over time



Whilst smart controls, grid flexibility, and incentive schemes are all beneficial to efficiently operating low carbon homes, the acoustic implications must not be forgotten. Operating heat pumps at night to reduce costs could cause sleep disturbance, or automating controls based on non-acoustic inputs could reduce overall occupant wellbeing. As it has been previously stated, if an occupant is not satisfied with the noise from low carbon technologies in their home, they will turn them off and raise a complaint.

Acousticians can play a vital role by engaging across all sectors of industry, stakeholders, and building occupants. Explaining the importance of good acoustic design, pushing for best practise installations, responding to public consultations, and educating on the impact of noise on health and wellbeing will all support net zero in homes, whilst also ensuring a pleasant soundscape.

5.3 Cooling

Finally, throughout this paper there has been a focus on home heating, but what about cooling? Average temperatures are rising and overheating is now a recognised requirement within Building Regulations. Low carbon homes of the future will need to consider cooling requirements. The draft version of Part L has the inclusion of comfort cooling. A proactive approach must be taken to building new homes and retrofitting existing homes to ensure future homes are fit for purpose, and acousticians must be part of this journey.

6 REFERENCES

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