SIENA Consortium

Sustainable Infrastructure and Evidence for Noise and Air

EVIDENCE REVIEW FOR EFFECTS OF SOUNDPROOFING ON RESIDENTS' MENTAL WELLBEING AND ALTERNATIVE DESIGNS

VOLUME II: Sound Insulation and Good Acoustic Design

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1. SOUND INSULATION & GOOD ACOUSTIC DESIGN

1.1. ABOUT THIS SECTION

Approach

Having considered each of the papers included within the systematic review we have prepared an opinion piece setting out a review of these topic areas and in response to the current evidence base. We've added our thoughts on the above with regard for the research question, which informs the responses later in this report. We have identified when this has been based on evidence or whether an opinion and the reasons for that. Although we have generally restricted references to those papers within the review, where is it necessary to refer to other material which is needed to anchor a comment beyond any explanation, we have added that within the reference section.

The approach we have taken is to consider the content of the 59 papers and refer to relevant findings under each heading. We have not included Covid-19 as a separate heading, as it is clear that the effects in studies over this 3-year search period are relatively consistently present in the studies.

Research question as it relates to sound insulation & good acoustic design

What are the effects of indoor sound environments on mental health, wellbeing, quality of life, annoyance and sleep, with particular regard for the role of sound insulation and good acoustic design?

Comments on Systematic Review and Search Terms

The ubiquitous nature of sound means that in order to consider this question meaningfully the search terms that were selected and reviewed with each of the section authors included a neutral position on sound, with both positive and negative effects of sound on humans considered. Studies were intentionally included from the well-developed noise pollution and negative health effects field and also from the much more recently emerging science related to the soundscape field, which focuses on positive health and wellbeing effects. The initial search results confirmed the broad nature of this question and the studies that related to it. The specific focus on indoor sound environments and the health and wellbeing of occupants narrowed the relevant papers substantially, but this has brought together a wide body of work, of which the shortlisted 59 studies between 2019 and 2023 are representative. It is this that we consider to be a strength of this work, rather than the depth and rigour of the studies alone. They include only 6 studies that are directly specific to the UK, but even some of these draw from comparisons with other countries and so may not be directly applicable. The research approaches range across a number of disciplines (from physiology to psychology, and mainstream acoustical research) with varying methodological approaches, which perhaps explains the challenges that have been encountered in the systematic review. The UK studies identified will be paid with particular regard, and include:

- 4 studies on working from home populations and indoor soundscape, conducted in the UK (Torresin et al. 2021, 2022a, 2022b, 2022c),
- 1 study on general adult populations to noise from a heliport, conducted in the UK (Dance & Gomez-Agustina, 2021),
- 1 study on soundscapes for different activities at home during COVID-19, conducted in London, UK (Torresin et al., 2022c).

The lack of comparable methodologies and high risk of bias were factors affecting the evidence but mainly the low numbers of studies have resulted in a 'mixed bag' of evidence for consideration, which is assessed to be generally of "very low confidence" (for the qualitative studies) or low to medium

quality (for quantitative studies). Evidence in this area is embryonic in terms of the research question being asked, but it is a beginning from which coherent areas for further work can emerge with some emerging trends which are discussed, despite the limited weight that they can be given. The body of primary evidence covers 5 broad areas, with subsets from which to consider how sound insulation and good acoustic design may play a part. These are listed below with the GRADE and GRADE CERQual ratings added below:

1. Survey studies on residential soundscapes and wellbeing/perceptions:
    - General adult populations:
        - Very low-quality evidence (quantitative),
        - Very low confidence findings (qualitative)
    - Elderly populations:
        - Very low-quality evidence (quantitative),
        - Very low confidence findings (qualitative)
    - Working from home (WFH) populations and activity-based considerations for homes:
        - Low quality evidence (quantitative),
        - Very low confidence findings (qualitative)
2. Effects and changes to sound and noise associated with COVID-19:
        - Moderate quality evidence (quantitative),
        - Very low confidence findings (qualitative)
3. Experimental studies on residential soundscapes and wellbeing/perceptions:
        - Very low-quality evidence (quantitative)
4. Residential care homes and dementia:
        - Moderate quality evidence (quantitative),
        - Very low confidence findings (qualitative)
5. Other areas, such as studies on:
    - Soundscapes before, during and after COVID-19 lockdowns,
    - Architects' vs non-architects' opinions on acoustic environments,
    - Characterisation, management and design of indoor soundscapes.

This shows the quality of quantitative evidence was moderate for some topics like COVID-19 effects (with 9 studies) and care homes (6 studies), but weaker for others, with the quality of qualitative evidence notably very low across all topics. Nevertheless, this represents the state-of-the-art at this

time. The outcomes included annoyance, stress, anxiety, loneliness, pleasantness, eventfulness, satisfaction, and quality of life from which physical and mental health and wellbeing assessments were drawn. There were also some limited examples of using physiological assessments of small sample sizes.

The conclusions from the work in each topic area generally focused on whether the indoor sound environment affects humans in the different settings in an objectively measurable and significant way. There is a general bias within the studies to considering the effects and implications of the Covid lockdowns because of the period considered for the systematic review with a focus on people isolated within their homes, including consideration of working from home, and also separately the elderly within care homes and interventions for dementia in particular. Relevant findings are discussed in the following sections in relation to the research question, with opinions offered by way of developing the discussion. Care has been taken to distinguish the evidence-based points from the expressed opinion.

1.2. SOUND INSULATION, VENTILATION & UNINTENDED CONSEQUENCES

What is meant by sound insulation

Sound insulation as discussed here refers to the reduction of transmission of sound (in air or through a structure) from one space to another, usually enclosed. The attenuation of the sound energy achieved through each building element, such as walls, floors, windows, doors, windows etc. is determined, with the overall value being the combined resistance to the passage of sound. This is an important part of providing acoustic privacy when considered together with the masking provided by the background sound in the space.

Regulatory drivers for sound insulation focus on noise pollution

To understand the historical basis for the current degree of residential protection from noise pollution, it assists to breakdown how this is achieved in England, and to some extent the other devolved nations of the UK. The term noise is taken to mean unwanted sound, which is set out more fully in the 'Noise versus sound' section on page 2 of Volume IV.

There are two types of sound insulation that need to be considered as part of residents' health and wellbeing in the protection against environmental noise, or noise from other occupants or neighbouring occupants or uses:

a. the airborne sound insulation of the façade and any ventilation paths protecting the occupant from environmental noise and providing masking sound.

b. the airborne and impact sound insulation within and between dwellings and other types of uses.

In the UK this has been historically managed through different regulatory mechanisms and systems. It requires some scene setting to be able to then dig into the implications of this in response to the research question.

a) airborne sound insulation of the façade and ventilation paths - Planning

The acoustic performance of the façade falls within the planning system, which relies on each Local Authority to apply the current policy of the Government in their area on a case-by-case basis. It is administered by Local Government Planning Officers, with decisions made by Councillors, moderated by the Planning Inspectorate on behalf of government Ministers. For noise there is an overall Noise Policy for England (NPSE 2010) which sets out a vision that makes noise management a part of the UK Government's policy on sustainable development. The NPSE has three aims that cover noise impacts on humans and includes a tie into health and quality of life, which in its explanatory note

says can be taken to mean health (including physical and mental wellbeing) and people's emotional, social and physical wellbeing. So, at its heart the policy requires the façade design to be sufficient to achieve that. The first two aims are focuses on controlling noise pollution. The third aim opens a way for using positive aspects of sound stating: "where possible, contribute to the improvement of health and quality of life", but this has been largely ignored in practice, in my experience and opinion, and remains a latent opportunity in which a soundscape approach could provide a meaningful contribution.

There is no national overarching strategy for noise for England, but there is one emerging that tackles soundscape and noise in Wales. Northern Ireland has comparable policy documents for noise[1] but Scotland has not developed strategies overtly, beyond continuing to prepare responses in compliance with the EU Environmental Noise Directive (END) and Environmental Noise Regulations (ENR) in the devolved nation's strategic noise mapping cycle and local noise action plans. Since the UK's exit from the EU the driver to continue this relies only on the ENR.

In England the policy feeds into a national planning guidance (National Planning Policy Framework, NPPF) at paragraphs 185 a) and b) with supporting guidance specific to noise (NPPG Noise), which is intermittently updated. In Wales the seven goals are defined by the Wellbeing of Future Generations (Wales) Act 2015. These are to create i) a prosperous Wales, ii) a resilient Wales, iii) a healthier Wales, iv) a more equal Wales, v) a Wales of cohesive communities, vi) a Wales of vibrant culture and thriving Welsh language and vii) a globally responsible Wales. Noise is specifically addressed within the Noise and Soundscape Action Plan for Wales (NSAP) 2018 – 2023 and the emerging Technical Advice Note 11 (2022 draft). The final regulatory piece of the puzzle being considered is The Environment (Air Quality and Soundscapes) (Wales) Bill 2023 which currently at Stage 1 in the Senedd. Assuming this passes, it will place a duty on the Welsh Ministers to publish a national soundscapes strategy, the first such duty in the world. The follow up to NSAP 2023 – 2028 is not yet in public consultation, which will be the policy that will discharge the duty imposed. This work feeds into the current state of knowledge. In Scotland national planning guidance is covered by Planning Advice Note (PAN) 1/2011, and the Technical Advice Note on the assessment of noise (2011). In Northern Ireland the Strategic Planning policy Statement (2015) provides a consistent position with England.

These documents do not currently include criteria or numbers relating to objective targets for noise inside residential dwellings, and Technical Advice Note (TAN) 11, Wales, is currently in draft, suggesting more of a framework than prescriptive objective thresholds, as the latest document to be updated. It is therefore left for the Local Planning Authorities to determine what is suitable for their area through their local policies and they may ascribe values for thresholds such as low and significant adverse effect levels caused by transportation noise sources mainly. They will also draw from their Pollution or Environmental Health Department and their own local planning guidance, which may or may not include objective targets for noise inside a habitable room. Determining noise criteria which may then get embedded in a planning condition must be necessary, relevant to planning and to the development to be permitted, enforceable, precise, and reasonable in all other respects to meet the tests for conditions. They may often draw from other guidance that is available with the aim of protecting residents sufficiently, in line with the overarching policy aims. This means the typical goal is to achieve a situation where not more than an adverse impact is caused by environmental noise ingress inside homes via the planning system, but where the statutory nuisance regime then picks up impacts that become so significant and substantial that they cause material interference to the ordinary use of the property. Guidance such as that in British Standard 8233:2014, WHO Guidelines for Community Noise (1999), WHO Environmental Noise Guidelines (2018) and WHO Night Noise Guidance (2009) is commonly applied as a way of delivering the planning concept,

[1] Noise Policy Statement for Northern Ireland (Sept 2014). In Scotland no separate overarching Policy exists currently.

supported by industry guidance such as the ProPG Planning & Noise (2021) to provide objective criteria to design and specify a façade design to. Sound insulation is identified as a part of good acoustic design. These criteria are typically based only on averaged $L_{Aeq,T}$ noise levels over specified durations in dB(A) (although some also include a criterion for maximum noise level L_{AFMax}), and predominantly have evolved to consider transportation noise sources. Where there is industrial or commercial noise this may be assessed under British Standard 4142:2014+A1:2019. The guidance also extends to include the quality of life and amenity in outside areas (e.g., balconies and/or gardens), which are not within the scope of this work.

Usually, an acoustic impact assessment is required to accompany a planning application, which determines what degree of protection is necessary by the façade design to achieve the defined noise guidance targets with windows open or closed, depending on the ventilation and overheating strategy. This is complicated by the need to consider the Agent of Change principle, which requires the sound from other commercial sources to be considered that were there first (like entertainment venues) and what suitable mitigation should be provided in the design to achieve the aims of the policy and prevent the existing business from being unreasonably restricted. This will be covered further in discussions on unintended consequences, point 6. The scope of this Volume covers the implications for the sound environment inside residential dwellings.

Regarding b) airborne and impact sound insulation within and between dwellings and other types of other uses - Building Regulations

The internal sound insulation is considered historically to be part of a health and safety driven suite of regulations (currently Building Regulations 2010). Compliance is administered by Building Control, which can be situated within Local Authorities or independently. In terms of sound, the aim is to limit excessive noise transmission between spaces internally between dwellings and to some extent within dwellings, which will result in minimum standards of speech privacy, sleep protection and overall comfort. This sets out key acoustic performance requirements in Approved Document E (ADE, 2010) for sound insulation between rooms (within the same dwelling) and also between rooms used for residential purpose or dwellings and other types of uses for new and materially altered building.

Where the adjoining uses are not residential, Section 0.8 of ADE makes clear that specialist advice should be sought to determine the appropriate level of sound insulation. This would apply to a new residential use next to an existing nightclub, or gym, for example. In this later case, industry guidance now also exists in ProPG Gym Acoustics Guidance (2023).

There are two other Approved Documents that have implications for the façade design and the overall acoustic protection achieved: Approved Document F relates to ventilation and includes noise levels for mechanical systems that are part of dwellings that provide minimum or purge ventilation; and Approved Document O (ADO) relates to overheating and includes a section at O1(a) on noise at night. ADO requires that the overheating strategy is usable. What is meant by that is considering if the environmental noise ingress that results from the windows being open is to the extend where the occupants may be exposed to high levels of noise pollution which make this option unusable. If so, they may prevent natural ventilation being a viable option for including within an overheating strategy, which should be addressed at planning stage to avoid a conflict where occupants must choose between overheating or overexposure to noise that may cause adverse impacts to their health or wellbeing under such conditions. Where environmental noise does prevent natural ventilation being an option, then this should be considered in the strategy and dynamic thermal modelling used and the alternative ventilation provisions. It sets threshold sound levels inside the room as an average and maximum above which it may be expected windows are “likely to be closed during sleeping hours”. Industry guidance is also referred to from this document, specifically the

Association of Noise Consultants' and IOA's 'Acoustics, Ventilation and Overheating: Residential Design Guide' (2020).

Finally, Approved Document L addresses conservation of fuel and power, which drives thermal efficiency and airtightness, which in turn affects indirectly the sound insulation properties of a building envelope. The drive for better airtightness and thermal insulation places a greater importance on the Overheating condition being addressed without reliance of openable windows, where environmental noise exposure may impact upon occupant quality of life. This conflict remains an area for tension where new residential development is being proposed closer to noise sources, and a reliance on co-ordination between the acoustic design and ventilation strategy is critical. In locations where it is not possible to rely on openable windows, sealed façades can result in highly sound insulated internal spaces, which are isolated from the surrounding soundscape and may have very low reliable masking sound that may affect privacy negatively within the building.

Enhancements on the minimum standards

There have been various schemes aimed at enhancing the minimum standards of the Building Regulations, such as BREEAM (Building Research Establishment Environmental Assessment Method), first launched in 1990; the Code for Sustainable Homes (CSH), introduced in 2007 and which is no longer running as a scheme; and Robust Details, introduced in 2004 as an independent scheme now widely used as providing enhanced sound insulation for new houses. Secure by Design also sets acoustic standards for walls and glazing but is focused on crime prevention through environmental design. These are all voluntary schemes and are not aimed at addressing the issue of good sound insulation for all homes. There is currently a gap, in my opinion, for what might apply to all homes to meet the more stringent conditions that may be required for good quality sleep, which is considered such an important aspect of maintaining health and wellbeing, free from disease. The internal noise targets promoted by the WHO Community Noise Guidelines (1999) remain valid, set out in Table 1 but include an external noise level outside bedrooms where windows are open. This ties up with that latest WHO Environmental Noise Guidelines (2018) and WHO Night Noise Guidelines for Europe (2009), which generally set outside levels, except for a reduction for maximum levels (as $L_{AFmax,\ inside}$) from 45dB(A) from the 1999 guidance to 32 to 35dB(A) for the threshold for EEG awakenings, motility, changes in sleep state and fragmentation. For wellbeing self-reported sleep disturbance has an outside maximum ($L_{night,\ outside}$) of 42dB(A). These are extremely challenging targets in most UK urban and semi-urban environments that are affected by transportation noise, but nevertheless represent the WHO current guidance for optimal conditions for human health and wellbeing according to evidence available. Whether these might be considered an enhanced target for protecting sleep in bedrooms or the expectation for minimum standards is therefore a tension that now exists, given that not all sound may be judged equally. It might be more accurate to focus understanding on these levels being specific to the transportation sources (generally road or aircraft) that the evidence comes from. The drive for ever quieter conditions in bedrooms does not consider the benefits of connection to the world around us and natural sounds in the environment. The Government under the Department of Levelling Up, Housing and Communities is understood to be reviewing the Decent Homes Standard for the private rental sector, and the Healthy Homes All-Party Parliamentary Group campaign provides some hope of developing enhanced sound insulation standards that result in sustainable homes that also support the health and wellbeing of those living within them through better privacy, the ability to sleep well and the adaptation of the function of their homes to the wider range of activities that we expect of them post Covid.

Compliance and unintended consequences

A number of unintended consequences that are relevant to the research question in the UK can be identified as a result of the focus on noise annoyance by regulation and planning policy. The following reflect our opinions:

1. The drive for energy efficient buildings has seen increasing thermal insulation for homes through tightening regulations (including Approved Document L) and airtightness, resulting in wider cavities between glazing panes and sometimes triple glazing to obtain required U-values for thermal reasons, which have higher acoustic insulation properties. This results in generally improved acoustic insulation also as a secondary consequence, with lower internal ambient noise levels when windows are closed, but mainly at the mid to high frequency bands, which is the region which provides masking at speech frequencies. This can create better conditions for hearing neighbours' speech and other sounds and leaves a dominance of sound at low frequencies where there are transportation and industrial sources in the vicinity which generate sound that contains that energy. This quite complex knock-on acoustic effect can result in an apparent reduction in perceived sound insulation and privacy from internal noise transmission, but also possibly may create an increased sense of separation or in the more extreme cases isolation from the outside environment. The trend has been closed, relatively airtight façades which now affects many new buildings, with ventilation strategies not always relying on openable windows.

2. An overheating strategy that conflicts with noise pollution ingress can create a situation where people need to choose whether to open their windows and be exposed to noise pollution or suffer the effects of overheating. Where natural ventilation strategies are not possible due to noise pollution this could result in reduced aural connection of people with the outside world. Discussion of this will be developed with regard to Health and Wellbeing outcomes in the next section.

3. Sound is treated as a pollutant and called noise unless it is part of a positive experience like a concert hall, stadium or cultural performance for instance, where the spaces are specifically designed to support the activity. By not treating a home as a place needing to be optimised for its many activities, but resorting to always protecting the occupants in acoustically isolated spaces from the outside environment the building construction provides a shield which cannot easily be set aside when it is not needed. The useful quality of sound as a pollutant is that it almost instantly dissipates once the source stops (after the reflected sound energy dies away). This is unlike some other pollutants, which remain in the environment for a longer duration (e.g., air pollution, water pollution such as micro-plastics etc). This provides an untapped opportunity to provide respite that instantly restores access to an acoustically clean and potentially health and wellbeing supporting sound environment, which could be achieved by opening a window, but other openings to quiet façades could also achieve similar outcomes.

4. Acoustics and the way sounds transmit through a building and then within a room is a complex issue which does not fit neatly into compliance with different regimes where there are overlaps that need co-ordination. The focus on insulation from sound that has negative effects (described as noise pollution) means that where sound that can have positive benefits to health and wellbeing occurs, it is being blocked out too and its benefit is then lost. This is illustrated an example such as the conflict created by high environmental noise conditions with a temporal feature (such as a music venue in a vibrant area which operates only at night). For the rest of the time, the venue may be relatively quiet and pleasant, offering a good quality connection to the locality which may also help social cohesion and a sense of community. The idea of respite can then be considered to allow potentially incompatible uses to exist in proximity with the right design protections rather than separating noise sources from residents. This can add to the next phase of development in our urban centres and cities, with sustainability at its heart to ensure a human approach is taken to making sure those environments are suitable for those using them. If this is not done the risk is wasted resources that do not work for those using the buildings, which is unsustainable.

5. The embodied energy within an existing building is an asset which needs to be re-used, rather than replaced with new, as a general approach. As the focus on net zero intensifies and the renewable energy transition takes place there is likely to be a change in the soundscape, with noise from combustion engines replaced by electric vehicles with Acoustic Vehicle Alert Systems (AVAS). Additional use of on shore wind farms and Air Source Heat Pumps (ASHP) that run continuously on many homes will provide a changed noise profile to that of fossil fuel boilers, which generate noise intermittently. It is necessary to consider how to adapt and balance the sound insulation of the façade with that of the future soundscape, making the most of the embodied carbon of the structure for as long as possible. This re-use means that a focus on refurbishment of the existing stock is important, with strategic interventions to improve and regenerate soundscape health and address noise pollution hot spots to increase property value and personal prosperity (in its widest sense) rather than a new build rush to meet housing targets. That would be a missed opportunity in my opinion, and when thinking about energy the design solutions should focus on people to ensure the solutions work. The soundscape inside the building is largely determined by the soundscape outside the building, where the building façade is perforated, and windows are open. The changing external soundscape therefore gives the opportunity to open back up façades in places where it has not previously been possible or healthy to do so. Shaping this opportunity proactively and strategically is an area where good acoustic design to create restorative changes would be a sensible driver. When the façade is closed, the soundscape is largely dominated by low frequency sound from the filtered outside transportation sound through the glazing together with mechanical and electrical systems (including music and technology) and noise from other people (such as footfall, voices etc).

6. Agent of Change and change of use from business use to residential use using Permitted Development Rights (PDR) are two areas of development in policy that conflict with one another and together cause issues when working together in my opinion. One consequence of this may result in people ending up trapped in homes that they cannot tolerably live in, because of the noise pollution regularly encountered. If a remedy is sought through statutory nuisance, then the commercial premises are placed in the spotlight. The current planning system in England (for example) has embedded a principle that those commercial premises are meant to enjoy the benefit of paragraph 187 of the NPPF (to “not have unreasonable restrictions placed on them as a result of development permitted after they were established”). However, when the use of nearby premises is changed to residential, using PDR, it is unlikely to be possible to determine what the full range of noise emissions that other nearby businesses will ever need to make, without co-operation with the businesses. Contact with them is likely to be avoided by the developer creating the homes, in my experience. Once this opportunity is missed and the acoustic report, which may have relied on a spot check, has been submitted, a scheme of mitigation that may include sound insulation work to the home or even possibly the premises may be included. This will be based on inadequate evidence in this example and may result in nearby businesses suffering restrictions once the homes are occupied and complaints are received, where a nuisance exists. It then falls to whether the business has a best practicable means defence, which could have been the position it was elevated to through mitigation works linked with the development. This rarely happens in my experience and would benefit in clearer guidance to join up and resolve this conflict. This situation places the businesses at risk and complainants under a long period of stress, which is likely to be harmful to mental and physical wellbeing.

Applying the evidence from the studies

With an abundance of caution, regard for the warnings of the evidence quality and confidence considering each of the key areas in turn we have the included my reactions and opinions to findings, with cross reference to the relevant papers in the following section.

1.3. GOOD ACOUSTIC DESIGN

Definitions

The understanding of what 'Good Acoustic Design' is intended to mean during this discussion is informed by the definition within ProPG Noise & Planning, Supplementary Document 2 (2017, SD2), and is sufficiently broad to apply to the approach that can be taken in planning façade design but also in the structural design that affects internal sound insulation. ProPG says:

"good acoustic design is about more than the numbers. It is a holistic design process that creates places that are both comfortable and attractive to live in, where acoustics is considered integral to the living environment."

SD2 sets out that considering both external noise control through layout and façade design of the built environment, as well as internal noise control through sound insulation, room layouts and noise-conscious design of services, all go towards delivery of good acoustic design. Summarising some of the key points to apply, with a focus on indoors, and expanding on some points, good acoustic design includes:

1. Consider both external noise ingress into buildings as well as internal noise transmission between spaces – sound insulation. Note : Whatever system is in place at the interface between indoor and outdoor sound environment it would be desirable to aim for it to be adaptive and dynamic to allow different profiles of users to be accommodated for (e.g. focus, relaxation, engagement) which should be considered against the 10 activities listed on page 12.

2. For external noise ingress, a site layout that distances dwellings from major noise sources and uses screening can help achieve suitable noise levels inside with windows open.

3. Dwellings should be designed to minimise the transmission of sound between rooms, floors, apartments to a degree that privacy and activities are not compromised.

4. Construction materials with adequate sound insulation and absorption properties should be selected, whilst also considering their embodied energy and most sustainable options.

5. Built environment designs for modern construction methods of new-build often attempt to minimise embodied carbon by making structures light weight. This makes sound insulation more challenging and places greater emphasis on detailing.

6. Room layouts should be optimised by locating noise-sensitive spaces away from lifts, garage doors, machinery like Air Source Heat Pumps etc.

7. Ventilation strategies should have the ability to limit noise ingress, when this is needed, while providing adequate airflow and to be able to cater for overheating also.

8. Building services like pumps, lifts and chutes should be designed and located to prevent undue noise transmission.

9. Noise from new fixed installations (like Air Source Heat Pumps) associated with the development should be suitably controlled.

10. Relevant indoor ambient, resting and sleeping noise level guidelines should be designed to as a minimum, but soundscape quality should also be a consideration.

11. Noise standards, regulations and good practice should be reviewed and followed as a minimum, but design interventions to optimise should also be considered (e.g., room acoustics design for comfort).

12. A developer should demonstrate with an acoustic design statement that the home will be designed to achieve suitable acoustic conditions and demonstrate through testing that it has been achieved. Any information the user should be aware of in terms of operating and maintaining the home to achieve the design benefits (e.g. ventilation systems) should be provided.

Good acoustic design for an optimal balance for occupants' health and wellbeing.

Beginning from a position of making the home supportive of health and wellbeing sets out some quite specific requirements. Torresin et al (2022c) colourfully sets out the range of some of the activities that need to be catered for at home for a case study, during Covid in London. This offers helpful insights, in my view, and informs the structure adopted in this section to navigate and consider evidence from the 59 studies. The risk acoustically is providing a flexible multi-use space which is not truly good for any one thing. Therefore, it is important, in my view, to prioritise what a home fundamentally needs to get right acoustically. It is also important to recognise that there are several non-acoustic factors that will also affect how the indoor soundscape in the home is ultimately perceived (See Table 1 in Volume IV, page 5).

To achieve good acoustic design that supports occupants' health and wellbeing means optimising the design of their home for the intended activities. Applying a holistic approach, as the SD2 guidance recommends, begins with early involvement of an acoustician in the design process. This means that orientation and layout considerations can be shaped to give access to quiet sides for windows and create a design strategy for façades affected by noise pollution. This may also lead to the consideration of the landscape design or connection to maximise the double benefit of bionet gain aims and to bring natural views and natural sounds into the locality which the indoor soundscape can benefit from. The use of water and vegetation in public areas is a consideration to introduce natural elements that can assist in creating more healthy soundscapes. Sound insulation remains a core consideration to suit a wide range of activities, but also suitable room acoustics for the activities affects acoustic comfort. Appropriate noise control of the mechanical and electrical services and technology is then needed to address noise or vibration sources where low or high frequency tonal or non-tonal sound might be generated. The design of the façades is critical so that the building can be ventilated without compromising the internal acoustic conditions to create dwellings that support the health, comfort, and wellbeing of people.

People's homes need to satisfy multiple uses, often at the same time, and be suitable to adapt throughout their lives or deal with physical and mental health and wellbeing challenges. The following core uses reflect my opinion of the ways in which activities within our homes have broadened post Covid, drawing from Torresin et al (2022c) and adding to that list considering the range of activities covered over the shortlisted studies:

1. Sleeping

2. Relaxation physically and mentally (respite)

3. Working (WFH) - including video conferencing

4. Exercising and physical activity

5. Entertainment (including music) and socialising (including cooking and eating).

6. Intimacy
7. Culture/ religious adaptions
8. Adaption for neurodiversity & Inclusion
9. Adaption for aging well and dementia care (studies were largely done in care homes)
10. Recuperation from physical or mental illness.

The good acoustic design considerations under each heading are discussed below.

Sleeping well

Disturbed sleep is one of the main direct health and wellbeing impacts influenced by the indoor soundscape in the space. Hearing does not switch off, with our brains monitoring our environments for threats unconsciously as we sleep. A shift in sleep state or awakening caused by sound is undesirable for achieving good quality sleep.

Andargie (2021) reports in a Canadian study how the main causes of reported sleep disturbance were construction and road traffic noise, although there is a higher proportion of detached properties in Canada than in the UK[2], which may contribute to a reduction in the occurrence of neighbour noise issues. Many of the studies use this as a key metric for determining health impacts. Argalasova (2022) reports from a Slovakian study that 30% of the 543 people surveyed in new homes had trouble going to sleep. A Spanish study in urban and rural regions by Santurtun (2022) reported that 27% of 344 people had sleep difficulties because of noise disturbance whilst in their homes, from neighbours in cities. 21% of people reported being awakened by noise.

WHO guideline targets, discussed on page 7 whether indoor or outside sound levels targets inform suitable levels in bedrooms during the day and night, but controlling average and maximum sound levels from environmental sound is not enough, it is also necessary to control the sound from elsewhere inside the building from other sources, ranging from mechanical noise (like ventilation or cooling plant to appliances) to footfall sound, voices, or music. This requires the sound insulation to be optimal or at least adequate to reduce normal use sounds to a degree that good sleep conditions are still possible.

There is an important need to ventilate homes, which have improved airtightness and thermal insulation, for indoor air quality and to accommodate overheating conditions without compromising their conditions for sleep. The solutions can range from having natural ventilation via opening windows on quiet sides to bringing air through the home passively through attenuated paths or with the help of a fan actively or in what is described as a hybrid approach. The other extreme is use of a fully mechanical system that removes the need to open windows when it is noisy outside. It is not generally desirable to place homes in locations in which people need to keep their windows closed to have good conditions to sleep, but as rapid urbanisation occurs this may be an adaption step that is necessary until an intervention to improve the soundscape or management to provide respite can occur (as it does for the UK's larger airports with limits on night flights). Amryar (2022) provides an interesting insight of poor protection from noise pollution being one of the casualties of rapid urban development in Kabul, Afghanistan. The idea of having mechanical systems providing a degree of sound masking in bedrooms is a helpful one to consider, providing it is not prominent as this may mitigate the low ambient sound levels that result from high thermal performance glazing.

[2] Canadian Statistics and UK Office for National Statistics website detailed in reference list

The content of the environmental sound that transmits indoors is also important, as it connects people with their natural surroundings. Having regard for how to open our façades as future soundscapes change through interventions, will be an area for further consideration and study.

Relaxation physically and mentally (respite)

Rest and relaxation during recreation is essential for people to recover and restore themselves from stressors, deal with fatigue and reset mood. It is often commonly described as "downtime".

Benz (2021) explored the challenge presented by urbanisation and the increasing density of living and annoyance with neighbours but found that creating social cohesion together with respite allowed a potentially restorative quality that reduced annoyance. The non-acoustic factors were thought relevant to this. Bower (2021) concluded, following a study in Australia during Covid, that the pandemic caused the collapse of boundaries at home, which was no longer reserved for rest and relaxation. The Dzhambov (2021) study agrees with this. The impact of natural light and external noise on depression symptoms (and anxiety symptoms for noise) and adequate space for social interactions, privacy, respite, and quiet reveal the importance of well-designed dwellings, where equitable access to controllable environments, choice and agency should be provided.

Frescura and Lee (2022) is a UK study on 41 people, testing physiological and psychological responses to footfall noise from adults and children and speech and music through simulated light-weight wall and floor constructions. When playing the single sounds and then combining them as footfall and voices, they found footfall and music and then all together that sound level causes reliable changes in patterns to physiological and psychological markers. Overall exposure to neighbours' sounds led to an increase in facial electromyography (fEMG) over the corrugator supercilii (CS) muscle group and a decrease in fEMG zygomaticus major (ZM) muscle group activity, heart rate (HR) and electrodermal activity (EDA). No significance to a change in sound level occurred, except for music (fEMG ZM) and individual sounds (EDA). The psychological markers indicated arousal ratings were significantly correlated with fEMG CS activity, while ratings of valence showed significant correlation with EDA. This implies that more arousing sounds generated greater fEMG CS activity and less pleasant sounds caused lower EDA response. Arousal and valence strongly associated with combined sounds, which were preferred to sound of individual footsteps.

Acoustically, having freedom from noise pollution and achieving acoustic comfort when indoors involved having sufficient speech privacy from others, again indicating the importance of sound insulation and sufficient background sound to provide masking, as well as access to relatively quiet and comfortable spaces in which physiological and psychological calm can be achieved and restoration can occur.

This wakeful state presents the opportunity for sound that is positive to health and wellbeing to be experienced with the objective to aid measurable restoration. Whilst we know from personal experience music can change how we feel, and stepping into a quieter space from a noisy one can be a relief, it is the indoor soundscape and how that is connected to the place and community in which it is situated that requires more careful consideration. Designing for the preservation and restoration of physical and mental wellbeing is an opportunity that exists, supported by this current evidence from these papers.

Sound that allows better connection to nature, encourages a state of 'soft fascination' (a concept which comes from the field of cognitive psychology as Attention Restoration Theory (ART) according to Kaplan (1989) and some sense of place and social connection may also assist to improve mental wellbeing markers. Dzhambov (2021) found from a study of 323 university students in Bulgaria during Covid restrictions that wanted natural sound was rated by participants to have a more restorative capacity with improved self-rated health (SRH) scores compared with mechanical sound which was described as unwanted and resulted in reduced SRH scores. In a framework for sounds in the home

and SRH scores relationships between wanted sounds (generally identified as natural sound) had connections with positive feelings of escape and improved SRH scores. Human sounds/ music caused a neutral/ ambivalent response, which is suggested to be more dependent on context specific factors like privacy or non-acoustic factors such as crowding, noise sensitivity, sociodemographic and (potentially) genetic components. Dzhambov concluded that a wanted indoor soundscape (meaning one which contains natural sound that breaks in from outside) has a restorative quality on self-reported health scores in this study, and the proposed a framework provides a way to consider and describe soundscapes and health outcomes in homes.

Working or educating from home (WFH)

The need for our homes to cater for people to work and educate from home has been one of the biggest changes post Covid-19, meaning that the ability to take part in video conferencing without distraction with or without headphone use, and having good enough acoustics for speech clarity to be adequate and professional is important. In the case of education, to provide quality learning from home has become a requirement provide societal resilience to shocks, such as Covid. It is not within the scope of this work to consider headphone use in greater detail, but it is an area that would benefit from further consideration and study. Also, the need to be able to concentrate free of distractions and work efficiently is important for productivity and achieving learning outcomes. Whilst educating is a slightly different use case, it is covered together with working as the essential mechanisms are similar as both rely on an online internet connection and video call or online working.

The 10 concepts highlighted by Boegheim et al. (2022) relating to workplace quality more broadly are: stress, fatigue, sleep quality, concentration, productivity, engagement, mental wellbeing, emotional exhaustion, depression, and mood, with connections between these affecting each other. Sound level is identified as influencing distraction, productivity and concentration, whereas noise is related to fatigue, depression and impaired mental health. Indoor Environmental Quality (IEQ), which includes consideration of sound as the objective IEQ and noise as the subjective IEQ, is the method proposed to assess that, with workplaces recommended to audit using IEQ sensors. This could be similarly applied for compliance with minimum standards for schools and could enable technology to assist in making sure the standard is achieved within the chosen place at home, if the pupils are provided with a sensor. Headphone use was not specifically considered in this study.

Andargie et al. (2021) found, during a longitudinal study, that noise from those within the house was the most problematic source, and that it was not promoting of productivity; however, this was from a small sample of 49 people. In a Japanese study by Natomi (2022), the lack of privacy in homes with housemates and inability to create separation of work-life spaces during Covid when WFH brought noise into the home resulting from teleconferencing caused stress when there was not enough privacy. It was concluded to affect workers mental health as a result, with 17% of 500 employees reported being highly stressed regardless of the residential type and being unable to adapt to WFH.

Torresin et al. (2021) completed a study in London during Covid which found better psychological wellbeing scores existed with more comfortable soundscapes for both WFH and relaxing. WFH also correlated with better wellbeing, concluding the need to design homes to support the variety of new activities based on tasks with implications for health-supportive soundscape design to improve comfort and support wellbeing. WFH needs for soundscape were low in terms of content, but there was a need for privacy and a controlled environment. For relaxing a greater degree of content that was engaging or assisting a sense of privacy with a similar need to be able to control the environment was found to be an appropriate aim. The home acoustic environment was perceived differently depending on the activity, with implications for how to design soundscapes for improved comfort and to be supportive of wellbeing.

Torresin et al (2022a) studied WFH for workers in London, UK and Italy for 848 participants. They concluded that rooms with less dominant building services noise were more appropriate for WFH

and relaxing. They also found that window opening behaviour while WFH in London was slightly affected by noise but that was not a significant relationship, whilst in Italy a view of vegetation made it more likely the window would be kept opened whilst WFH. Mimani (2022) considered the effect on wellbeing and productivity of the inside and outside soundscape when working from home during Covid, with a study of 942 people in India. The finding was it was perceived to be noisier inside due to human activity and that productivity was affected, with only 15% preferring the work from home model. 62% had reservations about the online education model.

With a particular focus on the good acoustic design, interventions that might bring benefit to health and wellbeing should include being able to have a good workplace quality when working from home by aiming to minimise distractions and in so doing minimising the risks of fatigue, depression, and impaired mental health. In order to maximise productivity and concentration the need for privacy and soundscape that is low in content but free from humanmade noise is desirable.

To achieve this, sound insulation of the façade and between homes is again important to control noise ingress from neighbours and break-out to other homes, for speech mainly. However, it is the sound transfer within the space that gives separation and privacy to others in the home and the distraction caused which is the main challenge not currently addressed. Currently, the minimum performance of walls and doors are not particularly suited to this and could be enhanced so that a basic level of sound insulation between spaces in a house is achieved. Acoustic treatments to control reverberation in defined areas as part of fixtures and fittings options provided by the workplace as part of the workplace risk assessment and mitigations would also be a way to address this. Some types of work may require acoustic conditions that require specialist design outside what would be expected in a home, which could then be tailored to the needs of the workplace or individual as part of a workplace IEQ assessment by the employer.

Exercising & physical activity

Physical exercise is an important part of achieving and maintaining health and wellbeing in a direct way. During Covid it became challenging for those without outside amenity space to exercise, with restrictions encouraging people to stay at home, which showed that exercise in the home required some innovative use of space. Exercise in the home may cause disturbance to others within the home or to neighbours because of the noise or vibration generated by those activities. Whilst some homes have space to create a dedicated place that can be set aside for equipment, like a garage for instance, or to achieve sufficient separation from others, many people must settle with using a habitable room.

Whether creating a dedicated gym, or flexibly using a habitable room, good acoustic design can be used to bring some of the gyms' technology to the home. Heavy impacts from free weights can be mitigated with different layers of foam or elastomeric resilient matting that can absorb the energy of the impacts. Equipment often has anti-vibration mounts that are available with them that do a similar job. Good quality resilient matting is also a good approach for absorbing vibrational energy from jumps at source. It is likely there will be a limit to what can be done where the home is not on a ground floor concrete slab, but it would certainly assist mitigation of the risk of causing others annoyance and negative health and wellbeing impacts. Resistance training with bands and other such techniques are good ways to minimise the noise and vibration created at source, making it possible to do a challenging cardio or aerobic session without causing adverse noise impacts to others.

Where music is used during exercise, the following section is also relevant.

Entertainment (including music) and socialising

Entertainment and socialising are often centred on vocal communication, which might sometimes be raised as part of communications or as part of singing or making music. The other element is the playing of pre-recorded music through technology, which may be a smart television or sound system which can reach high sound levels and generate considerable bass energy. The final one is making

music using instruments, which is the backbone of the grassroots music industry in the UK. Many bands began in their bedrooms before making it big and bringing joy to their fans in venues and festivals. This vibrancy is fed by what happens in the home. It is therefore a cultural consideration to encourage music playing as an opportunity. This could include acoustic instruments like a piano, guitar, flute, or drum kit, but these may also be amplified. Whilst this may seem to be the more extreme end of the spectrum it is more likely that managing the impact caused by limiting the duration or playing electronic instruments with headphones may provide the best option to control noise generation at source.

Social connection and community are an important part of building and maintaining relationships between humans, and, in my opinion, are important to mental wellbeing.

Park & Lee (2019) interviewed 57 residents in multi-family homes in South Korea, concluding that interpersonal relationships played a role in noise coping strategies, which could play a part in reducing neighbour disputes.

Applying good acoustic design in support of these activities requires places in the home which provide sufficiently good acoustics to support the sound of the instrument or voice but also contain it and provide privacy. The space needs to fulfil roles ranging from a music practice room to a theatre. Whilst sound insulation again plays an important role, making sure the room acoustics are supportive of speech and the instruments' sound is relevant to consider. Use of carpets and soft furnishing means this is usually the case for speech, but with the trend for hard floors and where surfaces are hard the acoustic environment can become harsh and unsupportive of good speech intelligibility, but good for supporting the sound of some instruments. The result can be blurred sound and noisy spaces for speech, which can make it difficult to communicate in and tolerate for long and in which reproduced music may have sound of poor quality. One option is to add removable acoustic panels or absorptive wall hangings to transform the acoustics of the space to suit the use. In this way it is possible to simply improve the acoustics flexibly and create more pleasant places to be able to socialise, whether using speech, recorded music, live music or a blend. Recent work on a number of studios intended to be the next step up from the music made in bedrooms shows that pipeline for music in the UK remains alive.

Intimacy

Time alone, enjoying a bath, intimate time of sexual activity with a partner within the home are all part of everyday life for many, and part of good mental wellbeing. A case study by Torresin et al (2022c) deals with this issue as part of a study into soundscapes that would work for a range of activities during Covid in London, UK. In this case, 30% of a sample of 239 people reported negative or mixed impacts to their sexual activity as a result of the soundscape, with 15% reporting positive impacts as a result of it on their sexual activity. Walsh (2021) considered 'obtrusive intimacy' being noise which could breach personal boundaries and privacy at home, affecting neighbour relations and wellbeing.

The ideal soundscape in the home to support this is described by Torresin et al as quiet, well sound insulated from others in the home, which provides access to positive sounds (including nature, music, or an urban background) resulting in privacy, intimacy and place to express self without a sense of noise related constraints.

Applying good acoustic design to this scenario again provides further evidence of the importance of sound insulation within and between homes, and problems that poor sound insulation may cause. Opportunities for nature-based solutions for creating positive soundscapes that support activity-based design of residential environments provides a broader consideration for the composition of homes, and improvements for internal sound insulation within that home.

Culture/ religious adaptions

The UK must cater for different cultural and religious practices in homes, given its multi-cultural make up. There is understandable caution in applying evidence from studies completed elsewhere in the world as the way people respond to sound differs depending on contextual variables of that place. These differences are noted in studies by Caniato et al (2021), Hasegawa et al (2022) and Torresin (2022a), Lee (2020) and can be summarised as representing the diversity of soundscapes that exist around the world.

It is not surprising then that cultural or religious differences may also affect the perception of noise pollution and soundscape and their wellbeing influences in homes in the UK, as those differences exist in the attitudes and practices of those different cultures and religions and have been transferred and provide a kind of integrated cultural memory. The study by Mohammed (2022) is specific to Turkey but compares responses from 201 Arab residents and 204 Turkish residents. Differences in responses to how noisy or quiet or stressful or peaceful a sound was rated existed with a significant correlation providing a tantalising suggestion which would benefit from further work to explore. The cultural and religious diversity in cities requires an equally diverse soundscape to capture what is perceived to be a pleasant 'sound mark' within that soundscape. Cultural or religious associations with sounds, and the meaning they represent, may be a useful starting point for a research question. The call to prayer is one example of this, or bells in a village church and whether the authenticity of that sound is of importance (i.e. whether a recording of church bells achieves the same response or not).

Good acoustic design indoors in this context is difficult to suggest until there is a clearer understanding of how much of an influence this is and the objectives for such design in the home to achieve improved wellbeing outcomes.

Adaption for Neurodiversity & Inclusion

There is one study that explicitly considers diverse needs in nursing homes in China Wu (2022), for blind residents, which considers their responses to sound. The specific needs of residents relied on sound cognition and access to contextual memory to then inform the information gained from the acoustic environment. It was concluded that they had specific needs linked with the perception of sound in such settings, and that to support inclusive design of care homes this should be taken into account. This prompts the need to consider the different needs of neurodivergent people within their homes who may respond to sound differently, and who may have their health and wellbeing improved by better acoustic conditions.

It is likely that good acoustic design can provide a range of measures to achieve those conditions, and these could be referred through medical or psychological services for assessment and interventions. This would provide a way to improve the care within the community by improving and adapting people's home environments to better suit their particular needs, and to adequately protect neighbours from excessive noise from vocalisations that may be associated with some conditions for instance.

Adaption for aging well and evidence from Care Homes

As humans age they gather wisdom and life experience, but also experience changes in their physical and psychological capabilities, becoming generally less able. The Physiological Society report "Growing Older, Better" (2019) sets out a way forward for the UK, aiming towards the UK Government's target of at least 5 extra healthy years by 2035. Remaining healthy for as many years as possible, within homes (or care homes), is a direct link to health and the benefit of homes providing supporting and safe environments. Wellbeing is more reliant on the connection and support from community, a healthy lifestyle and the ability to sleep well, which can all decline with age. Social isolation, loneliness and mental health decline are risks where people in their homes do not get regular social contact.

Graham (2020) explored long term care and the importance of sound in long-term care facilities, the space between hospital and home. It was concluded that sound may be beneficial or detrimental, and what is ideal is a debate that continues in this topic, mindful that in later life people tend to want to be engaged and in a lively environment rather than silence, although this was not a statistically significant finding.

Good acoustic design can potentially encourage social connection using layout and orientations for homes suitable to be occupied by aging people in the community, which face onto community areas, and are protected from environmental noise pollution sufficiently to allow openable windows to be viable, providing a strong connection to others. This must in my opinion be weighed against a tendency for a perception of vulnerability, so that personal safety and security is maintained. Whilst reasonable sound insulation is still required for acoustic privacy[3] reasons it would be potentially more reassuring and less likely to result in depression and loneliness where other neighbours could be heard, to some extent.

Mu (2021), Mu (2022) indicate that older people achieve the highest comfort ratings with ambient noise levels of below 55 dB(A), with music being the preferred sound and traffic and sports the least from a 101-sample size. Kosters (2022) also found an improvement in soundscape resulted from raising awareness in staff. Kosters (2023) study into 110 people over 5 care homes for a 15-month longitudinal trail found that dementia patients had reduced neuropsychiatric symptoms that correlated with increased staff awareness of the soundscape and ways in which they could tailor it to a patient's needs. Only a weak correlation was found for the patients' response to loudness and soundscape quality ratings, indicating that the quality of the sound is of more consequence than the overall sound level in this study. The studies in care homes, assessed as moderate quality, indicate that sound can have a positive effect for dementia patients, via soundscape interventions, supported by De Pessemier (2022) study on personalising soundscapes for dementia patients. Generally, bringing 'the outside in', creating restorative social and experiential engagements using sound which also helped orientate them in time and place, feel safe and reduce behaviour symptoms.

The opportunity to use sound directly through soundscape interventions and design can be considered to fall within good acoustic design, which would be likely to reduce symptoms for those suffering dementia, where the carers were trained and made aware of how to make that intervention. This is a direct health benefit for patients, but also provides staff with another tool to assist them in what might be better described as soundscape therapy, given the reported improvements in the De Pessemier study.

Recuperation from physical or mental illness

Many people have recently suffered ill physical health ranging from mild to very serious symptoms because of Covid-19, as continues to be reported on the Government's coronavirus.data.gov.uk website. Mental health and harm to wellbeing caused by the disease and the secondary restrictions imposed within the UK are in my opinion likely to have followed, but these are helpfully also described for Australia by Bower (2021). The national collective memory currently makes it easy to point to the pressure that the UK National Health Service was placed under and which to some extent it remains under over each winter as the virus is resurgent. People will inevitably continue to be ill with various complaints into the future or may be suffering at home. Whilst hospitals are designed to comply with acoustic standards, they are inherently noisy places where it can often be difficult or impossible to sleep. The home provides a sanctuary where non-serious illnesses can be recovered

[3] Privacy in this context is taken to mean the acoustic property being the product of sound insulation and masking background sound, rather than the broader application of the term privacy, which could then be described as acoustical privacy (Hunt 1955).

from, as the ‘stay at home’ message from the pandemic indicates until the condition requires medical treatment.

Optimising homes to create the best environment for people to recover and restore their health is likely to be necessary to ease the burden on the health service and would be an area to explore further.

Good acoustic design again can directly affect health, providing a home with sufficient sound insulation to protect people who need rest and good sleep, potentially through the daytime as well as night, as they recover. Connection to natural sound in the soundscape also has been shown through various studies to have a restorative benefit, and the ability to open windows to get good ventilation and natural daylight provides optimal conditions for recovery.

2. CONCLUSIONS

This section presents an overview of the factors affecting façade and internal sound insulation that affects indoor environments, with unintended consequences identified and discussed in terms of health and wellbeing impacts as an opinion piece.

It is concluded that sound insulation is a fundamental requirement in homes and care home facilities to provide acoustic privacy, allow restorative sleep, and control noise ingress from outside. However, over-insulation can lead to a lack of connection to the outside and community. Striking the right balance is therefore important when designing for health and wellbeing.

Good acoustic design should aim to optimise indoor spaces for the diverse range of activities needed to support health and wellbeing at home. This includes suitable noise levels and soundscapes for sleeping, relaxing, working/learning, exercising, socialising, intimacy, cultural needs, neurodiversity, catering for aging well and recovery or coping with illness such as dementia, or disease. This review of recent evidence on indoor sound environments and their effects on mental health, wellbeing, quality of life, annoyance and sleep has revealed some key considerations for the role of sound insulation and good acoustic design. While the overall quality and confidence in the evidence was low to moderate, some tentative findings emerged across the studies which were discussed and considered to inform more robust studies in the future.

While minimum standards address noise as a pollutant, a more holistic human-centred approach is needed to consider the positive aspects that sound can have on health and wellbeing indoors, to achieve a truly sustainable outcome once married with the built environment solutions. Homes that work for their occupants is central to human success and should provide both refuge from noise when needed through good sound insulation, and also access to positive natural and community sounds that restore and connect our physical and mental health and wellbeing. Façade design can help achieve this balance. The diverse soundscapes preferred cross-culturally indicates that more research is needed on cultural influences on health responses. Overall, the evidence indicates a need for homes that are adaptable across their lifespan to support changing physical, sensory and psychological needs of those using them. Good acoustic design that considers activities, soundscapes and diverse needs can contribute to improved mental health, wellbeing and quality of life.

This provides a good position to launch further works to strengthen the evidence in areas to support the delivery of the emerging Government strategy on Noise and Soundscapes in Wales, and UK Government delivery of the third aim of the noise policy and paragraph 185 b) of the NPPF in England and through it similar policy in Northern Ireland to deliver more sustainable residential development through the renewable energy and net zero transition which is designed to be supportive of their health and wellbeing. In Scotland there is currently no overarching noise policy, with specific guidance provided on noise currently only. The challenge for the people of the UK remains the same.

3. ABOUT THE AUTHORS

Peter Rogers is a Chartered Engineer and Fellow of the Institute of Acoustics with over 30 years of experience as an acoustic practitioner. His first degree in Physics and Medical Physics and then a Masters in Building and Environmental acoustics in the context of 21 century challenges led to a growing focus on how acoustics is relevant to creating sustainable outcomes, which has become the central focus of his work within his consultancy, Sustainable Acoustics. His experience in Local Government and his first degree in Physics and Medical Physics provides him with a physiological angle when applying acoustics to noise pollution and the emerging field of soundscape quality assessment and design. He has written several papers and is involved in a number of industry guidance documents on the wide variety of topics that acoustics affects and is now focusing efforts on how acoustics can deliver regenerative design.

Angela Lamacraft has been a Member of the Institute of Acoustics since 2010. She has achieved BSc (Hons) Audio and Music Technology, the IOA Diploma in Acoustics and Noise Control and the University of Southampton MSc Sound and Vibration. Angela's background is related to environmental noise, transportation noise and vibration and industrial noise control, however, she has also undertaken acoustic assessments in other areas, such as for schools. Angela's experience in environmental acoustic assessment ranges from the impacts of noise to single dwelling assessments to Environmental Statement chapters for large mixed-use developments, and sources from transportation to industrial and open mining. Angela is an active Ordinary Member of the IOA Council, particularly regarding equity, diversity and inclusion and organising the school competitions for the Institute. She has also written several papers and articles.

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