January 2020

Version 1.1

ACOUSTICS VENTILATION AND OVERHEATING

Residential Design Guide

Foreword

For those acousticians involved in the design of buildings to prevent noise ingress to reasonable internal levels, issues related to overheating of properties and the adverse impacts that may occur have become more prevalent in recent years. This is an area which has been difficult to reconcile with the competing requirements to ensure that properties do not overheat and a requirement to maintain the acoustic integrity of the proposed buildings.

Time and time again we are encountering buildings where even in the winter the occupiers are identifying a need to open the windows on some properties in order to regulate the internal temperatures to a comfortable level. This opening of windows then invariably exposes the occupiers to levels of noise which the acoustic design of the buildings has been trying to avoid.

The Acoustics, Ventilation and Overheating Residential Design Guide provides an approach as to how the competing aspects of thermal and acoustic comfort can be managed. This important publication has taken a long time to complete due to its technical complexities and all of those involved in the process deserve our thanks for the immense time and effort that they have put in to make this a valuable resource for the future.

The Association of Noise Consultants and its member companies is made up of a large number of individual members of the Institute of Acoustics and the Association recognises the immense value that the two organisations working together bring to endeavouring to solve those acoustic and other environmental issues which we encounter on a daily basis.

Graham Parry, ANC President

The need to reconcile what can be competing demands of sound insulation and ventilation has been one of the challenges faced by practitioners in this field for many years. The production of this document now, which brings together guidance on acoustics and ventilation, is particularly timely given the concerns about climate change and the likely need to adapt our approach to design to account for it.

The Acoustics, Ventilation and Overheating Residential Design Guide provides an integrated approach to sustainable design for both thermal and acoustic comfort in our work and living spaces. The advice is needed in this period of increased urbanisation and the growth of heat islands, increased land costs and the demand for housing resulting, at times, in building closer to highways, industrial processes and flight paths than would be otherwise desirable. It should become the key guide for planners, designers, building services engineers, noise control engineers, consultants and regulators dealing with this issue.

It has been prepared by experts from all these sectors and I would like to thank them for volunteering their valuable time and experience in producing this guide, which I am sure will become the first reference point for practitioners.

The Institute of Acoustics gratefully acknowledges the lead taken by the Association of Noise Consultants and is pleased to have been involved in the production of this Guide.

Barry Gibbs, IOA President

Further Work

Many buildings require closed windows to provide good internal acoustic conditions whereas opening a window is the normal way to keep a building cool. These opposing requirements are becoming a major issue in the design of buildings, in particular for housing, especially if we are to avoid the widespread use of mechanical cooling. This document starts to tackle the issue by helping those involved in building design and/or the Planning process to understand the likely degree of noise disturbance when windows are opened. To enable designers and planners to make fully informed decisions, however, requires two further pieces of information. The first is to know how long windows will need to be open, which may be determined from a dynamic thermal model, or more qualitatively from the GHA Overheating Risk Tool. The second requires a better understanding of the potential adverse impact of combined exposure to noise and overheating. Crucially, how long will people tolerate higher noise levels in order to stay cool? One suggestion is to consider the overall average day (16h) and night (8h) time average noise levels. There is some logic to this as we all know that we can tolerate high noise levels for a short duration and moderately high levels for a little longer. But is it that simple? The Association of Noise Consultants wants to work together with natural ventilation experts and thermal modellers to build on the excellent work done to date in creating this Guide so that we can better understand this complex issue and possibly find more effective ways of ventilating and cooling spaces. The ultimate goal is to create cost effective and sustainable buildings where people can live and work in comfort.

TABLE OF CONTENTS

1 Introduction

Acknowledgements

1.1 The guide has been prepared with contributions from members of the Association of Noise Consultants' Acoustics, Ventilation and Overheating (AVO) Group.

1.2 The principal authors of the guide include:

- Anthony Chilton, Max Fordham (Chair of Working Group)
- Andrew Long, Sandy Brown Associates
- David Trew, Bickerdike Allen Partners
- Jack Harvie-Clark, Apex Acoustics
- James Healey, WSP
- Mathew Hyden, Cundall
- Nick Conlan, Apex Acoustics
- Stephen Turner, Stephen Turner Acoustics

1.3 Additional support was provided by the following AVOG committee members:

- Adrian Passmore, Arup
- Barry Jobling, Hoare Lea
- Ian MacArthur, Clarke Saunders Acoustics
- John McCullough, Mid Kent Shared Service
- Juliette Paris-Newton, Robin Mackenzie Partnership
- Mark Scaife, MLM Group
- Michael Swainson, BRE
- Robert Osborne, ANC

Background

1.4 This Acoustics, Ventilation and Overheating Guide ('AVO Guide') is intended to be used by acoustics practitioners as well as all those involved in the planning, development, design and commissioning of new dwellings. It recommends an approach to acoustic assessments for new residential development that take due regard of the interdependence of provisions for acoustics, ventilation, and overheating. Application of the AVO Guide is intended to demonstrate good acoustic design as described in the ProPG: Planning & Noise, May 2017 [1] ('ProPG'), when considering internal noise level guidelines.

1.5 Indoor environmental quality (IEQ) is dependent on air quality (and hence ventilation), thermal comfort and acoustic comfort. These factors are clearly interdependent but, due to lack of guidance, have hitherto typically only been addressed independently. Provisions for both ventilation and mitigation of overheating may include façade openings that permit external noise ingress, and/or mechanical equipment that generates noise. In both cases, there is potential for noise impact. The noise impact itself may be the problem for occupants, or it may lead to consequential action by occupants such as turning off ventilation systems. In modern dwellings with high standards for airtightness such action can have unintended adverse consequences for air quality.

1.6 Previously, the provision of façade sound insulation to protect against outdoor sound has been considered separately from the ventilation strategy and any strategy for mitigating overheating. A review [2] of recent planning applications for major developments in London reveals the problem. Of the applications reviewed, 122 had both noise and overheating assessments; 85% of these developments required closed windows for reasonable noise conditions, while the overheating assessment relied on open windows for reasonable thermal conditions. The result is residential accommodation in which the occupants may choose either acoustic comfort or indoor air quality and thermal comfort, but not achieve both simultaneously.

1.7 The AVO Guide aims to assist designers to adopt an integrated approach to the acoustic design within the context of the ventilation and thermal comfort requirements.

1.8 A requirement to assess and provide mitigation against outdoor sound for a residential development may be invoked through the planning system; thus the local planning authority may be responsible for assessing and enforcing the proposed mitigation. The need for, and provision of adequate ventilation is outlined in building regulations, and therefore managed through the building control system. Although an overheating assessment to inform the design of dwellings is not currently mandatory under The Building Regulations, an assessment may be undertaken to meet planning and/or the developer's requirements. Hence, as well as being undertaken by different designers, the adequacy of the provisions for each aspect of IEQ may be assessed by different bodies and potentially based on different assumptions regarding use of the building.

1.9 The evolution of energy performance requirements under The Building Regulations has led to increased airtightness and enhanced thermal insulation. However, these changes can have unintended consequences. Internal air quality can be poor unless ventilation systems are effective, whereas the efficacy of ventilation systems in leakier buildings was of less consequence. When there is an increased capacity to retain heat, dissipation of excessive heat gains can become more problematic, with the consequential increase in overheating risk. Other factors currently contributing to overheating risk include global heating (climate change) and the urban heat island effect.

1.10 A fragmented design approach results in accommodation that may be uncomfortable to occupants, and hence may be unsustainable. Residual risks for stakeholders include:

- Health & wellbeing risks for occupants
- Design risks for consultants; and
- Legal risks for developers.

1.11 The increasingly urgent need for an integrated approach to consider noise, ventilation, and overheating has been the motivation to produce the AVO Guide. The purpose of this document is to help avoid these risks by delivering accommodation that is comfortable, resilient and sustainable.

Overview of Document

1.12 The AVO Guide includes:

- an explanation of ventilation requirements under The Building Regulations as described in 'Approved Document F – Means of Ventilation, 2010 Edition' [3] ('ADF') along with typical ventilation strategies and associated noise considerations;
- an explanation of the overheating assessment methodology described in CIBSE *'Design methodology for the assessment of overheating risk in homes'* [4] ('TM59');
- potential acoustic scale and guidance relating to different ventilation and overheating conditions, for both environmental noise ingress and building services noise; and
- a worked example of the application of the AVO Guide including indicative design constraints for different ventilation and overheating mitigation strategies.

In the case of environmental noise ingress, a two-level assessment procedure is described for the overheating condition. The first level is a site risk assessment based on external noise levels and the assumption that opening windows are the primary means of mitigating overheating. The second level assessment considers the potential for adverse effect on occupants based on internal ambient noise level.

Scope

1.13 The AVO Guide is intended for the consideration of new residential development that will be exposed predominantly to airborne sound from transport sources, and to sound from mechanical services that are serving the dwelling in question. Other sources of noise, such as noise from industrial, commercial or entertainment premises, and of ground-borne noise and vibration, are outside the scope of the AVO Guide. New apartments, flats and houses are the most common type of new residential development. The approach may also be used for other types of residential development such as residential institutions, care homes etc, although it needs to be remembered that some of the occupants of these types of premises can be more sensitive to indoor environmental conditions.

1.14 The AVO Guide seeks to:

- encourage an assessment of noise that recognises the interdependence between the acoustics, ventilation and overheating designs;
- provide a means of assessment to satisfy the need to consider acoustics, ventilation and overheating at the planning stage;
- assist in educating clients, environmental health/planning officers and other stakeholders of the interdependence of design for acoustics, ventilation and overheating.

1.15 Although the policy coverage is limited to England, the approach may be applicable in other parts of the UK.

1.16 This document assumes the user has general knowledge of acoustics and standard terminology. To assist the reader, a glossary of terminology used throughout this document is provided (see Part 4).

1.17 The external air quality environment may also impact on the ventilation strategy adopted, and influence selected locations for any external air inlets. This aspect is outside the scope of the AVO Guide.

1.18 There are other benefits for occupants from opening windows, such as the connection with the outside, sense of fresh air, experience of draughts when overheating, and sense of control over one's environment. Consideration of these factors is also beyond the scope of the AVO Guide.

Good Acoustic Design

1.19 The ProPG emphasises the importance and principles of good acoustic design; the AVO Guide is intended to contribute to the practice of good acoustic design. It is noted that the over-arching aspiration of good acoustic design is that residents may open windows without any adverse acoustic impact (ProPG paragraph 2.33); where a site layout achieves these conditions, the portion of the AVO Guide relating to environmental noise is not applicable.

1.20 In particular, the paragraphs 2.34 – 2.36 of the ProPG indicate that an integrated design approach must be taken to acoustic, ventilation and thermal comfort conditions:

- Paragraph 2.34: "*design the accommodation so that it provides good standards of acoustics, ventilation and thermal comfort*"
- Paragraph 2.36: "*[where a] scheme is reliant on open windows to mitigate overheating, it is also necessary to consider the potential noise impact during the overheating condition. In this case a more detailed assessment of the potential impact on occupants should be provided in the ADS*".

1.21 In addition, paragraph 2.38 says: "*Where mechanical services are used as part of the ventilation or thermal comfort strategy for the scheme, the impact of noise generated by these systems on occupants should also be assessed*".

1.22 The AVO Guide provides a practical method to address these requirements.

1.23 Good acoustic design may be considered as a component of sustainable design. Other aspects of sustainable design include a response to climate change, in terms of aiming to minimise use of energy and other resources.

1.24 The UK's Committee on Climate Change [5] notes that:

"UK homes are not fit for the future ... The quality, design and use of homes across the UK must be improved now to address the challenges of climate change. Doing so will also improve health, wellbeing and comfort...", and *"new homes must be built to be low-carbon, energy and water efficient and climate resilient"*.

1.25 The AVO Guide is essential to fill the gap left between other guidance in achieving comfortable, climate-resilient, sustainable dwellings.

Application of this Guide

1.26 The practical application of the AVO Guide is described in Appendix B. The starting position when considering mitigation of noise impact on new residential development is to apply good acoustic design, site-wide, as described in the ProPG.

1.27 Prior to further developing the design, the acoustician should highlight this to the wider design team/developer. The role of the acoustician is then to assist the team in developing options to suitably control external noise ingress in conjunction with adequate ventilation and mitigation of overheating.

1.28 There is a need to address how:

- The ventilation strategy impacts on the acoustic conditions.
- The strategy for mitigating overheating impacts on the acoustic conditions, and whether a more detailed overheating assessment is required to inform this.

1.29 The guidance in Appendix B aims to:

- help acousticians prepare suitable advice for developers and their design teams so that informed decisions can then be made on how best to progress designs.
- assist local planning authorities to seek evidence of appropriate design details and of post-completion verification, to comply with suitably-worded planning conditions.
- enable a consistent and practical approach to considering noise impact under different ventilation and overheating conditions.
- outline where there is evidence for risks of adverse noise effects and the need for balanced consideration with other aspects of indoor environmental quality when developing the design of new homes.

2 Relevant Legislation and Guidance

2.1 This chapter presents some of the key legislation, policy and guidance relevant to ventilation, overheating and acoustics.

Ventilation

2.2 Guidance on ventilation requirements for dwellings under The Building Regulations is described in Approved Document F ('ADF').

2.3 ADF describes three types of ventilation provision and associated ventilation rates for dwellings. The types of ventilation are summarised in Table 2-1.

2.4 The document then goes on to state that:

"*Ventilation may also provide a means to control thermal comfort but this is not controlled under the Building Regulations*".

However, it is important to differentiate between the need to provide 'purge ventilation' as required occasionally under ADF (i.e. to remove smoke from burnt food etc.); against the provision of ventilation to help control overheating, which is not covered by The Building Regulations.

2.5 ADF provides details of four template '*Systems*' which comply with the ventilation requirements for new dwellings and can be adopted to demonstrate compliance.

2.6 These '*Systems*' are summarised in Table 2-2 and further details are provided in Appendix A. See note to Table 3-1 and notes in paragraphs A.8 and A.9.

Table 2-1 ADF types of ventilation required

Type of ventilation	Definition in ADF	Location/reason for ventilation	Required
Whole Dwelling Ventilation [Note 1]	Whole building ventilation (general ventilation) is nominally continuous ventilation of rooms or spaces at a relatively low rate to dilute and remove pollutants and water vapour not removed by operation of extract ventilation, purge ventilation or infiltration, as well as supplying outdoor air into the building. For an individual dwelling this is referred to as "whole dwelling ventilation".	To provide fresh air to the building and to dilute and disperse residual water vapour not dealt with by extract ventilation as well as removing other pollutants which are released throughout the building.	Continuously
Extract Ventilation	Extract ventilation is the removal of air directly from a space or spaces to the outside. Extract ventilation may be provided by natural means (e.g. by passive stack ventilation) or by mechanical means (e.g. by an extract fan or central system).	From rooms where most water vapour and/or pollutants are released, e.g. due to activities such as cooking or bathing. This is to minimise their spread to the rest of the building.	Continuously or intermittently
Purge Ventilation	Purge ventilation is manually controlled ventilation of rooms or spaces at a relatively high rate to rapidly dilute pollutants and / or water vapour. Purge ventilation may be provided by natural means (e.g. an openable window) or by mechanical means (e.g. a fan).	Throughout the building to aid removal of high concentrations of pollutants and water vapour released from occasional activities such as painting and decorating or accidental releases such as smoke from burnt food or spillage of water.	Occasionally

Note 1 'Whole Dwelling Ventilation' is often confused with 'background ventilation', a term used in the 1995 version of ADF. In the current ADF, the term 'background ventilator' refers to trickle vents.

Table 2-2 ADF template systems

Ventilation system	Provision with ADF system / purpose		
	Whole dwelling ventilation	Extract ventilation	Purge ventilation
System 1: Background ventilators and intermittent extract fans	Background ventilators (trickle vents)	Intermittent extract fans	Typically provided by opening windows
System 2: Passive stack ("natural")	Background ventilators (trickle vents) and passive stack ventilation	Continuous via passive stack	Typically provided by opening windows
System 3: Continuous mechanical extract (MEV)	Continuous mechanical extract – minimum low rate Trickle vents provide inlet air	Continuous mechanical extract – minimum high rate Trickle vents provide inlet air	Typically provided by opening windows
System 4: Continuously mechanical supply and extract with heat recovery (MVHR)	Continuous mechanical supply and extract – minimum low rate	Continuous mechanical supply and extract – minimum high rate	Typically provided by opening windows

Overheating

2.7 There are no specific requirements relating to overheating in The Building Regulations. Both ADF and Approved Document L1A of The Building Regulations briefly mention overheating but do not provide details on what constitutes overheating.

2.8 For the purposes of this document, overheating is taken to mean:

"the phenomenon of excessive or prolonged high temperatures in homes, resulting from internal or external heat gains, which may have adverse effects on the comfort, health or productivity of the occupants." [6]

2.9 TM59 (CIBSE: Design methodology for the assessment of overheating risk in homes) sets out a methodology for predicting temperatures inside dwellings and provides overheating compliance criteria which are discussed in more detail in Appendix A.

2.10 It also provides a standardised approach to predicting overheating using dynamic thermal modelling. TM59 acknowledges that the methodology is necessarily prescriptive to enable it to be consistently applied.

2.11 To undertake the assessment, information on the heat loads, thermal properties of the building construction, weather data and methods of providing ventilation are required.

2.12 Alternative assessment methods such as the Passive House Planning Package [7] (PHPP) may also be suitable for assessing overheating if considered appropriate for the specific project.

2.13 Developments will normally (but not always) require additional ventilation (above ADF whole dwelling ventilation provisions) in order to mitigate overheating. Where an overheating assessment is undertaken, it should provide details as to the duration and rate of any additional ventilation required to meet overheating compliance criteria. Where this additional ventilation is provided passively, the overheating assessment should also provide information about the required size of façade openings.

2.14 See Appendix A2 for a list of output data from an overheating assessment that may be necessary to undertake the acoustic assessment.

2.15 The *Overheating Risk – Early Stage Tool* [8] produced by the Good Homes Alliance may be used to evaluate overheating risk at the stage that the acoustic assessment is carried out.

2.16 An overheating assessment might not always be undertaken for a project and without this information it is difficult to identify noise impacts that may occur during the overheating condition.

Cooling strategies

2.17 A range of design measures can be incorporated into a residential building to control / reduce overheating. A number of these are identified in the London Plan 'Cooling Hierarchy'.

2.18 The London Plan Policy [9] encourages the design of places and spaces to avoid overheating and excessive heat generation, and to reduce overheating due to the impacts of climate change. Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the cooling hierarchy identified. The cooling hierarchy seeks to reduce any potential overheating and also the need to cool a building through active measures. Air conditioning or comfort cooling systems are a very resource intensive form of active cooling, increasing energy use.

2.19 In accordance with sustainable design and construction principles, development proposals should, amongst other things, maximise opportunities to orientate buildings and streets to minimise summer and maximise winter solar gains; use trees and other shading; increase green areas in the envelope of a building, including its roof and environs; and maximise natural ventilation. These sustainable design principles mirror good acoustic design as described in the ProPG. More information is available in paragraph A.19.

2.20 To minimise the risk of overheating in most residential buildings it is normally necessary to use some form of cooling system. The three main methods of providing additional cooling are:

- Passive ventilative cooling – Introducing external air to a space to provide a cooling effect without the use of fans. The most common method is to use open windows but other façade openings can also be used. Note that trickle vents do not enable sufficient airflow to have a significant cooling effect.
- Mechanical ventilative cooling – Using fans to introduce external air to a space to provide a cooling effect. Due to the airflow required, this type of system often involves significant plant and duct size requirements.
- Comfort cooling – Using a mechanical system to cool the air within a space to achieve a user-defined setpoint. This type of system will require some form of mechanical device to cool the air, such as a fan coil unit (FCU).

2.21 A more recently developed alternative to the systems above is a tempered fresh air system. These systems add a small amount of cooling to the whole dwelling ventilation supply system (e.g. to the MVHR). This provides a reduced temperature fresh air supply which can provide some cooling to a space. Unlike comfort cooling, these systems are not designed to achieve a specific temperature in a space.

Acoustics

Current planning policy, regulations and guidance

2.22 Noise management is a devolved issue. This means that, although there are many similarities, different policies and regulations apply in England, Wales, Scotland and Northern Ireland. In England, the overarching policy on noise management is set out in the Noise Policy Statement for England [10] ('NPSE'). The NPSE contains the vision of promoting good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development.

2.23 The NPSE also contains three aims:

"Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- *avoid significant adverse impacts on health and quality of life;*
- *mitigate and minimise adverse impacts on health and quality of life; and*
- *where possible, contribute to the improvement of health and quality of life."*

2.24 In the explanatory note to the NPSE, reference is made to concepts from toxicology that had previously been applied to noise impacts (e.g. by the World Health Organisation). They are:

- No Observed Effect Level (NOEL) which is the level below which no effect can be detected;
- Lowest Observed Adverse Effect Level (LOAEL) which is the level above which adverse effects on health and quality of life can be detected.

2.25 The explanatory note goes on to introduce the concept of a Significant Observed Adverse Effect Level (SOAEL) which is the level above which significant adverse effects on health and quality of life occur.

2.26 Although for both LOAEL and SOAEL, the word 'level' is used, this does not mean that the impact can only be described as an individual noise level or exposure. It could also include factors such as the number of times the noise impact occurs, the duration of the impact, and the time of day the impact occurs. Thus, depending on the circumstance, the noise impact could be managed by reducing how often it occurs rather than just reducing the level of impact when it does occur.

2.27 The NPSE states that it is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times.

2.28 The explanatory note confirms that the first aim of the NPSE states that significant adverse effects on health and quality of life should be avoided while taking account of the guiding principles of sustainable development. The second aim refers to the situation where the impact lies somewhere between LOAEL and SOAEL. To meet this aim requires that all reasonable steps should be taken to mitigate and minimise adverse effects on health and quality of life while also taking into account the guiding principles of sustainable development. The explanatory note goes on to state that this does not mean that such adverse effects cannot occur.

2.29 With regard to land-use planning in England, the relevant policy is primarily set out in the National Planning Policy Framework [11] ('NPPF').

2.30 For noise, the NPPF states that planning policies and decisions should:

"Ensure that new development is appropriate for its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development. In so doing they should:

- *Mitigate and reduce to a minimum potential adverse impacts resulting from noise from new development – and avoid noise giving rise to significant adverse impacts on health and quality of life (See Explanatory Note to the Noise Policy Statement for England)"*

2.31 The NPPF also states:

"Planning policies and decisions should ensure that new development can be integrated effectively with existing businesses and community facilities (such as places of worship, pubs, music venues and sports clubs). Existing businesses and facilities should not have unreasonable restrictions placed on them as a result of development permitted after they were established. Where the operation of an existing business or community facility could have a significant adverse effect on new development (including changes of use) in its vicinity, the applicant (or 'agent of change') should be required to provide suitable mitigation before the development has been completed."

2.32 Elsewhere the NPPF states that:

"Planning policies and decisions should contribute to and enhance the natural and local environment by: .....

preventing new and existing development from contributing to, being put at unacceptable risk from, or being adversely affected by, unacceptable levels of soil, air, water or noise pollution or land instability. Development should, wherever possible, help to improve local environmental conditions such as air and water quality, taking into account relevant information such as river basin management plans."

2.33 The implementation of the policies in the NPPF is supported by a suite of web-based guidance, including the Planning Practice Guidance on Noise [12] ('PPG(N)'). It includes a table which summarises the noise exposure hierarchy based on the likely average response. The Noise Exposure Hierarchy is reproduced in Table 2-3.

Table 2-3 Summary of noise exposure hierarchy based on the likely average response (from PPG(N))

Perception	Examples of Outcomes	Increasing Effect Level	Action
Not present	No Effect	No Observed Effect	No specific measures required
Present and not intrusive	Noise can be heard, but does not cause any change in behaviour or attitude. Can slightly affect the acoustic character of the area but not such that there is a perceived change in the quality of life.	No Observed Adverse Effect	No specific measures required
		Lowest Observed Adverse Effect Level	
Present and intrusive	Noise can be heard and causes small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; where there is no alternative ventilation, having to close windows for some of the time because of the noise. Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a perceived change in the quality of life.	Observed Adverse Effect	Mitigate and reduce to a minimum
		Significant Observed Adverse Effect Level	
Present and disruptive	The noise causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion; where there is no alternative ventilation, having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.	Significant Observed Adverse Effect	Avoid [Note 1]
Present and very disruptive	Extensive and regular changes in behaviour and/or an inability to mitigate effect of noise leading to psychological stress or physiological effects, e.g. regular sleep deprivation/awakening; loss of appetite, significant, medically definable harm, e.g. auditory and non-auditory.	Unacceptable Adverse Effect	Prevent

2.34 The PPG(N) makes it clear that noise can override other planning concerns, where justified, although it is important to look at noise in the context of the wider characteristics of a development proposal, its likely users and its surroundings, as these can have an important effect on whether noise is likely to pose a concern. [See Footnote]

2.35 In clarifying how the term 'the context of Government policy on sustainable development' should be interpreted, some assistance can be obtained from the Government decision letter associated with the Thames Tideway Tunnel project. In that letter, it is stated that:

"The National Planning Policy Framework, the National Planning Practice Guidance on noise and the Noise Policy Statement for England are all clear that noise management should be determined in the context of sustainable development including the environmental, economic and social benefits of the proposal."

2.36 The PPG(N) states that local authority planning policies can include noise standards which apply to various forms of proposed development and locations in their area. The PPG(N), however, states that care should be taken to avoid these standards from being applied as rigid thresholds as specific circumstances may justify some variation being allowed.

2.37 Furthermore, as mentioned above, the explanatory note to the NPSE states that the policy does not mean that adverse effects arising from noise cannot occur.

2.38 Not all development is required formally to seek planning consent from the relevant Local Planning Authority (LPA). Some proposals fall under the terms of Permitted Development Rights (PDR). The definition of those developments which can be promulgated under PDR is set out in Statutory Instrument 2015/596. This order was amended by SI 2016/332 requiring that, in the case of a change of use of offices to dwelling houses:

"the developer must apply to the LPA for a determination as to whether the prior approval of the authority will be required as to....impacts of noise from commercial premises on the intended occupiers of the development."

2.39 In SI 2016/332, commercial premises are defined as:

"any premises normally used for the purpose of any commercial or industrial undertaking which existed on the date of the application, and includes any premises licensed under the Licensing Act 2003 or any other place of public entertainment."

2.40 This definition means that there is no formal requirement for a developer to determine whether prior approval is needed regarding any noise from transportation sources affecting such a change of use. However, it may be in the interests of the developer to consider the transportation noise impacts and the associated ventilation/ overheating issues with such a change of use.

2.41 For Nationally Significant Infrastructure Projects promulgated under the Planning Act 2008, the relevant policy is set out in the topic specific National Policy Statements (NPS). For noise, the policies in the various NPSs reflect the NPSE.

Guidance on the effects of noise

2.42 As indicated in the NPSE, objective values associated with SOAEL will depend on the specific circumstances. More information can be derived for values associated with LOAEL from existing guidance. Relevant examples are set out below.

BS 8233:2014 [13]

2.43 This standard provides a wide range of guidance regarding sound insulation and noise reduction in buildings. In the Foreword, it states that:

"As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it."

2.44 BS 8233:2014 states that,

"for steady external noise sources, it is desirable that the internal ambient noise level does not exceed the guidelines values in Table 4."

Footnote - When stating that noise can override other planning concerns, the original version of the PPG(N) stated that neither the NPSE nor the NPPF expects noise to be considered in isolation, separately from the economic, social and other environmental dimensions of proposed development. This is still the case.

2.45 Table 4 from BS 8233:2014 is reproduced in Table 2-4. Some local authorities have used these values to represent LOAEL as far as applying the policy in the NPPF and NPSE is concerned for that situation.

Table 2-4 Desirable indoor ambient noise levels for dwellings (reproduced from Table 4 of BS 8233:2014)

Activity	Location	07:00 to 23:00 ($L_{Aeq,16hr}$)	23:00 to 07:00 ($L_{Aeq,8h}$)
Resting	Living room	35 dB	
Dining	Dining room/area	40 dB	
Sleeping (daytime resting)	Bedroom	35 dB	30 dB

2.46 These levels are accompanied by various notes including:

- The levels are based on existing guidelines issued by the World Health Organisation [14] and assume normal diurnal fluctuations in external noise;
- The levels are based on annual average data and do not have to be achieved in all circumstances. For example, it is normal to exclude occasional events such as fireworks night and New Year's Eve;
- If relying on closed windows to meet the guide values, there needs to be an appropriate alternative ventilation that does not compromise the façade insulation or resulting noise level. If applicable, any room should have adequate ventilation (e.g. trickle ventilators should be open) during assessment;
- Where a development is considered necessary or desirable, the levels in Table 2-4 may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

2.47 BS 8233:2014 also sets out the maximum steady noise levels that can permit reliable speech communication. These are reproduced in Table 2-5.

Table 2-5 Maximum steady noise levels for reliable speech communication (reproduced from Table 7 of BS 8233:2014)

Distances between talker and listener (m)	Noise Level (dB(A))	
	Normal Voice	Raised Voice
1	57	62
2	51	56
4	45	50
8	39	44

2.48 The values from this table can be used to estimate the extent of the impact on speech communication from the internal noise levels.

ProPG: Planning & Noise 2017

2.49 The ProPG was prepared in 2017 by a group comprising members representing the Chartered Institute of Environmental Health (CIEH), the Institute of Acoustics (IOA) and the Association of Noise Consultants (ANC).

2.50 This document provides technical guidance on how to assess the impact of transportation noise on new residential development. It is designed to assist with the implementation of existing planning policy.

2.51 The ProPG promotes the use of 'Good Acoustic Design' as a primary noise management measure to optimise the acoustic environment that would be experienced by the residents. It recognises that there will be some situations where there would be a need to rely on closed windows and associated ventilation in order to achieve the desired acoustic outcome. In that situation it states that:

"special care must be taken to design the accommodation so that it provides good standards of acoustics, ventilation and thermal comfort without unduly compromising other aspects of the living environment. In such circumstances, internal noise levels can be assessed with windows closed but with any façade openings used to provide "whole dwelling ventilation" in accordance with Building Regulations Approved Document F (e.g. trickle ventilators)."

2.52 The document also states that:

"It should also be noted that the internal noise level guidelines are generally not applicable under "purge ventilation" conditions as defined by Building Regulations Approved Document F, as this should only occur occasionally (e.g. to remove odour from painting and decorating or from burnt food)."

2.53 The document continues

"In addition to providing purge ventilation, open windows can also be used to mitigate overheating. Therefore, should the LPA accept a scheme is to be assessed with windows closed, but this scheme is reliant on open windows to mitigate overheating, it is also necessary to consider the potential noise impact during the overheating condition. In this case a more detailed assessment of the potential impact on occupants should |be provided in the ADS [Acoustic Design Statement]*."*

2.54 The aim of this document is to assist the acoustician making this more detailed assessment.

2.55 ProPG concludes that:

"It should be noted that overheating issues will vary across the country and any specific design solutions will need to be developed alongside advice from energy consultants."

2.56 The ProPG is referenced in the PPG(N) as a document published by other organisations which may be of assistance.

WHO Environmental Noise Guidelines for the European Region [15] (WHO 2018)

2.57 This document has been produced with two key objectives:

- *"In the general population exposed to environmental noise, what is the exposure–response relationship between exposure to environmental noise (reported as various indicators) and the proportion of people with a validated measure of health outcome...*
- *In the general population exposed to environmental noise, are interventions effective in reducing exposure to and/or health outcomes from environmental noise?"*

2.58 The document also provides recommendations regarding external noise exposures that should be achieved to protect human health.

2.59 The noise sources covered by these guidelines are road traffic, rail traffic, aircraft and wind turbines. Recommendations are also provided regarding leisure noise.

2.60 The document is clear that the recommended values are not LOAELs and that meeting the recommended values would not protect every person affected. The document does, however, state that the *"GDG [Guideline Design Group of WHO] stresses that the aim of the current guidelines is to define an exposure level at which effects certainly begin"*.

2.61 The document also states that

"The current environmental noise guidelines for the European Region supersede the CNG from 1999 [WHO 1999]. Nevertheless, the GDG recommends that all CNG indoor guideline values and any values not covered by the current guidelines (such as industrial noise and shopping areas) should remain valid. Furthermore, the current guidelines complement the NNG from 2009."

WHO Night Noise Guidelines for Europe [16]

2.62 Within these guidelines it is stated that $L_{night,outside}$ 40 dB is equivalent to the LOAEL for night noise.

2.63 The guidelines also suggest that $L_{night,outside}$ above 55 dB represents a situation that is considered increasingly dangerous for public health.

Individual Noise Events

2.64 The WHO Night Noise Guidelines (2009) state that:

"The 1999 guidelines are based on studies carried out up to 1995 (and a few meta-analyses some years later). Important new studies (Passchier-Vermeer et al., 2002; Basner et al., 2004) have become available since then, together with new insights into normal and disturbed sleep. New information has made more precise assessment of exposure-effect relationship. The thresholds are now known to be lower than L_{Amax} of 45 dB for a number of effects."

2.65 More recent research [17, 18], some of which is contained within ProPG, has examined the probability of additional awakenings caused by individual noise events.

2.66 This approach combines the number of events and the maximum level of those events inside the bedroom. It may be possible to use this approach to evaluate a SOAEL in relation to individual noise events, albeit in the context of the development under consideration.

Dose Response Relationship

2.67 As required by policy, any acoustic guidelines should not be regarded as fixed thresholds. In reality, there is a continuous relationship between the noise level and the resulting effects. WHO 2018 present dose-response relationships between environmental noise and effects on humans including annoyance, sleep disturbance and other health effects derived from systematic reviews of the evidence.

All Party Parliamentary Group for Healthy Homes and Buildings – White Paper (October 2018) [19]

2.68 The publication of this document followed the gathering of evidence from various sources including the Institute of Acoustics and the HEMAC [Health Effects of Modern Airtight Construction network] Noise Group. One of the recommendations in the white paper states:

"Maximising the occupant's health and wellbeing must be placed at the centre of housing and building design and a holistic approach should be taken including elements of safety, space, energy efficiency, ventilation, heating, noise, air quality and lighting."

3 Internal Ambient Noise Level Guidelines

3.1 This chapter presents guidance regarding indoor ambient noise levels in new residential development that will be exposed predominantly to airborne sound from transport sources, and to sound from mechanical systems serving the development.

3.2 The contribution to internal noise levels from transport sources and from mechanical services are considered separately and independently, because there is evidence [20] that occupants have a different tolerance to each. The next Section considers transport noise sources and the subsequent Section considers mechanical services noise.

3.3 Where there are other requirements to manage the total internal noise exposure there will be a need to consider how the level due to transportation sources combines with that due to mechanical services and there may be a requirement to set separate lower limits for each component.

3.4 For both sources of noise, the guidance makes a clear distinction between provisions for fresh air to achieve whole dwelling ventilation rates ('ADF ventilation condition'), and provisions for ventilative cooling to mitigate overheating ('overheating condition').

3.5 In terms of noise effect, the important distinction between these two situations is that the ADF ventilation condition applies for the entire time whereas the overheating condition applies only for part of the time.

3.6 In the case of noise from mechanical services, the guidance for the overheating condition makes reference to existing guidance documents. In the case of noise from transport sources, there is no appropriate existing guidance for the overheating condition. Instead, the guidance presented here considers the suitability of higher internal ambient noise levels in terms of the effect on occupants.

3.7 In the case of noise from transport sources, a two level assessment procedure is described for the overheating condition as summarised in Figure 3-1. Level 1 is a site risk assessment based on external noise levels and the assumption that opening windows are the primary means of mitigating overheating. Based on the Level 1 indication of risk, a subsequent Level 2 assessment may be required. The Level 2 assessment considers the potential for adverse effect on occupants based on internal ambient noise level.

3.8 Where Tables 3-2 and 3-3 indicate different categories, these should not be regarded as fixed thresholds and reference can also be made to relevant dose-response relationships [15, 18].

Internal Ambient Noise Levels due to Transport Noise Sources

Introduction

3.9 It is suggested here that the desirable internal noise standards within Table 4 of BS 8233:2014 should be achieved when providing adequate ventilation as defined by ADF whole dwelling ventilation. However, it is considered reasonable to allow higher levels of internal ambient noise from transport sources when higher rates of ventilation are required in relation to the overheating condition.

3.10 The basis for this is that the overheating condition occurs for only part of the time. During this period, occupants may accept a trade-off between acoustic and thermal conditions, given that they have some control over their environment. In other words, occupants may, at their own discretion, be more willing to accept higher short-term noise levels in order to achieve better thermal comfort. The importance of control is relevant to daytime exposure, but not to night time exposure where the consideration is sleep disturbance.

3.11 It is important to note that there is no specific research available to support this view regarding human response to combined exposure to heat and noise. However, the notion that control over one's environment moderates the response to exposure is well established in the field of thermal comfort, and underpins the adaptive thermal comfort model.

3.12 The suitability of higher internal ambient noise levels in the case of the overheating condition has been considered in terms of various effects such as:

- Daytime annoyance
- Daytime interference with activities (conversation/telephone)
- Night-time sleep disturbance (using average noise level parameters such as L_{Aeq})
- Night-time sleep disturbance (using parameters for individual noise events L_{Amax} /SEL).

3.13 The values in Table 3-2 are based on the assumption of a 13 dB difference between external free-field noise levels and internal ambient noise levels. Refer to paragraph 3.24 for further discussion.

3.14 Table 3-2 suggests that a Level 2 assessment is not required in situations where it is expected that reasonable internal conditions, described in ProPG as BS 8233 levels relaxed by up to 5 dB, will be achieved.

3.15 For the daytime period, the upper category in Table 3-3 is defined on the basis that $L_{Aeq,T}$ 50 dB represents the upper end of the range for reliable speech communication.

3.16 For the night-time period, the upper category in Table 3-3 is defined with reference to the WHO Night Noise guidelines, which state that for external levels above $L_{Aeq,T}$ 55 dB:

"*adverse health effects occur frequently and a sizeable proportion of the population is highly annoyed and sleep-disturbed*".

3.17 The individual noise event L_{max} value associated with the upper category in Table 3-3 refers to the level that has been shown in Basner et al [17] to result in longer duration awakenings that are more likely to be remembered the next day. The paper states that *"from a medical point of view, recalled awakenings …should be prevented as much as possible"*. It is noted that the paper uses the $L_{AS,max}$ metric, whereas $L_{AF,max}$ is used here. Given that $L_{AF,max}$ is typically between 1dB and 4dB higher than $L_{AS,max}$, this is a conservative amendment. Refer to references [1, 17, 18, 22] for further guidance regarding individual noise events.

3.18 In the case of the overheating condition, the effect of increased internal ambient noise from external noise sources will depend both on the absolute noise level and the amount of time for which the overheating condition occurs. A good design process should therefore, as a priority, seek to minimise heat gains thereby reducing the amount and duration of ventilation required to control overheating and the consequential effect from increased ingress of noise.

3.19 No quantitative guidance regarding the combined effect of level and duration for the overheating condition is included in the current version of this document. However, the situation is summarised qualitatively in Figure 3-2 and also addressed in the worked examples included in Appendix B.

3.20 Appropriate research work is urgently needed to better inform the guidance for the overheating condition.

Approved Document F (ADF) Ventilation Condition

3.21 Recommendations for desirable internal ambient noise levels for ADF ventilation conditions are set out in Table 3-1.

Overheating Condition

3.22 A two-level assessment procedure is recommended to estimate the potential impact on occupants in the case of the overheating condition. Refer to Figure 3-1.

3.23 The Level 1 site risk assessment is based on external free-field noise levels and the assumed scenario where a partially open window is used to mitigate overheating. The Level 1 assessment is sufficient for developments on 'Negligible' risk sites (as defined by Table 3-2). The Level 2 assessment is recommended for 'High' risk sites. For 'Low' and 'Medium' risk sites, a Level 2 assessment can optionally be undertaken to give more confidence regarding the suitability of internal noise conditions. This may be particularly appropriate for sites in the 'Medium' risk category.

3.24 For the purposes of the Level 1 assessment, it is assumed that a partially open window will provide an outside-to-inside level difference of 13 dB. This level difference is considered representative of typical domestic rooms with simple façade openings of around 2% of the floor area. Refer to Table B-4 and Appendix C for further information.

3.25 The outside-to-inside level difference for a partially open window is related to the window opening area, type and orientation in respect of directional noise sources. This is likely to differ from project-to-project and would require due consideration as part of a Level 2 assessment. A 13 dB correction ought not to be automatically taken as appropriate for all cases.

3.26 The Level 2 assessment suggests that assessment of the adverse effect from noise exposure should include an estimate of how frequently and for what duration the overheating condition occurs. Reference should be made to Figure 3-2 and the worked examples included in Appendix B.

3.27 The noise levels suggested in Tables 3-2 and 3-3 assume a steady road traffic noise source but may be adapted for other types of transport by taking account of the differing responses to different transport sources.

Table 3-1 Indoor Ambient Noise Levels resulting from transport noise sources - ADF ventilation condition

Ventilation condition	Operational condition of System	Desirable internal ambient noise level from transport noise sources
Part F - Whole dwelling ventilation	Systems 1 & 2: Background ('trickle') ventilators open to provide whole dwelling ventilation in the winter period. Additional ventilation required at other times of the year – windows are assumed to be ajar for assessment [Note 2].	Guideline values from Table 4 of BS 8233:2014.
	System 3: Continuous mechanical extract with background ('trickle') ventilators open [Note 2].	
	System 4: Continuous mechanical supply and extract with heat recovery (MVHR) – no trickle vents required.	
Part F – Purge Ventilation [Note 1]	Option 1: Opening external window(s) meeting requirements described in Appendix B of Part F.	No specific acoustic criterion needs to be met in a room using purge ventilation for the purpose of rapidly diluting indoor pollutants.
	Option 2: Manually controlled fan extracting 4 air changes per hour.	

Note 1 ADF has a clearly defined objective definition of purge ventilation to rapidly dilute pollutants and/or water vapour for indoor air quality purposes. This is defined as 4 air changes per hour in Appendix A of the Approved Document. This is used for occasional activities such as painting and decorating or accidental releases such as smoke from burnt food or spillage of water. Provisions for purge ventilation can also be used to improve thermal comfort. This is not controlled under the Building Regulations. Purge ventilation may form one part of a design strategy to control the risk of overheating. The level of ventilation required to control overheating will depend on the details of the individual room and dwelling and can be different than the 4 air changes per hour required to dilute pollutants/water vapour. See Table B-4. When using provisions for purge ventilation (eg opening windows) to mitigate overheating, refer to Tables 3-2 and 3-3.

Note 2 For Systems 1 and 2, the background ventilators are sized for the winter period as described in Tables 5.2a, b of ADF. For Systems 3 and 4, the systems are sized for the winter period. If additional ventilation is required to control excess humidity in warmer months, appropriate consideration should be given to the resulting internal ambient noise levels under this condition.

Figure 3-1 Two-level noise assessment procedure - overheating condition

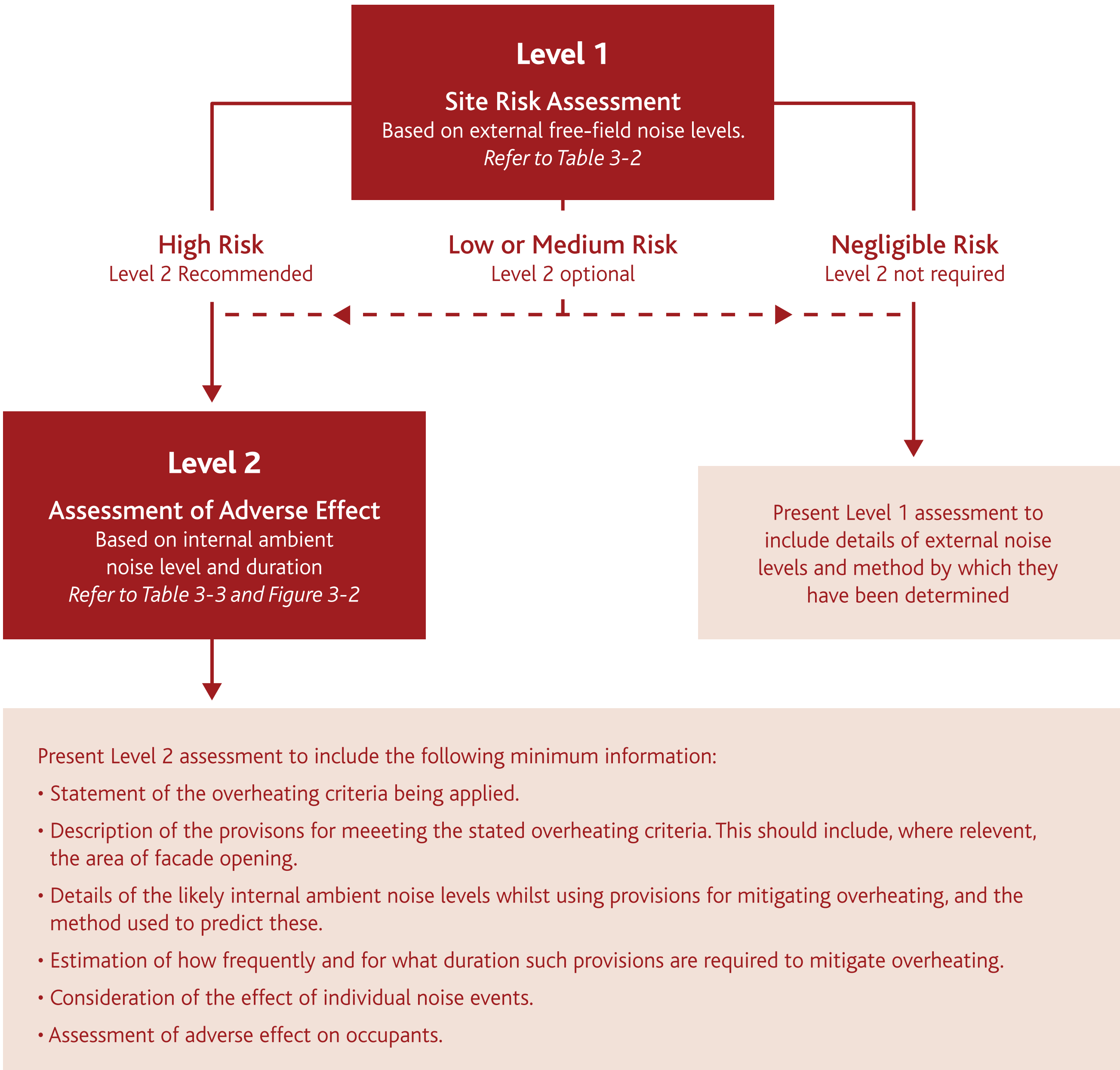
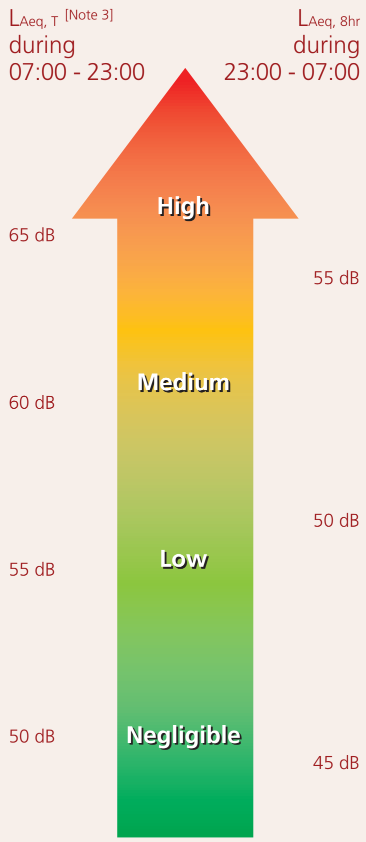


Table 3-2 Guidance for Level 1 site risk assessment of noise from transport noise sources [Note 1] relating to overheating condition

Risk category for Level 1 assessment [Note 5]	Potential Effect without Mitigation	Recommendation for Level 2 assessment
	Increasing risk of adverse effect	Recommended
		Optional
	Use of opening windows as primary means of mitigating overheating is not likely to result in adverse effect	Not required

Note 1 The noise levels suggested assume a steady road traffic noise source but may be adapted for other types of transport. All levels are external free-field noise levels.

Note 2 The values presented in this table should not be regarded as fixed thresholds and reference can also be made to relevant dose-response relationships, [15, 17].

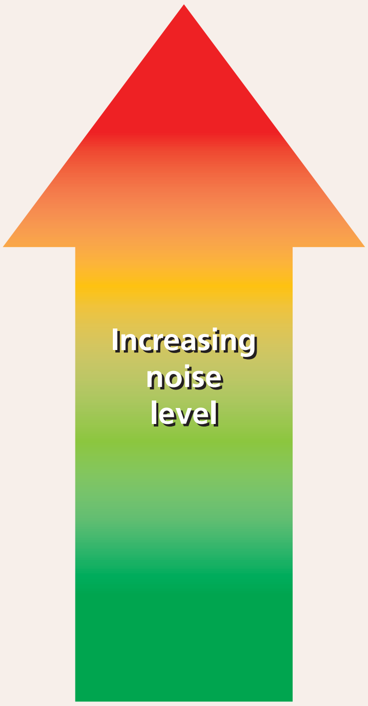
Note 3 A decision must be made regarding the appropriate averaging period to use. The averaging period should reflect the nature of the noise source, the occupancy profile and times at which overheating might be likely to occur. Further guidance can be found within the 2014 IEMA Guidelines [23].

Note 4 Refer also to references [1, 17, 18, 22] for further guidance regarding individual noise events. Where 78dB LAFmax is normally exceeded during the night-time period (23:00-07:00), a Level 2 assessment is recommended.

Note 5 The risk of an adverse effect occurring will also depend on how frequently and for what duration the overheating condition occurs. Refer to Figure 3-2.

Note 6 To evaluate the risk category for a dwelling, all three aspects of external noise exposure (i.e. daytime, night-time and individual noise events) should be evaluated. The highest risk category for any of the three aspects applies.

Table 3-3 Guidance for Level 2 assessment of noise from transport noise sources[Note 1] relating to overheating condition

Internal ambient noise level [Note 2]			Examples of Outcomes [Note 5]	
$L_{Aeq,T}$ [Note 3] during 07:00 – 23:00 [Note 6]	$L_{Aeq,\,8h}$ during 23:00 – 07:00	Individual noise events during 23:00 – 07:00 [Note 4]		
> 50 dB	> 42 dB	Normally exceeds 65 dB $L_{AF,max}$	Noise causes a material change in behaviour e.g. having to keep windows closed most of the time	Avoiding certain activities during periods of intrusion. Having to keep windows closed most of the time because of the noise. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.
			Increasing likelihood of impact on reliable speech communication during the day or sleep disturbance at night	At higher noise levels, more significant behavioural change is expected and may only be considered suitable if occurring for limited periods. As noise levels increase, small behaviour changes are expected e.g. turning up the volume on the television; speaking a little more loudly; having to close windows for certain activities, for example ones which require a high level of concentration. Potential for some reported sleep disturbance. Affects the acoustic environment inside the dwelling such that there is a perceived change in quality of life. At lower noise levels, limited behavioural change is expected unless conditions are prevalent for most of the time. [Note 8]
≤ 35 dB	≤ 30 dB	Do not normally exceed $L_{AF,max}$ 45 dB more than 10 times a night	Noise can be heard, but does not cause any change in behaviour	Noise can be heard, but does not cause any change in behaviour, attitude, or other physiological response[Note 9]. Can slightly affect the acoustic character of the area but not such that there is a perceived change in the quality of life.

Note 1 The noise levels suggested in Tables 3-2 and 3-3 assume a steady road traffic noise source but may be adapted for other types of transport.

Note 2 The values presented in this table should not be regarded as fixed thresholds and reference can also be made to relevant dose-response relationships such as those described in a DEFRA 2014 study [15, 21, 22]. With the exception of individual noise events, the references [15,21] are based on evidence drawn from *external* noise levels. There is currently very little robust evidence linking *internal* averaged noise levels with health outcomes and occupant behaviour. Internal ambient noise levels would normally be considered for living rooms and bedrooms during the daytime. At night, the levels would normally only be applicable to bedrooms.

Note 3 A decision must be made regarding the appropriate averaging period to use. The averaging period should reflect the nature of the noise source, the occupancy profile and times at which overheating might be likely to occur. Further guidance can be found within the 2014 IEMA Guidelines.

Note 4 Refer to references [1, 17, 18, 22] for further guidance regarding individual noise events. The $L_{AF,max}$ indicator associated with the upper category is intended for road traffic; it may be more appropriate to use the "one additional noise-induced awakening" method for noise from rail traffic or aircraft.

Note 5 The potential for adverse effect will also depend on how frequently and for what duration the overheating condition occurs. Refer to Figure 3-2.

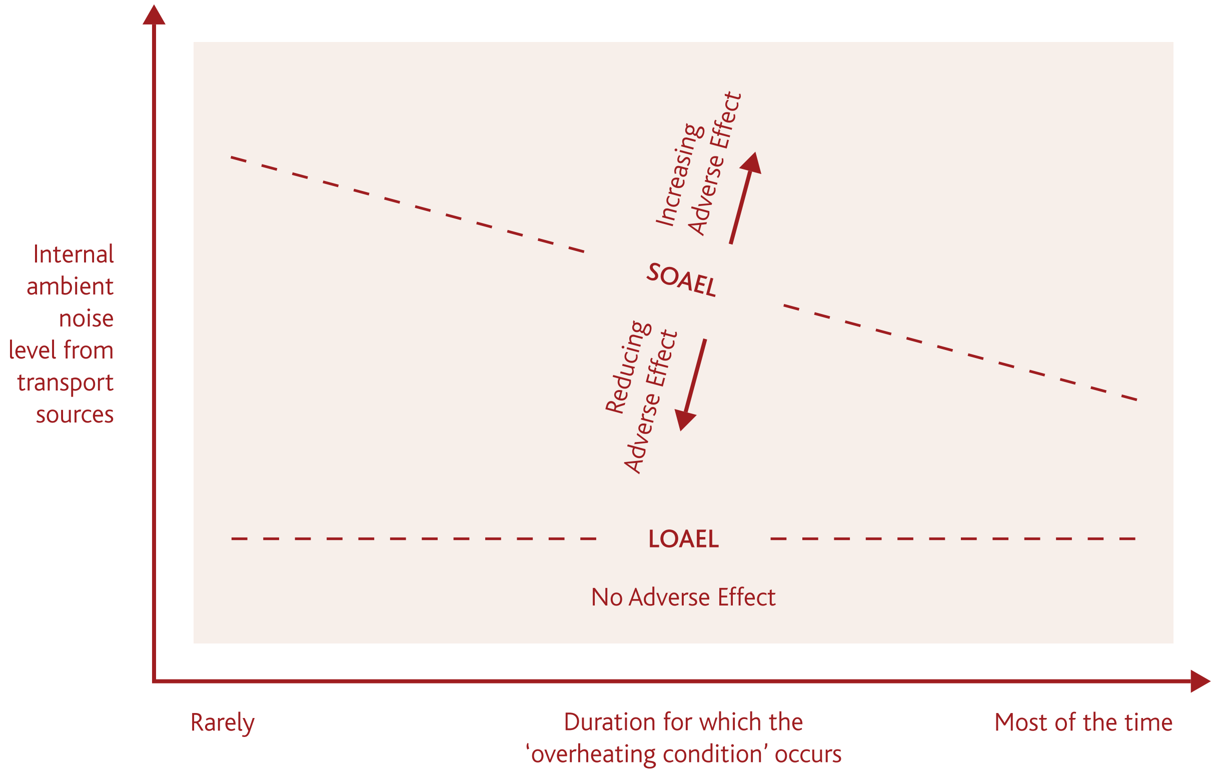
Note 6 The daytime levels presented in this table may not be appropriate for residential care homes or other situations where conditions for daytime resting are known to be of particular importance.

Note 7 When evaluating the potential for adverse effect, all three aspects of noise exposure (i.e. daytime, night-time and individual noise events) should be evaluated.

Note 8 BS 8233 states that where development is considered necessary or desirable, the internal target levels may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

Note 9 It is known that physiological responses do occur at lower levels of L_{AFmax} than 45 dB.

Figure 3-2 Qualitative guidance on combined effect of internal ambient noise level and duration for the overheating situation



Internal Ambient Noise Levels from Mechanical Services

Introduction

3.28 Human hearing response, annoyance and the health-related effects of noise are of primary concern when considering building services noise in dwellings. Research [20], [24], [25], [26], [27], [28] demonstrates that occupants will adjust mechanical ventilation systems to a level of noise that is tolerable, or disable it entirely. Either of these actions result in insufficient ventilation; the adverse effects of this include poor indoor air quality for the occupants in airtight dwellings.

3.29 While these studies are examples of how occupants respond to the noise from the equipment, the actual noise levels or the character of the noise that people may tolerate are not well documented in the literature. The guidance values in this chapter assume steady noise levels without distracting characteristics.

3.30 ADF suggests that to ensure good acoustic conditions, the noise levels within living rooms and bedrooms should not exceed $L_{Aeq,T}$ 30 dB for mechanical systems operating at the whole dwelling ventilation rate. It is included as additional commentary within the document and is not a mandatory requirement. This originates from the BS 8233:1999 [29] noise limits for noise ingress and the levels for living rooms are lower than those within CIBSE Guide A 2015 [30] and Sound Control for Homes [31] guidance.

3.31 Evidence [20] indicates that *"a more prudent limit for mechanical services noise around 24 – 26 dB(A) is likely to be required to prevent an adverse reaction from most occupants while falling asleep."*

3.32 A summary of the proposed noise levels from various guidance is provided in Appendix A.

3.33 There is very little information relating to mechanical ventilative cooling. Comfort cooling is more commonly used and its operation can be complex, with a combination of cooling options with associated airflow rates and noise levels.

Approved Document F (ADF) Ventilation Condition

3.34 Recommendations for desirable internal ambient noise levels for ADF ventilation conditions are set out in Table 3-4.

Table 3-4 Indoor ambient noise levels from mechanical services - ADF ventilation condition

Ventilation condition	Possible system or design solution	Desirable internal ambient noise levels from mechanical services
ADF – Whole Dwelling Ventilation	System 3: Continuous mechanical extract (MEV), minimum low ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum low ventilation rates	Bedrooms ≤ L_{Aeq} 26 or 30 dB [Note 1] Living Rooms ≤ L_{Aeq} 30 dB
ADF – Extract Ventilation	System 1: Intermittent extract fans System 3: Continuous mechanical extract (MEV), minimum high ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum high ventilation rates	Bedrooms ≤ L_{Aeq} 26 or 30 dB Living / Dining Rooms ≤ L_{Aeq} 35 dB Bathroom / WC / Kitchen ≤ L_{Aeq} 45 dB
ADF – Purge Ventilation	Manually controlled fan exchanging a minimum 4 air changes per hour	No desirable noise levels are currently proposed based on the lack of evidence of acceptable noise levels when providing purge ventilation for the purpose of rapidly diluting indoor pollutants.

Note 1 A lower level may be more appropriate; refer to paragraph 3.31.

Overheating Condition

3.35 The use of mechanical systems to control overheating could include systems which provide ambient air at high ventilation rates (ventilative cooling) or systems which provide cooled air, commonly referred to as comfort cooling systems. Refer to paragraphs 2.20 and 2.21 for further details.

3.36 These systems would normally be occupant controlled, but there may be options for automation.

3.37 Recommendations for desirable internal ambient noise levels for overheating conditions are set out in Table 3-5.

Table 3-5 Indoor ambient noise levels from mechanical services - Overheating condition

Possible system or design solution	Desirable upper internal ambient noise levels from mechanical services
Ventilative cooling or Comfort cooling	Bedrooms L_{Aeq} 30 (± 5) dB Living / Dining Rooms L_{Aeq} 35 (± 5) dB

3.38 The desirable noise levels shown in Table 3-5 are based on systems which are operated to meet the design conditions to control overheating.

3.39 Section 1.10.10 of CIBSE Guide A 2015 states that the values are only a guide and that:

"Higher or lower values may be appropriate based on economics, space use, user needs etc."

3.40 It goes on to state that a range of +/- 5 dB may be acceptable depending on the particular situation.

3.41 The duration, how frequently they occur, degree of occupant control and magnitude of the noise levels associated with the overheating condition should be taken into consideration when establishing suitable noise levels.

3.42 Higher noise levels, e.g. 5 or 10 dBA higher (refer to BS ISO 17772-1 [32] are likely to be acceptable in some operating scenarios, where rapid changes to the cooling or ventilation rates quickly improve the thermal comfort of the occupant.

3.43 Equally, lower noise levels may be appropriate for some types of residential development.

3.44 When considering variations to the proposed desirable levels, the classification system from Cost Action TU0901 [33] and default design values from BS EN 15251 [34] may be used as a guide.

4 Glossary

Acoustic terminology

Noise	Typically defined as unwanted, unpleasant or disturbing sound.
Frequency (Hz)	The number of oscillations in acoustic pressure per second. It represents the 'tone' of the sound. Often determined in octave bands.
Maximum sound pressure level (L_{AFmax})	The maximum or highest sound pressure level measured with a 'fast' time weighting.
Equivalent continuous sound pressure level ($L_{eq,T}$)	The average of the total sound energy over a specified time period (T). L_{eq} represents the equivalent sound level that a fluctuating source would have compared to a steady source with the same total sound energy over a specific time period. Commonly used as a descriptor of human perception of sound over time.
'A' weighting	Frequency-dependent weighting based on the response of the human auditory system which has been found to correlate well with the subjective response to sound. Denoted by the use of the letter 'A'. For example, dBA denotes an 'A' weighted sound level in decibels, or L_{Amax} denotes an 'A' weighted maximum sound pressure level.
Internal Ambient Noise Level (IANL)	The noise level within a room or enclosed space. Usually determined as an equivalent continuous sound pressure level over a specific time period ($L_{Aeq,T}$, dB).
Noise Rating (NR) curve	A single figure term used to reflect the spectral frequency content of noise. Although originally proposed to assess environmental noise, NR curves are now typically used to describe noise from mechanical ventilation systems in buildings.
$L_{night,outside}$	The incident external A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year, in which the night is eight hours between 23:00 and 07:00.

Other terms

AVO	Acoustics, Ventilation, Overheating (e.g. AVO Guide, AVO Group).
ADF	Approved Document F.
Overheating condition	The situation where measures are in place to mitigate overheating to meet agreed compliance criteria.
Dynamic thermal modelling	A technique that can be used to simulate internal temperatures in dwellings before they are built.
Heat recovery	The process of using warm air extracted from the room to heat incoming colder air before it is supplied to the room, thereby reducing the ventilation heat-losses.
Ventilative cooling	Cooling by means of introducing external ambient temperature air at a high ventilation rate. Can be either passive (no fans) or mechanical (with fans).
Purge ventilation	Ventilation to aid removal of high concentrations of pollutants and water vapour released from occasional activities such as painting and decorating or accidental releases such as smoke from burnt food or spillage of water.
Comfort cooling	Cooling by means of a refrigerant cycle. This would include 'air conditioning' systems and the use of fan coil units (FCUs).
FCU	Fan coil unit.
MEV	Mechanical extract ventilation.
MVHR	Mechanical ventilation with heat recovery.
IEQ	Internal Environmental Quality, typically considering the internal environmental conditions for light, sound, thermal comfort and air quality.
Free area, A_f	The measurable, cross-sectional, geometric area of an opening. This should not be used for comparing the air-flow performance of elements because this will also be dependent on factors such as depth (length of air-path), surface roughness and tortuosity. Refer to [56] for further information.
Effective area, A_{eff}	Defined as the product of the free area and discharge coefficient, this is the preferred parameter for comparing the air-flow performance of elements. Refer to [56] for further information.
Equivalent area, A_{eq}	The area of a sharp-edged, circular orifice that gives the same flow rate as the actual opening at a given pressure-difference. In other words, the free-area of a notional circular hole made in an infinitely thin, infinite extent baffle that gives the same air-flow performance as the real opening. Used to describe the area of trickle vents in Approved Document F. Not to be confused with Effective area. Refer to [56] for further information.

A Appendix A – additional information

A.1 This appendix provides additional information on ventilation and overheating to help provide further context to the guidance in Section 2 of this document. This is not an exhaustive list of relevant information but does signpost a number of documents referred to during the production of this guide.

Ventilation

A.2 Ventilation requirements for dwellings (and other buildings) are covered under the Building Regulations and set out within ADF, which requires that:

"There shall be adequate means of ventilation provided for people in the building."

A.3 The document then goes on to state that:

"Ventilation is simply the removal of 'stale' indoor air from a building and its replacement with 'fresh' outside air.

Ventilation is required for one or more of the following purposes:

a) Provision of outside air for breathing;

b) Dilution and removal of airborne pollutants, including odours;

c) Control of excess humidity (arising from water vapour in the indoor air);

d) Provision of air for fuel-burning appliances (which is covered under Part J of the Building Regulations)

Ventilation may also provide a means to control thermal comfort but this is not controlled under the Building Regulations. Part L addresses minimising energy use due to the effects of solar gain in summer."

A.4 ADF describes three types of ventilation provision and associated ventilation rates. These are summarised in Table 2-1 of this guide.

A.5 In addition to the above ADF also states:

"Purge ventilation provisions may also be used to improve thermal comfort, although this is not controlled under the Building Regulations."

A.6 Section 5 of ADF provides details of four template 'Systems' which comply with ventilation requirements for new dwellings and can be adopted to demonstrate compliance.

A.7 Each of these 'Systems' demonstrates adequate ventilation provision, the details of each system are summarised in Table 2-2 of this guide.

A.8 With reference to the design of ventilation systems 1 and 2, ADF states the following:

"The background ventilators have been sized for the winter period. Additional ventilation may be required during warmer months and it has been assumed that the provisions for purge ventilation (e.g. openable windows) could be used."

A.9 The document also provides similar advice with respect to the sizing of systems 3 and 4.

A.10 With regard to the provision of purge ventilation within habitable rooms, the approved document provides the following note:

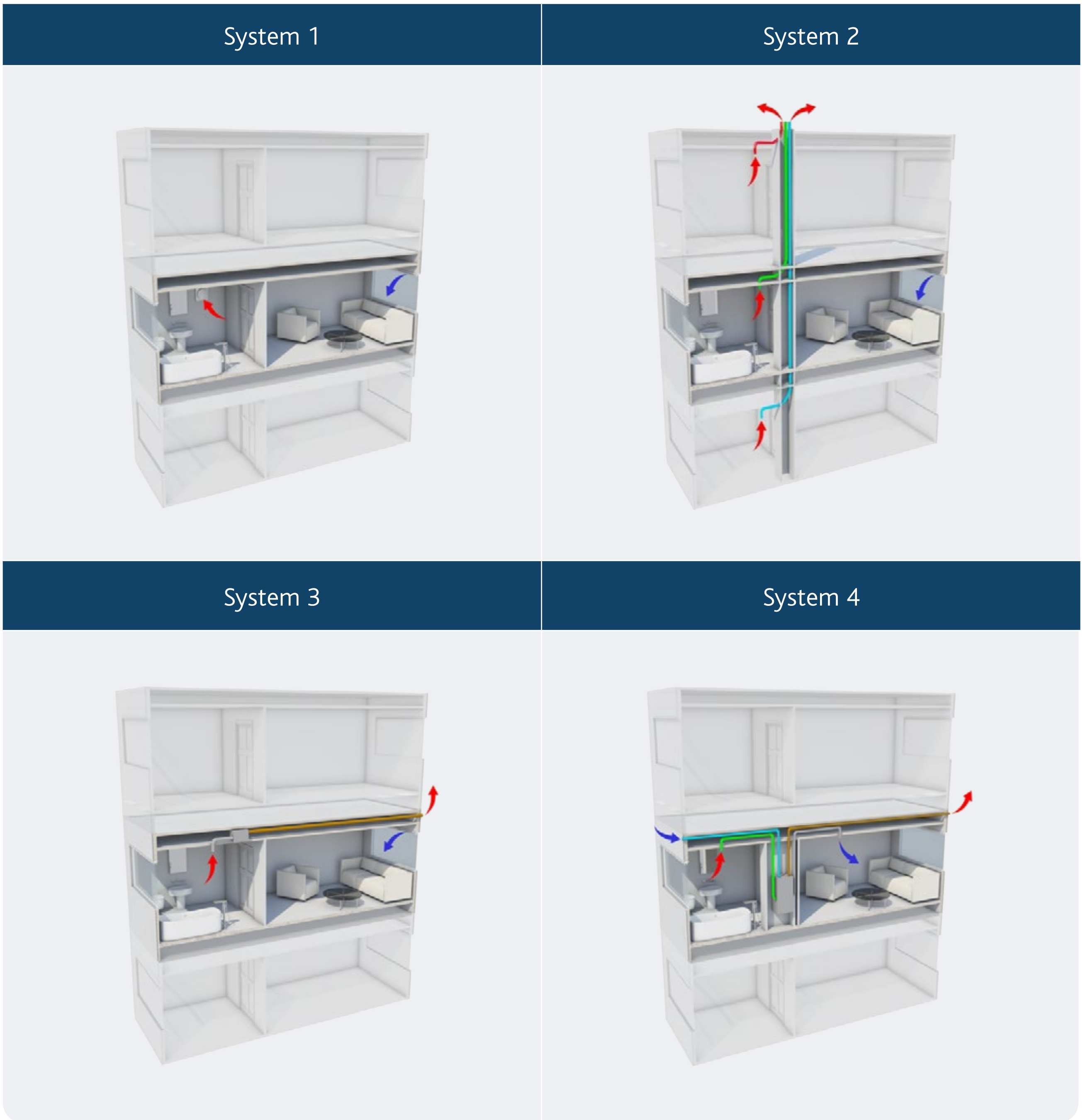
"There may be practical difficulties in achieving this (e.g. if unable to open a window due to excessive noise from outside."

A.11 No objective guidance is provided in the Approved Document as to what constitutes an 'excessive' level of noise.

A.12 Figure A-1 illustrates the principles of the ventilation systems described in Table 2-2 (i.e. systems 1, 2, 3 and 4).

A.13 Notwithstanding the above information, it is important to note that the ventilation requirements contained in ADF are a minimum standard only.

Figure A-1 Illustrations of ADF ventilation systems



Thermal Comfort and Overheating

A.14 ISO 7730 [35] describes thermal comfort as:

"that condition of body and mind which expresses satisfaction with the thermal environment."

A.15 Part of providing thermal comfort in a residential building is avoiding 'overheating'. In the Zero Carbon Hub discussion paper 'Next Steps in Defining Overheating' [6] ('ZCH') the following definition of overheating in dwellings is provided:

"In a general sense, by overheating we mean the phenomenon of excessive or prolonged high temperatures in homes, resulting from internal or external heat gains, which may have adverse effects on the comfort, health or productivity of the occupants."

Building Regulations

A.16 There are no specific requirements relating to overheating in residential dwellings as part of The UK Building Regulations. Both ADF (see above) and Part L1A of The Building Regulations [36] briefly mention overheating but do not provide detail on what constitutes overheating. In the section on 'buildings other than dwellings' ADF refers to Part L2A of The Building Regulations for guidance, however this guidance is related to limiting solar gains rather than avoiding overheating.

A.17 Approved Document L1A provides guidance on limiting the effects of heat gains in summer although no objective performance standards are identified. However, reference is provided to the SAP 2012 Appendix P assessment methodology and this document includes a simplified test for overheating risk (this is discussed in more detail below).

The London Plan – Policy 5.9 Overheating and Cooling

A.18 Policy 5.9 of the London Plan 2016 specifically mentions overheating and states the following:

"The Mayor seeks to reduce the impact of the urban heat island effect in London and encourages the design of places and spaces to avoid overheating and excessive heat generation, and to reduce overheating due to the impacts of climate change and the urban heat island effect on an area wide basis."

A.19 In relation to planning decisions the policy states that:

"Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the following cooling hierarchy:

1. minimise internal heat generation through energy efficient design

2. reduce the amount of heat entering a building in summer through orientation, shading, albedo, fenestration, insulation and green roofs and walls

3. manage the heat within the building through exposed internal thermal mass and high ceilings

4. passive ventilation

5. mechanical ventilation

6. active cooling systems (ensuring they are the lowest carbon options).

Major development proposals should demonstrate how the design, materials, construction and operation of the development would minimise overheating and also meet its cooling needs. New development in London should also be designed to avoid the need for energy intensive air conditioning systems as much as possible. Further details and guidance regarding overheating and cooling are outlined in the London Climate Change Adaptation Strategy."

A.20 In relation to Local Development Framework (LDF) preparation the policy also states:

"Within LDFs boroughs should develop more detailed policies and proposals to support the avoidance of overheating and to support the cooling hierarchy."

Overheating Criteria and Guidance

CIBSE Technical Memorandum 59 'Design methodology for the assessment of overheating risk in homes'

A.21 CIBSE TM59 provides guidance on the assessment of overheating in dwellings (including care homes and student accommodation). The document sets out a standardised methodology for predicting temperatures inside dwellings (using dynamic thermal modelling) and also provides overheating 'compliance criteria'.

A.22 CIBSE TM59 notes that:

"This methodology is proposed for all residences and should especially be considered for:

— large developments

— developments in urban areas, particularly in southern England

— blocks of flats

— dwellings with high levels of insulation and air-tightness

— single aspect flats.

Individual houses and developments with a low risk of overheating may not require the use of dynamic thermal modelling...

A.23 If taking the decision to omit dynamic thermal modelling to test overheating, TM59 states that the risk must be considered in the context of the project and the decision should be taken jointly with the client, design team and planners. A list of risk factors for identifying properties at high risk of overheating is provided in Energy Planning — Greater London Authority guidance on preparing energy assessments [37] and in BRE's Home Quality Mark [38]."

A.24 TM59 provides separate compliance criteria for dwellings that are 'predominantly naturally ventilated' and dwellings that are 'predominantly mechanically ventilated'. In relation to the different methods of ventilation TM59 states the following:

"Homes that are predominantly naturally ventilated, including homes that have mechanical ventilation with heat recovery (MVHR), with good opportunities for natural ventilation in the summer should assess overheating using the adaptive method based on CIBSE TM52 (2013)

In order to allow the occupants to 'adapt', each habitable room needs operable windows with a minimum free area that satisfies the purge ventilation criteria set in Part F of the Building Regulations for England (NBS, 2010), and equivalent regulations in other countries, i.e. the window opening area should be at least 1/20th of the floor area of the room (different conditions exist for windows with restricted openings, and the same requirement applies for external doors). Control of overheating may require accessible, secure, quiet ventilation with a significant openable area.

Homes that are predominantly mechanically ventilated because they have either no opportunity or extremely limited opportunities for opening windows (e.g. due to noise levels or air quality) should be assessed for overheating using the fixed temperature method."

A.25 The compliance criteria for each ventilation type, taken directly from TM59 are detailed below.

A.26 Compliance criteria for predominantly naturally ventilated homes:

"Compliance is based on passing both of the following two criteria:

a) For living rooms, kitchens and bathrooms: the number of hours during which ΔT is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3 per cent of occupied hours (CIBSE TM52 Criterion 1: Hours of exceedance).

b) For bedrooms only: to guarantee comfort during the sleeping hours the operative temperature in the bedroom from 10 pm to 7 am shall not exceed 26 °C for more than 1% of annual hours. (Note: 1% of the annual hours between 22:00 and 07:00 °C will be recorded as a fail.)

Criteria 2 and 3 of CIBSE TM52 may fail to be met, but both a) and b) above must be passed for all relevant rooms."

A.27 Compliance criteria for predominantly mechanically ventilated homes:

"For homes with restricted window openings, the CIBSE fixed temperature test must be followed, i.e. all occupied rooms should not exceed an operative temperature of 26 ˚C for more than 3% of the annual occupied annual hours (CIBSE Guide A (2015a))."

A.28 In addition to the compliance criteria above TM59 provides further information on adjustments for homes with vulnerable occupants and 'non-mandatory' criteria for temperatures in corridor areas.

A.29 TM59 refers to the adaptive thermal comfort criteria in CIBSE Technical Memorandum 52 (TM52) [39] and these are described in more detail in the following paragraphs.

A.30 TM52 outlines three overheating design criteria. These are all defined in terms of ΔT, the difference between the actual operative temperature in the room at any time (Top) and the limiting maximum acceptable temperature (Tmax). ΔT is calculated as:

$\Delta T = Top - Tmax$ (K)

A.31 ΔT is rounded to the nearest degree (i.e. for ΔT between 0.5 and 1.5 the value used is 1K, for 1.5 to 2.5 the value used is 2K and so on).

A.32 Criteria 1 - Hours of Exceedance (He): The number of hours (He) that ΔT is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3% of occupied hours.

A.33 How often a building/zone exceeds its comfort range during the summer months (May-September) is a useful indicator of its thermal characteristics and potential risk of overheating.

A.34 Criteria 2 – Daily Weighted Exceedance (We): To allow for the severity of overheating the Daily Weighted Exceedance (We) shall be less than or equal to 6 in any one day.

A.35 The value of 6 is an initial assessment of what constitutes an acceptable limit of overheating on any single day.

A.36 Criteria 3 - Upper Limit Temperature (Tupp):

A.37 To set an absolute maximum value for the indoor operative temperature the value of ΔT shall not exceed 4K.

A.38 This criterion covers the extremes of hot weather conditions and future climate scenarios.

Standard Assessment Procedure for Energy Rating of Dwellings' (SAP), 2012

A.39 Appendix P of 'The Government's Standard Assessment Procedure for Energy Rating of Dwellings' [40] ('SAP'), 2012 provides a method for assessing the energy performance of dwellings and as part of this provides an 'Assessment of internal temperature in summer' (the document does note that this assessment is not integral to SAP and does not affect the calculated SAP ratings).

A.40 The SAP Appendix P assessment predicts a likelihood of high internal temperature during hot weather that varies from 'not significant' to 'high'. However, it should be noted that this method is a relatively simple tick box type assessment that only considers a few basic variables as it is focussed on assessing the energy efficiency of a dwelling and not thermal comfort or health impacts etc.

Housing Health and Safety Rating System

A.41 The Housing Health and Safety Rating System [41] ('HHSRS') is a 'risk-based evaluation tool to help local authorities identify and protect against potential risks and hazards to health and safety from any deficiencies identified in dwellings'.

A.42 In Section 3 of the HHSRS document 'Guidance for landlords and property related professionals', the following is stated in relation to the effects on health as temperatures rise:

"increase in thermal stress, increase in cardio vascular strain and trauma, and increase in strokes. Mortality increases in temperatures over 25°C. Although not common, problems can occur in the UK."

A.43 In addition to the above, in the HHSRS 'Operating Guidance' document, further information in relation to overheating and noise is provided in paragraph 3.17:

"There should be means for cooling during hot summer weather, either by natural ventilation or by air conditioning. The means should be controllable, properly installed and maintained, and appropriate, having regard to the particular part of the dwelling. While openable windows can provide ventilation, occupiers may be reluctant to use them for security reasons, or because of external noise levels, especially at night."

IEA Energy in Buildings and Communities Programme – Annex 62 – Ventilative Cooling

A.44 The International Energy Agency (IEA) Energy in Buildings and Community (EBC) Programme [42] carries out research and development activities towards near zero energy and carbon emissions.

A.45 Annex 62 of the Programme looks at 'ventilative cooling' and provides the following definition of the term 'ventilative cooling':

"The application of ventilation air flow to reduce the cooling loads in buildings"

A.46 To help address cooling challenges in buildings, Annex 62 focuses on the following:

- *"Development of design methods and compliance tools related to predicting, evaluating and eliminating the cooling need and the risk of overheating in buildings, and*
- *To develop new attractive energy efficient ventilative cooling solutions."*

Dynamic Thermal Modelling

A.47 Dynamic thermal modelling is a technique that can be used to simulate internal temperatures in dwellings before they are built. This enables engineers to identify if and how often rooms in dwellings are likely to 'overheat'.

A.48 Building services engineers generally use thermal analysis software to undertake dynamic thermal modelling.

A.49 In order to model temperatures inside dwellings a large amount of information is required, including the following:

- Site location and building orientation
- Weather files for the site
- Details of elevational treatments (areas, insulation performance and solar transmittance etc.)
- Thermal mass properties
- Details of opening doors and windows (size, shape, opening type)
- Details of any mechanical ventilation and / or heat recovery systems
- Internal and external shading
- Room types and information
- Occupancy profiles (occupied hours, resident's activities etc.)
- Details of internal thermal gains (lighting, equipment, pipework etc.)

A.50 Before the release of TM59, the results of dynamic thermal modelling assessments were highly dependent upon assumptions made by the engineer undertaking the analysis, particularly in relation to occupancy profiles.

A.51 However, the CIBSE TM59 document now provides a standardised approach to predicting overheating using dynamic thermal analysis. The methodology is necessarily prescriptive to enable it to be consistently applied and it also includes clear reporting requirements to enable all stakeholders to understand the assumptions made, review the conclusions and understand the likely design implications.

A.52 To assist with the acoustic assessment, modellers should be asked to provide the information described in Table A-2 from the dynamic thermal model.

A.53 The free area may be used to assess potential external noise ingress, e.g. by reference to NANR-116 [43], or Annexe D of BS EN 12354 [45]. The effective area may be used to determine the requirements for another type of system, such as an attenuated passive vent.

A.54 It is anticipated that in a future version of this AVO Guide there will be a quantitative assessment of the overheating condition to combine with the acoustic assessment. At present the extent of time for which the overheating condition occurs can only be assessed qualitatively.

A.55 In future it is anticipated that the number of hours for which open windows are required to mitigate overheating within the daytime (07:00 - 23:00) and separately, night-time (23:00 - 07:00) periods will be detailed.

Table A-2 Information required from thermal model

Information required from dynamic thermal model in order to undertake the acoustic assessment
The physical opening area (*free area*) in the facade
The *effective area* of opening achieved

Overheating risk – early stage tool

A.56 This early stage tool [8] may be of great assistance in enabling the non-specialist to get a quantitative feel for the overheating risk. This includes assessment of where noise levels may be a reason that occupants may prefer to keep windows closed for all or part of the day or night- time periods.

B Appendix B – example application of this guide

Introduction – observing internal noise level guidelines

B.1 This appendix offers an overview of the typical design process, and provides a worked example to illustrate the steps that may be appropriate.

B.2 The level of assessment (i.e. a level 1 or level 2 assessment, and detail included for each) may be proportional to the scale of the development. This Appendix outlines an extensive assessment.

B.3 At any scale of development, it is always appropriate to integrate any façade sound insulation requirements with the ventilation strategy.

B.4 On smaller developments it may be disproportionate to carry out a formal overheating assessment. In this case, the risk factors for overheating may be noted [41] along with the provisions for mitigating overheating and the associated noise levels anticipated. The level of risk to occupants may then be considered in a qualitative manner.

B.5 A qualitative overheating assessment is likely to assume opening windows to mitigate overheating. Thus even when the overheating risk may appear to be low, the acoustic conditions during the overheating condition should be considered.

Approach to assessment & preparing advice – key steps

B.6 Prior to the acoustic assessment of ventilation and overheating the site should be assessed using guidance for good acoustic design as recommended within ProPG: Planning & Noise. In particular, where a site is considered medium or high risk following an initial site noise risk assessment, it is recommended that the examination of acoustically critical issues such as site layout, building heights, materials, landform contouring, detailed design and landscaping, the location of vehicle and pedestrian access, boundary treatments, amenity spaces etc. must be assessed at an early stage.

B.7 The suggested process in this section assumes that the site layout including building orientation has already been optimised following a process of good acoustic design, as has the space planning within the building.

B.8 There are three key steps in the process of considering the effect that noise can have in relation to design strategies for ventilation and mitigating overheating and these are highlighted in Table B-1 and illustrated in Figure B-1.

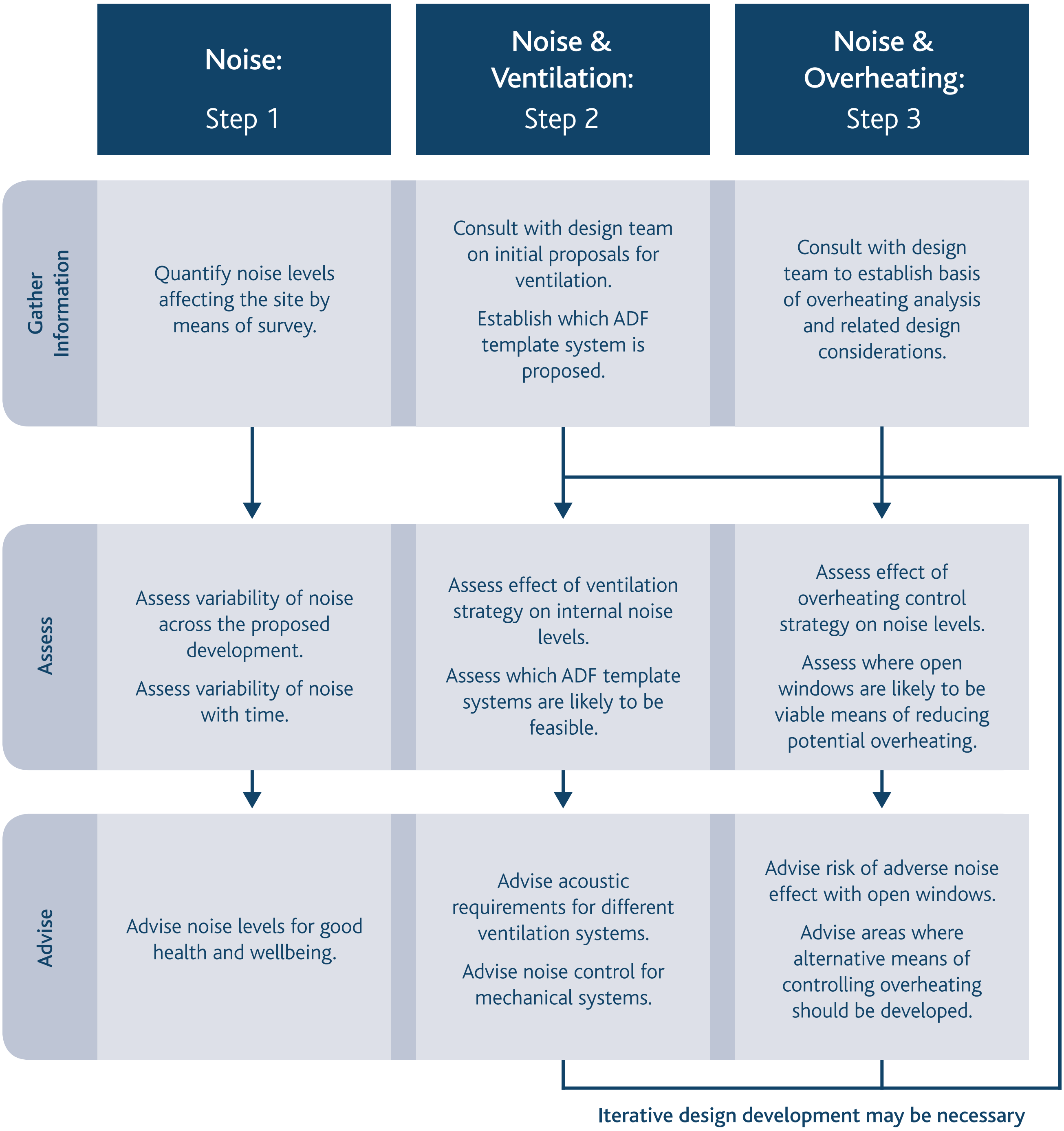
B.9 To carry out a Level 1 assessment, it is useful to consider guideline values that may inform the boundaries between negligible, low, medium, and high risk sites or aspects in this worked example.

B.10 Table 3-2 illustrates the increasing risk in a qualitative manner; paragraph 3.13 indicates that the values in Table 3-2 are based on a difference of 13 dB between external free-field and internal reverberant levels indicated in Table 3-3. Paragraphs 3.24 and 3.25 and note that the value of 13 dB is not appropriate for all situations; this approach nonetheless enables a Level 1 assessment to be undertaken before details of the proposed accommodation are known.

Table B-1 Three key steps in considering noise in relation to ventilation and overheating strategies

Step	Activity	Output advice
1	**Quantify external noise levels** Determine external noise levels impacting on proposed living rooms and bedrooms.	Report the following values and describe the method by which they have been determined. These should consider any increases that may reasonably be expected in the foreseeable future. • Daytime ($L_{Aeq,16h}$) • Night-time ($L_{Aeq,8h}$) • Ventilation design case night-time maximum (L_{AFmax}) level. • Overheating design case night-time maximum (L_{AFmax}) level.
2	**Assess noise & ventilation** Consider the effect of the proposed or potential ventilation strategies on the acoustic conditions in living rooms and bedrooms. Consider noise ingress through other parts of the building envelope as appropriate.	Refer to Table 3-1 for indoor ambient noise level guidelines from external sources, and Table 3-4 for mechanical services noise associated with ventilation provision. The facade sound insulation assessment should either include details of the proposed ventilation strategy and façade element sound insulation performance, or identify feasible ventilation strategies and the associated acoustic constraints for façade element performances. **Section on Beginning Step 2 (paragraphs B11 to B35) gives further information on this.**
3	**Assess noise & overheating** Rooms may be grouped by Negligible, Low, Medium and High risk categories according to Table 3-2 to determine the extent of further analysis or mitigation required. Consider noise from mechanical systems associated with controlling overheating.	It may be appropriate to carry out an overheating assessment regardless of the noise impact on the proposed development. Risk factors for overheating are listed in CIBSE TM59, although other methods of carrying out an overheating assessment may also be suitable. Refer to Table 3-5 for mechanical services noise associated with controlling overheating. Follow procedure in Figure 3-1 for noise from external sources. **Negligible risk category rooms according to Level 1 assessment** A "Level 1" assessment is sufficient, as noise can be heard but does not cause any change in behaviour. **Low risk category rooms according to Level 1 assessment** A "Level 1" assessment is likely to be sufficient. It is unlikely that external noise ingress will be problematic if using opening windows to mitigate overheating, although it may be appropriate to demonstrate this with calculations. **Medium risk category rooms according to Level 1 assessment** It would be prudent to carry out more detailed analysis for rooms in this category, because if open windows are required for extended periods to reduce potential overheating (i.e. during the "overheating condition") the noise impact may be significant. It may be appropriate to consider the generic overheating risk factors for the proposed development (refer to Appendix A, paragraph A.23, or use of the Good Homes Alliance Early Stage Overheating Risk Tool) along with the noise levels in order to take a balanced view of the level of formal assessment that is suitable. **High risk category rooms according to Level 1 assessment** A "Level 2" assessment is normally appropriate in accordance with Table 3-3. For rooms in this noise exposure category, an integrated approach should consider the overheating strategy along with external noise ingress. The potential adverse acoustic impact during the overheating condition should be assessed. **Section on Beginning Step 3 (paragraphs B36 to B49) gives further information on assessing noise and overheating.**

Figure B-1 Typical activity of the acoustician in developing the design



Beginning Step 2: consider noise effects of ventilation strategy

B.11 The first step in the assessment is for the acoustician to review and understand the ventilation strategy that is being proposed in relation to ADF. In the absence of a firm proposal, the acoustician might consider the viability of each of the standard ADF systems.

B.12 Acoustic considerations associated with ventilation strategies described in ADF are summarised in Table B-3. It is noted that there is no obligation to adopt one of these template systems from ADF; other systems may be considered by reference to the similar system described, subject to satisfaction of the Building Control officer.

B.13 Table B-3 indicates approximate guideline external noise levels for each system.

Potential facade elements and their associated performance

B.14 It is assumed for the sample calculations below that external noise ingress through the glazing and any vent is the most significant route, and the noise ingress through other facade elements is not significant by comparison. This is likely to be a reasonable assumption where low or moderate levels of façade sound insulation are required. Where higher levels of sound insulation are needed, consideration should also be given to other façade elements.

B.15 The calculations here assume double glazing; the sound insulation of triple glazing is not generally much better than that of double glazing. The sealing of any opening elements may be the limiting factor when trying to achieve higher levels of sound insulation, particularly the sealing of sliding doors, for example. Any performance considered for glazing should include the frame and seals for opening elements.

B.16 In the interests of simplicity in this worked example, it is assumed that the external continuous equivalent sound field is well represented by the road traffic noise spectrum described in BS EN 1793-3 [44]. On this basis façade sound insulation is well described by the (R_w+C_{tr}) parameter.

B.17 The values for attenuation of noise from events is calculated based on the weighted sound reduction indices (R_w, $D_{n,e,w}$) *without* the C_{tr} adaptation term, on the basis that noise from events typically has more energy in the higher frequency bands and attenuation is typically better represented by this parameter.

B.18 The assumptions above are made for simplicity in this example; in practice, the acoustician should determine the type of calculation that is appropriate for the particular circumstances. This may be a simple calculation using broadband sound levels, or may be a frequency-band calculations using the procedure in BS EN ISO 12354-3:2017.

Guideline external noise constraints for ADF ventilation Systems 1 & 2

B.19 The trickle vent areas indicated in ADF to provide whole dwelling ventilation rates are based on calculated air flow rates for the winter condition; provisions for purge ventilation (i.e. opening windows) may be used at other times of the year.

B.20 Two trickle vents to provide an equivalent area of 5000 mm^2 are assumed for the assessment of Systems 1 & 2. It is noted that the trickle vents are sized based on winter conditions; at other times of the year, partially open windows may be required to avoid poor indoor air quality. However, there is no guidance provided in ADF on the area of opening that may be required; therefore this assessment is based on external noise ingress through closed windows and open trickle vents.

B.21 External levels for use of ADF System 1 are based on calculations according to the detailed method described in BS 8233, (equivalent to the method in BS EN 12354-3) [45] A typical small bedroom is considered. The *Technical housing standards – nationally described space standard* [46] indicates that a single bedroom should be at least 7.5 m^2. The glazed area is considered to 25% of the floor area, as described in SAP.

B.22 These dimensions represent unfavourable ratios between element performance and overall facade level difference, but worse case conditions may be found in practice. On the basis of these assumptions, the relation between element performance and partial internal level ($L_{2,route}$) due to each noise ingress path reduces to the following relationship, following the detailed method in BS 8233 Section G.2:

- $L_{2,\,glass} = L_{1,ff} - (R_w+C_{tr}) - 2$
- $L_{2,\,vent} = L_{1,\,ff} - (D_{n,e,w}+C_{tr}) + 5$ [for each vent]

B.23 Where the total internal level is the logarithmic sum of the partial level due to ingress through the glass, $L_{2, glass}$, and ingress through the vent, $L_{2, vent}$, assuming that these routes dominate over other ingress transmission routes as noted above.

B.24 The following assumptions are made regarding potential glazing and trickle vent performance:

- Standard domestic double glazing with R_w (C_{tr}) 29 (-4) dB, from BS EN 12758 [47]
- High acoustic performance windows with R_w (C_{tr}) 43 (-6) dB, from proprietary manufacturer's data. Note that the details of the frame and sealing arrangements are important to maintain this performance for the whole window system.
- Two standard trickle vents, approx. 2500 mm^2 equivalent area, $D_{n,e,w}$ (C_{tr}) 31 (0) dB, typical manufacturer's data.
- Two high acoustic performance trickle vents, approx 2500 mm2 equivalent area, $D_{n,e,w}$ (C_{tr}) 44 (-3) dB from proprietary manufacturer's data.

B.25 Note that the total equivalent area of ventilators required to comply with AD-F may mean that more than two trickle vents are required in some rooms, but two vents are assumed in this example.

Guideline external noise constraints for ADF ventilation System 3

B.26 The guideline values for ADF System 3 are based on the same assumptions as for Systems 1 and 2, but with a single trickle vent in the façade providing a minimum equivalent area of 2500 mm^2, as indicated in ADF.

B.27 In particular, note the comment regarding the performance of the frame for the glass, sealing arrangements and other facade elements where a higher overall sound insulation performance is sought.

Guideline external noise constraints for ADF ventilation System 4

B.28 The guideline values for ADF System 4 are calculated on the same basis as for ADF System 3, omitting the trickle vent. In particular, note the comment regarding the performance of the frame for the glass, sealing arrangements and other facade elements where a higher overall sound insulation performance is sought.

Table B-2 Potential level differences associated with different ventilation Systems from ADF

Ventilation System from ADF	Cont. equiv. (L_{Aeq}) or events (L_{AFmax})	Level Difference, external free field level – internal reverberant level, dB	
		Typical windows and vent	Higher acoustic performance windows and vent
1, 2	L_{Aeq}	21	31
	L_{AFmax}	22	35
3 (with trickle vent)	L_{Aeq}	23	33
	L_{AFmax}	24	38
4 (no trickle vent)	L_{Aeq}	27	38
	L_{AFmax}	31	45

Assessment of Individual Noise Events

B.29 An assessment of the potential impact from individual noise events on sleep during the night-time should always be undertaken.

B.30 The paper Assessing L_{max} *for residential developments: the AVO Guide Approach*[22] describes the approach adopted in this guide. Representative external values of L_{AFmax} on different façade portions may be determined to establish a "design case" as described in the ANC Green Book [48] (ANC Green Book). However, the frequency content of the noise from events may be of more significance than the overall A-weighted level.

B.31 When assessing the ventilation strategy, the L_{AFmax} level associated with the ventilation design case should be used. Note that this may be a different level from the L_{AFmax} used with the overheating design case. Refer to Assessment of Individual Noise Events (paragraphs B45 –B49)

B.32 When the noise from events is transmitted through the façade, the highest internal levels of L_{AFmax} may not be caused by the same events that cause the highest L_{AFmax} externally.

B.33 On the basis of survey measurements, the acoustician must exercise discretion to determine the appropriate values and frequency content to use for the design case for noise from events. It may be necessary to use a range of values and calculate the internal values of L_{AFmax} for each scheme of façade sound insulation in order to determine external values that are suitable to use.

B.34 In particular, where the noise from events contains a high proportion of energy in the lower or higher frequency bands, the overall performance of the façade sound insulation may be poorly represented by single-figure weighted values compared to frequency-band calculations.

B.35 Either a single value or range of values for the design case for noise from events may be determined with guidance from the ANC Green Book.

Table B-3 Summary of potential noise issues associated with ventilation strategies described in ADF

ADF System	External noise ingress considerations	Mechanical system noise considerations	Approximate guideline free-field external noise limits. [Note 1]
1 or 2	Noise ingress is likely to be defined by the performance of the background ventilators (trickle vents), windows and other façade elements. Note that use of System 1, relying on the use of open trickle vents without opening windows may give rise to poor indoor air quality in airtight dwellings outside the winter period.	For System 1, intermittent kitchen and bathroom fans should have suitable noise levels to meet the guidelines in Table 3-4. System 2 has no mechanical components.	With standard double glazing and two trickle vents: • ~$L_{Aeq,16h}$ 56 dB day • ~$L_{Aeq,8h}$ 51 dB night • L_{AFmax} not normally exceeding ~ 67 dB more than 10x per night With high performing acoustic glazing and two 'acoustic' trickle vents: • ~ $L_{Aeq,16h}$ 66 dB day • ~ $L_{Aeq,8h}$ 61 dB night • L_{AFmax} not normally exceeding ~ 80 dB more than 10x per night
3	Noise ingress is likely to be defined by the performance of the background ventilators (trickle vents), windows and other façade elements. ADF advises that: "*controllable background ventilators having a minimum equivalent area of 2,500 mm² should be fitted in each room, except wet rooms…*"	This could be a centralised or decentralised MEV system. Guideline levels are shown in Table 3-4. For a centralised system, the location of the fan is important for structure-borne and airborne noise. System noise may affect living rooms and bedrooms as well as the rooms in which the extract inlets are located i.e. wet rooms. For a decentralised system, there are individual fans extracting from each bathroom, toilet, kitchen and utility room. The noise effects on adjacent living rooms and bedrooms should be considered. [Note 2]	With standard double glazing and trickle vent: • ~$L_{Aeq,16h}$ 58 dB day • ~$L_{Aeq,8h}$ 53 dB night • L_{AFmax} not normally exceeding ~ 69 dB more than 10x per night With high performing acoustic glazing and an 'acoustic' trickle vent: • ~ $L_{Aeq,16h}$ 68 dB day • ~ $L_{Aeq,8h}$ 63 dB night • L_{AFmax} not normally exceeding ~ 83 dB more than 10x per night
4	No trickle vents required. Consider noise ingress through other facade elements.	MVHR is a centralised system ducted to supply outlets in living rooms and bedrooms as well as to extracts in wet rooms. Guideline levels are shown in Table 3-4. The unit location is important for structure-borne and airborne noise. Consider ducted noise, particularly to bedrooms. Consider also cross-talk sound transmission via ducts. [Note 2]	With standard double glazing and no trickle vent: • ~ $L_{Aeq,16h}$ 62 dB day • ~ $L_{Aeq,8h}$ 57 dB night • L_{AFmax} not normally exceeding ~76 dB more than 10x per night With high performing acoustic glazing: • ~ $L_{Aeq,16h}$ 73 dB day • ~ $L_{Aeq,8h}$ 68 dB night • L_{AFmax} not normally exceeding ~ 90 dB more than 10x per night N.B. With secondary glazing higher sound insulation may be achieved.

Note 1 Refer to paragraphs B14 to B27 for the basis of calculated noise levels

Note 2 Hybrid ventilation strategies may involve mechanical supply and/or extract to specific habitable rooms, in which case those sources of noise should be considered.

Beginning Step 3: consider noise effects of overheating mitigation strategy

B.36 The first step in any assessment is for the acoustician to review and understand the strategy that is being proposed for meeting overheating design criteria. The strategy will normally consist of limiting heat gains (e.g. solar gains) and providing a means of cooling.

B.37 Table B-4 indicates acoustic considerations for four common means of cooling, noting that other means of cooling are available. Appropriate noise levels for each type of cooling strategy should also take account of how often the means of cooling needs to be employed and for what duration. See Section 3 for the detail of the assessment of overheating and noise level guidance.

B.38 It may be helpful for the acoustician to produce a mark-up indicating the Level 1 assessment risk category for each façade in accordance with guidance in Table 3-2. This will allow the other members of the design team (especially those involved in the assessment of overheating) to understand locations in which the use of opening windows to mitigate overheating may not be appropriate.

The significance of non-acoustic factors

B.39 The acoustic assessment is influenced by non-acoustic factors. The level of overheating risk will influence how often the means of cooling needs to be applied and for what duration. In the case of passive ventilative cooling, the overheating risk will also influence the size of the ventilation opening required: this changes the noise impact on occupants.

B.40 The Early Stage Overheating Risk Tool may be used to inform the overheating in conjunction with the acoustic assessment.

B.41 It may be possible to reduce the noise impact by further reducing the heat gains, and hence reducing the regularity and/or duration for which the means of cooling needs to be employed. The London Plan overheating policy provides a useful reference as to the various mitigation options and their preferred hierarchy (refer to paragraph A.19).

B.42 For example, by reducing the extent of external glazing, by improving solar shading or using exposed thermal mass, the amount of cooling that is required to meet overheating criteria may be reduced. This will likely reduce either the magnitude or duration of any noise impact associated with the cooling provision.

B.43 Clearly, it is not the role of the acoustic practitioner to advise on the strategy for mitigating overheating. However, where relevant, the acoustic practitioner is encouraged to communicate to the design team and developer any acoustic benefit of reducing heat gains or increasing thermal mass.

B.44 Ceiling mounted fans do not reduce the ambient temperature but can be used to increase air-movement in the room, and thus improve thermal comfort at hotter temperatures. If used, noise from ceiling mounted fans should be considered in the assessment.

Assessment of Individual Noise Events

B.45 Paragraphs B29 to B35 discuss potential issues with the measurement and assessment of L_{AFmax}.

B.46 Higher values may be acceptable for limited periods of the year, depending on the level and frequency of events. Refer to ProPG Appendix A for information on assessing individual noise events.

B.47 The paper *Assessing L_{max} for residential developments: the AVO Guide Approach* [22] describes the approach adopted in this guide.

B.48 Table 3-3 indicates that for the overheating design case L_{AFmax} levels up to but not normally exceeding 65 dB may be acceptable for limited periods.

B.49 For simplicity, it is considered that the external design case maximum level determined for the overheating condition should not result in the L_{AFmax} within bedrooms exceeding a value of 65 dB.

Table B-4 Summary of potential noise issues associated with cooling strategy

Means of cooling	Description	External noise ingress considerations	Mechanical system noise considerations
Passive ventilative cooling	Introducing external air to a space to provide a cooling effect without the use of fans. The most common method is to use open windows but other façade openings can also be used. It is important to note that trickle vents do not provide sufficient airflow to have a significant cooling effect.	Will require significant openings in the façade. Ingress of external noise via these openings will need to be considered. A level difference of around 13 dB from external free-field levels to reverberant internal levels can typically be assumed for a window that is sufficiently open to enable some ventilative cooling. However, the actual open area that may mitigate overheating depends on many factors [4, 8], and may differ significantly from this proportion. Therefore this should be reviewed for the specific project (refer to paragraphs 3.22 to 3.27 and IEA EBC Annexe 62 [42]). Where opening windows result in unacceptably high internal levels, other solutions can be considered – see Table B-5.	N/A (unless ceiling fans used)
Mechanical ventilative cooling	Using fans to introduce external air to a space to provide a cooling effect. Due to the airflow required, this type of system often involves significantly increased plant and duct size requirements.	These are likely to be sufficient to attenuate external noise ingress via the ducts. If intake and/or exhaust ducts penetrate the facade locally, the effect on sound insulation should be reviewed.	Air-flow rates will be significantly higher than those required for ADF whole dwelling ventilation. Fan noise will therefore be higher and duct-borne, breakout and structure-borne paths must be appropriately considered. Airflow (regenerated) noise will also need to be considered at grilles.
Comfort cooling	Using a mechanical system to cool the air within a space to achieve a user-defined setpoint. This type of system will require some form of mechanical device to cool the air, such as a fan coil unit (FCU).	No air-path to outside. Consider noise ingress through other facade elements.	Indoor units (fan-coils, cassettes etc.) include a fan and require significant air-flow rates to convey cooling to the room. Both the fan and the airflow are sources of noise and must be appropriately addressed. Outdoor units (which reject heat to the atmosphere) also generate noise and this may have an impact on nearby external amenity spaces or result in break-in to nearby dwellings.
Tempered fresh air system	These systems add a small amount of cooling to the whole dwelling ventilation supply system (e.g. to the MVHR). This provides a reduced temperature fresh air supply which can provide some cooling to a space. However, this may not be able to control overheating in isolation. Unlike comfort cooling, these systems are not designed to achieve specific temperature in a space.	No additional air-path to outside. Consider noise ingress through other facade elements.	Addition of cooling may affect noise generated by MVHR (or other ventilation supply system).

Passive ventilative cooling solutions providing enhanced sound insulation

B.50 Refer to Table B-5 for examples of passive ventilative cooling solutions that are able to provide an enhanced level of sound insulation when compared to a standard opening window. Solutions can be sized to enable the passive ventilation rate required by the design, which is identified by the mechanical engineers. At the time of writing there is little evidence of the successful use of many of these innovative systems in residential environments.

Table B-5 Examples of passive ventilation solutions providing enhanced sound insulation

Design option	Description and references	Approximate Level Difference (external free field level – internal reverberant level)	Improvement relative to a window providing a similar amount of ventilation
Standard opening windows	Window(s) open sufficiently to provide a ventilation free-area equivalent to 2% of the floor area. [42]	13 dB	0 dB
Open windows with sound attenuating balconies	Window(s) as above. Balconies may have a solid balustrade or be enclosed to a further degree (maintaining an open area for ventilation). Absorption may be provided to the balcony soffit or potentially to other surfaces. [49, 50, 51]	17 – 23 dB	4 – 10 dB
Attenuated or plenum windows	Dual windows (spaced by around 200mm) with staggered openings and absorptive linings to the cavity reveals. Various other configurations also possible in principle. [52, 53]	17 – 24 dB	4 – 11 dB
Attenuated vents/ louvres	Ventilation openings with integral means of attenuating sound. Typically this may be acoustic louvres or acoustically lined ducts/plena. [54, 55]	17 – 29 dB	4 – 16 dB
Attenuated windows or vents/ louvres with sound attenuating balconies	Combined use of balconies to provide screening and acoustically attenuated windows or vents. Refer to above for description of each element.	21 – 39 dB	8 – 26 dB

Information that may be appropriate or required to accompany a planning submission

B.51 Table B-6 lists information that may be appropriate or required by the Local Planning Authority (LPA) to provide with a planning application.

B.52 Individual circumstances of the project and the requirements of the LPA can vary. Reference should be made to local development plans.

B.53 An example of the typical full range of tests that are possible are listed in Table B-7. It is not intended that the full range of tests be carried out on every project; however, where the design information demonstrating compliance with particular criteria is not evident to the LPA, they may require completion tests to demonstrate compliance with the agreed criteria.

B.54 It may be appropriate to adopt a risk-based approach to selecting performance parameters for post-completion testing.

Table B-6 Information that it may be appropriate to provide with the planning application

<table>
<tr><th>Planning stage</th><th>Noise impact</th><th>Noise implications for ventilation strategy</th><th>Noise implications for overheating strategy</th></tr>
<tr><td rowspan="2">Outline application</td><td rowspan="2">Details of environmental noise impact across the site and proposed development if known.
Potential effect of mitigation such as barriers, or use of buildings following good acoustic design to reduce noise impact on outdoor amenity areas and facades of habitable rooms.</td><td>Feasibility of ventilation strategies across the site with the noise levels measured and with any potential mitigation.
Refer to Table B-2 or B-3, or provide alternative calculations to demonstrate feasibility of façade sound insulation with ventilation strategies.</td><td>Level 1 assessment of risk in accordance with Figure 3-1, for different aspects of the proposed development as appropriate.
Feasibility of potential overheating strategies with the noise levels measured and with any potential mitigation. Reference can be made to Tables B-4 or B-5.</td></tr>
<tr><td colspan="2">Suggest a schedule of testing is developed for a proportion of dwellings at detailed design stage. Testing to include both external noise ingress and any mechanical systems in accordance with the updated ANC Guidelines - Sound Measurement in Buildings (which replaces the previous version known as Noise Measurement in Buildings).</td></tr>
<tr><td rowspan="2">Detailed application</td><td rowspan="2">Details of environmental noise impact across the site and proposed development.
Potential effect of mitigation such as barriers, or use of buildings following good acoustic design to reduce noise impact on outdoor amenity areas and facades of habitable rooms.
Details of anticipated noise levels at an appropriate selection of residential properties.</td><td>Calculations demonstrating that the internal noise levels from external sources are consistent with the levels in Table 3-1, with justification where there are exceedances.
Specifications for noise levels from mechanical ventilation systems.</td><td>Calculations demonstrating that the internal noise levels from external sources are consistent with the guideline levels in Table 3-3, with justification where there are exceedances.
Specifications for noise levels from mechanical cooling systems.</td></tr>
<tr><td colspan="2">Consider a schedule of testing, particularly for any mechanical systems in accordance with ANC Guide to Measurement of Sound levels in buildings.[Note 1]</td></tr>
</table>

Note 1 Where the development is subject to EIA Regulations, a reference to compliance testing should be included within the monitoring commitments.

Table B-7 A schedule of performance requirements that may be appropriate to include in a testing schedule

Noise Source	Time Period / function	Living rooms	Bedrooms	Bath,WC, Kitchen
Environmental noise ingress limit with provisions for whole dwelling ventilation rate	Daytime, $L_{Aeq,16h}$	≤ 35 dB	≤ 35 dB	-
	Night-time, $L_{Aeq,8h}$	-	≤ 30 dB	-
	Night-time, ventilation design case L_{AFmax}	-	≤ 45 dB	-
Environmental noise ingress limit with provisions for mitigating overheating	Daytime, $L_{Aeq,16h}$	[Note 1]	[Note 1]	-
	Night-time, $L_{Aeq,8h}$	-	[Note 1]	-
	Night -time, overheating design case L_{AFmax}	-	[Note 1]	-
Mechanical services noise, where systems present	Whole dwelling ventilation rate, $L_{Aeq,T}$	≤ 30 dB	≤ 26 or 30 dB [Note 2]	-
	Extract ventilation rate, $L_{Aeq,T}$	≤ 35 dB	≤ 26 or 30 dB [Note 2]	≤ 45 dB
	At design duty to control overheating [Note 3]	≤ 35 dB	≤ 30 dB	-

Note 1 Agreed limits for environmental noise ingress while using provisions for mitigating overheating may vary depending on the overheating risk and extent of time these measures may be required.

Note 2 Suitable limits for mechanical services noise should be adopted, see Paragraphs 3.28 to 3.34

Note 3 Refer to Table 3-5 and consider whether this criterion should be + or – 5 dB.

Sampling of rooms for environmental noise

1. Measurements should be carried out and reported by a suitably qualified person following procedures in the latest version of the ANC Guide to Measurement of Sound Levels in Buildings.
2. Specific rooms for sampling should be agreed with the local authority, or at least notified to them in writing, prior to commencing measurements.
3. Environmental noise levels may be measured in a representative sample comprising at least two dwellings on each façade where there are different provisions for façade sound insulation. The rooms sampled should include those most exposed to environmental noise ingress, i.e. those with the highest external noise impact and those most susceptible to external noise ingress due to the façade elements and element areas.
4. Measurements of mechanical services noise may be made in at least one in ten dwellings. Mechanical services noise should be free from audible tones or particular characteristics that attract attention.
5. A set of measurements in a dwelling may comprise measurements in all habitable rooms serviced by the mechanical systems, for ventilation and mitigating overheating separately. The measurements may be standardised to a reference reverberation time of 0.5 seconds across the frequency range, and corrected for background sound if required.

Worked example

Step 1: External noise levels impacting on the proposed development

B.55 The external free-field noise levels at each of four notional receptor locations are described in Table B-8. The four notional receptor locations correspond to the rooms, dwelling or groups of dwellings that are being assessed.

B.56 The noise levels have been determined by means of a combination of site noise survey and noise modelling. It is appropriate to provide full details of the method by which levels have been determined and include an estimate of uncertainty in the values. This portion of the assessment is omitted from this example for brevity.

B.57 For some receptor category noise levels, both North East and South West façades are considered, to illustrate potentially different approaches for differing overheating risk.

B.58 In some cases, more than one solution is considered; this leads to a large number of potential solutions illustrated in this worked example. The solutions are summarised at the end of this section.

Table B-8 Consider noise levels at four different receptors across the example site

External free-field noise level	Receptor A	Receptor B	Receptor C	Receptor D
Daytime $L_{Aeq,16h}$, dB	53	59	64	72
Night-time $L_{Aeq,8h}$, dB	45	52	59	67
Ventilation design case Night-time L_{AFmax}, dB	63	69	78	83
Overheating design case Night-time L_{AFmax}, dB	72	77	87	94

Notes **Ventilation design case Night- time L_{AFmax}** is the level that is not normally exceeded more than 10 times per night

Overheating design case Night- time L_{AFmax} is the level that is not normally exceeded.

Step 2: assessment

B.59 In all cases below, an assessment or specifications for noise from mechanical systems for ventilation should be carried out in accordance with Table 3-5.

Table B-9 Worked example of Step 2 assessment – considering the effect of potential ventilation strategies on the acoustic conditions

Receptor	Summary of ventilation strategies
A	ADF System 1. See notes in Table B-3. No further calculations provided beyond discussion in Table B-10 and summary of anticipated performance in Table B-14.
B	ADF System 3 (noting that System 1 may be feasible). Standard glazing and trickle vents with enhanced acoustic performance are required for ventilation – see discussion in Table B-11 and requirements in Table B-14. Detailed calculations presented (omitted from this worked example for brevity).
C	ADF System 3. Windows and trickle vents enhanced acoustic performance are required. See discussion in Table B-12 and summary of calculated requirements in Table B-14. Detailed calculations presented (omitted here for brevity)
D	ADF System 4. High performance acoustic glazing is required – see discussion in Table B-13 and summary of requirements in Table B-14. Detailed calculations presented (omitted from this worked example for brevity)

Step 3: assessment

B.60 It may be helpful to mark up different facades with the various constraints for ventilation strategies and strategies for mitigating overheating in different dwellings.

B.61 Those receptors that are considered "negligible risk" from the Level 1 assessment according to Table 3-2 do not require any further qualification of the overheating strategy to inform the acoustic strategy. This should not be construed as a comment on the overheating risk of the design – simply that there are no acoustic constraints on the use of opening windows to control overheating.

B.62 In this example, no receptors fall into the "low risk" category according to Table 3-2. Where receptors do fall into this category, a Level 1 assessment is likely to be sufficient.

B.63 For the receptors that are considered "medium" or "high risk" from the Level 1 assessment according to Table 3-2, a detailed overheating assessment has been carried out in accordance with CIBSE TM59. This demonstrates that on the north eastern elevations, open windows are required infrequently for a relatively short portion of the year. On the south-western elevations, opening windows are required frequently and extensively through the summer season.

B.64 Worked examples of Step 3 assessments for each receptor are set out in Tables B-10, B-11, B-12, and B-13.

B.65 For the purpose of this worked example, noise levels are associated with the levels of adverse effect noted in Figure 3-2, as illustrated by the AVO Diagrams shown in Figure B-2 and B-3.

B.66 For the purpose of this worked example, based on a level difference of 13 dB between inside and out, external levels can be determined for a Level 1 assessment to distinguish between different categories.

Figure B-2 'AVO Diagram' indicating noise levels associated with adverse effects during the daytime used in this worked example

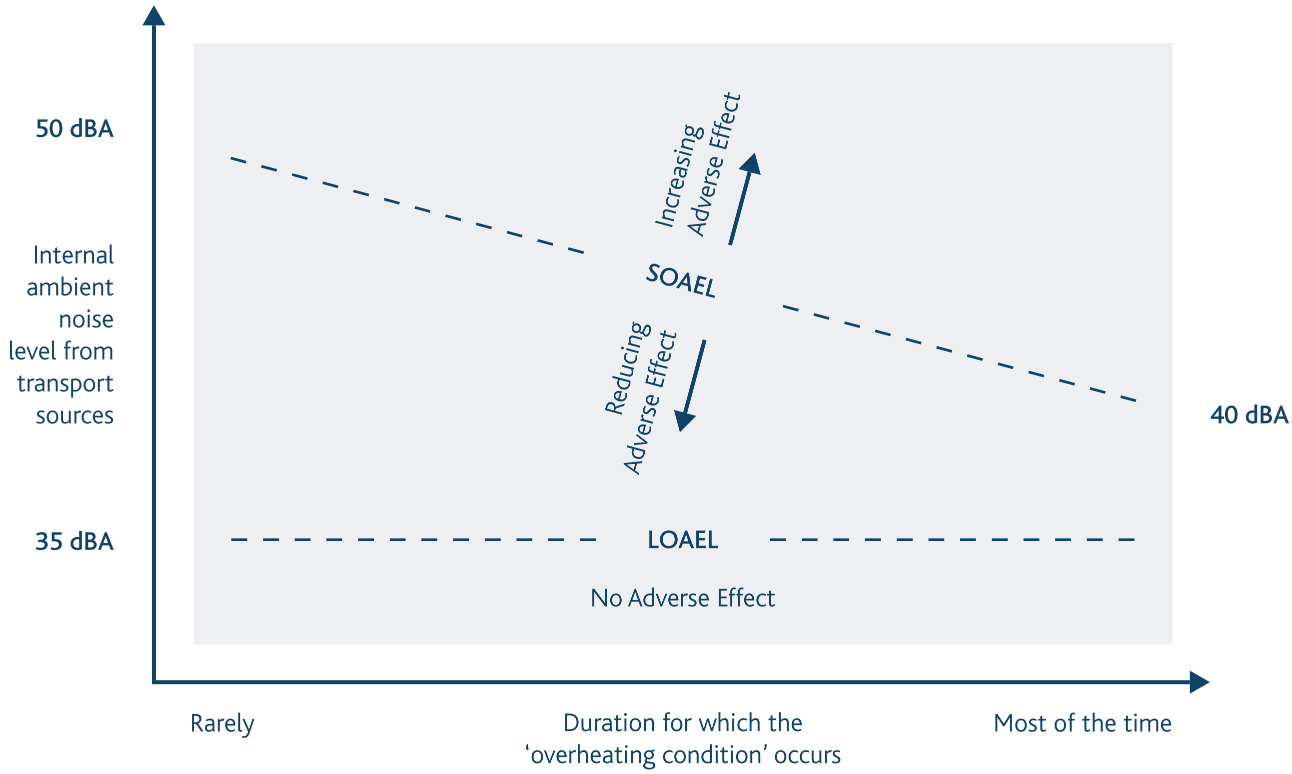


Figure B-3 'AVO Diagram' indicating noise levels associated with adverse effects during the night-time used in this worked example

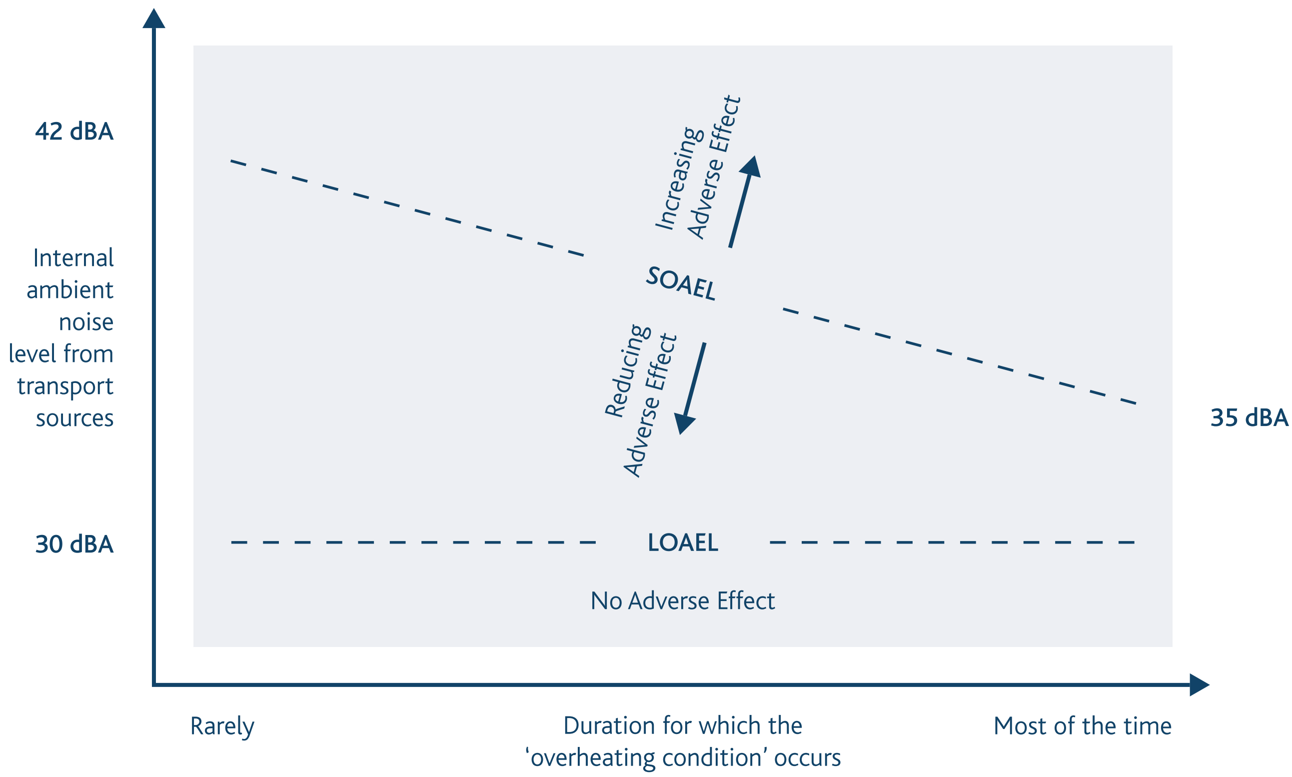


Table B-10 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor A

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 risk assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ **53** **Night-time** $L_{Aeq,8h}$ **45** **Overheating design case** L_{AFmax} **72**	Negligible	The negligible risk category according to the Level 1 assessment indicates that internal levels are expected to achieve BS 8233 reasonable conditions if overheating control is provided by means of partially open windows. When windows are partially open, there is a negligible risk of adverse effects; no further noise assessment is proposed in this example. An overheating assessment may therefore assume opening windows without acoustic constraint, and no special facade sound insulation features are required.	Not required - on basis of Level 1 assessment

Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 1 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ 59 **Night-time** $L_{Aeq,8h}$ 52 **Overheating design case** L_{AFmax} 77	Medium	**North east elevations, all room types** The overheating assessment indicates a low risk of overheating. The anticipated internal levels with a partially open window (13 dB attenuation) to control overheating would be 46 dB during the day and 39 dB at night, with overheating design case L_{AFmax} levels up to 64 dB. Considering these levels on the AVO diagrams below, these levels are below the "SOAEL" level, and below a level at which noise causes a material change in behaviour in Table 3-3. They are considered to be suitable for occupants given the relatively low overheating risk, and hence limited periods of time that windows are required to be open to mitigate overheating, especially during the night-time period.	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Illustration of daytime conditions is shown below:

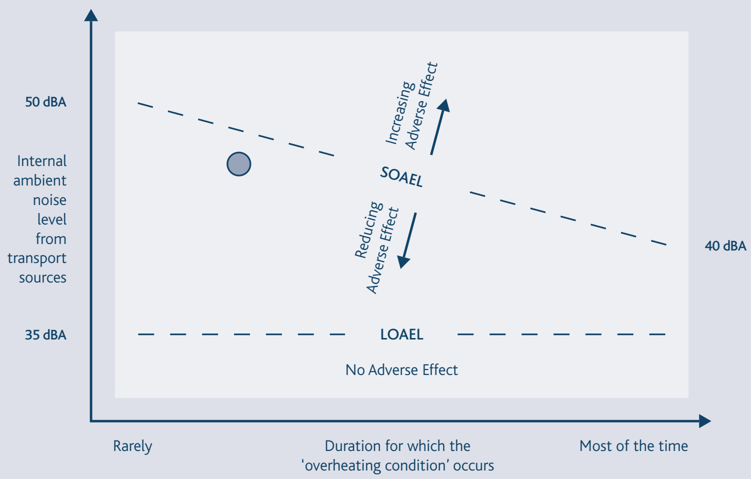


Illustration of night-time conditions is shown below:

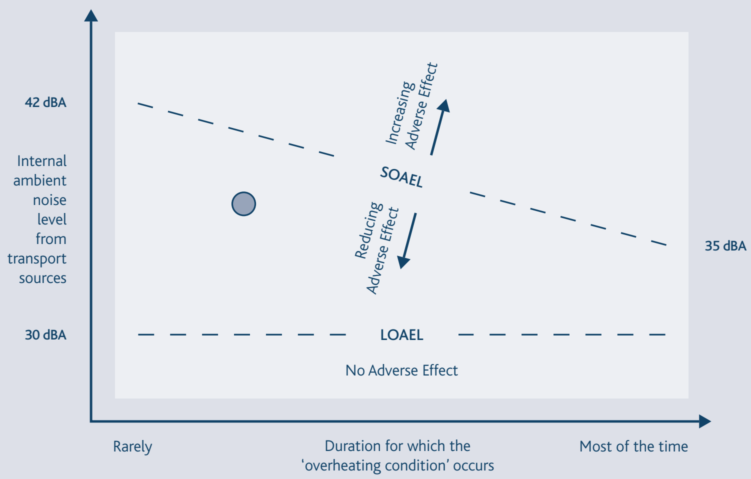


Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 2 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
		South west elevations, living rooms The overheating assessment indicates a high risk of overheating. **Scenario 1 – Mitigation of noise** Standard opening windows are not considered to be a suitable solution for SW elevations because of the higher overheating risk meaning that open windows are required more often and for longer periods, including during the night-time. These elevations therefore incorporate measures to mitigating the noise impact. Living rooms have balconies that enable staggered openings into the balcony area, containing sound absorption, so that opening windows are protected from direct noise impact. Detailed calculations demonstrate that the balcony and opening window arrangement achieve a level difference of 17 dB for the incident noise spectrum, while providing sufficient open area to enable control of overheating (the acoustician should cross-reference assumptions regarding open areas used in the overheating assessment). Thus, while mitigating overheating, the internal noise level is calculated to be 42 dBA during the daytime. This level is considered to be below a SOAEL on the AVO Diagram (see AVO Diagram below), and therefore considered suitable for the number of occasions for which open windows are required. An alternative approach to balconies may be to use passive attenuated vents.	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Illustration of daytime conditions is shown below:

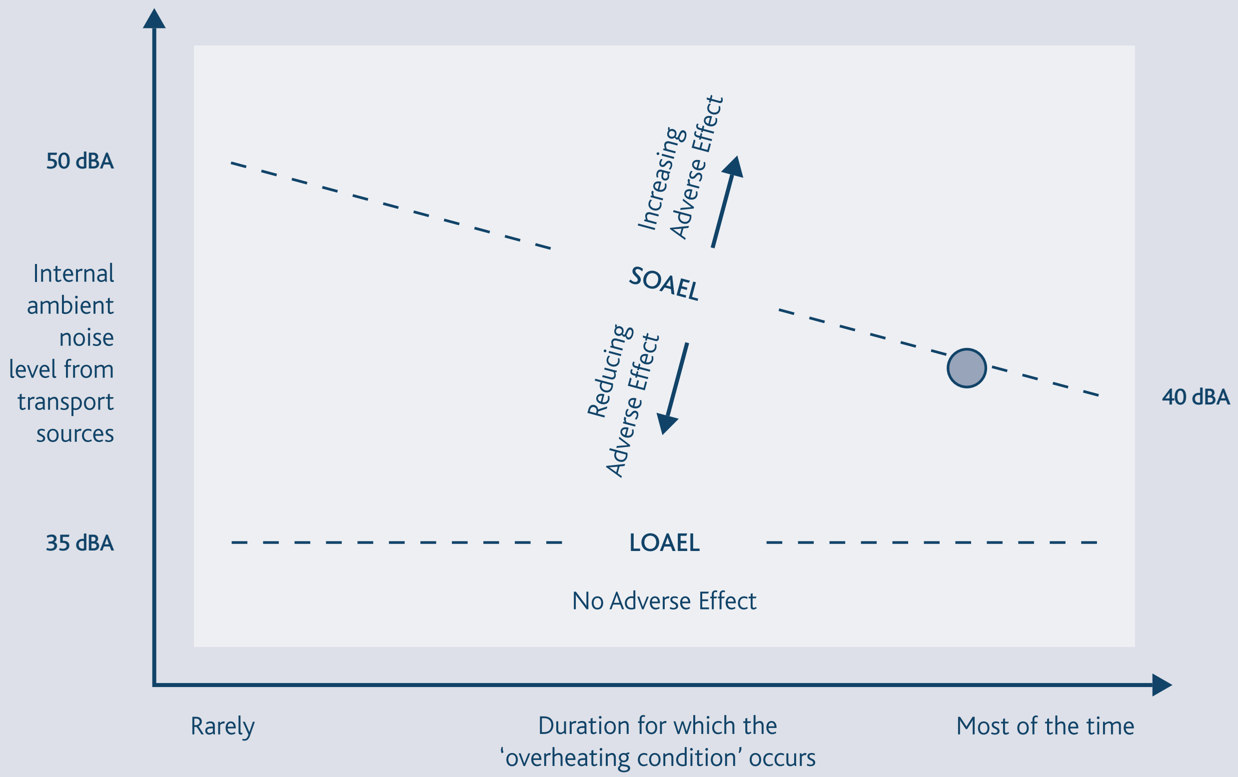


Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 3 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
		South west elevations, living rooms **Scenario 2 – Mitigation of overheating** Standard opening windows are not considered to be a suitable solution for SW elevations because the higher risk of overheating means that windows are required to be open more often. Design team are informed of the environmental noise constraint in relation to opening windows. Design changes are made to the building envelope to reduce heat entering the building. Window sizes are reduced, solar control glazing is introduced (lower G value), solar shading is added and insulation amended. There is enhanced provision of thermal mass and high ceilings with ceiling fans provided. The Good Homes Alliance Early Stage Overheating Risk Tool score is reduced from "High risk" to "Low risk". The risk of overheating is substantially reduced and hence windows are required to be open less frequently and for a shorter duration. As for the NE elevation, the anticipated internal levels with a partially open window would be 46 dBA during the day. The AVO Diagram below illustrates that these levels are considered to be below the significant adverse effect level, and are therefore considered to be suitable for occupants given the low overheating risk, and limited periods of time that windows are required to be open to mitigate overheating.	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Illustration of daytime conditions is shown below:

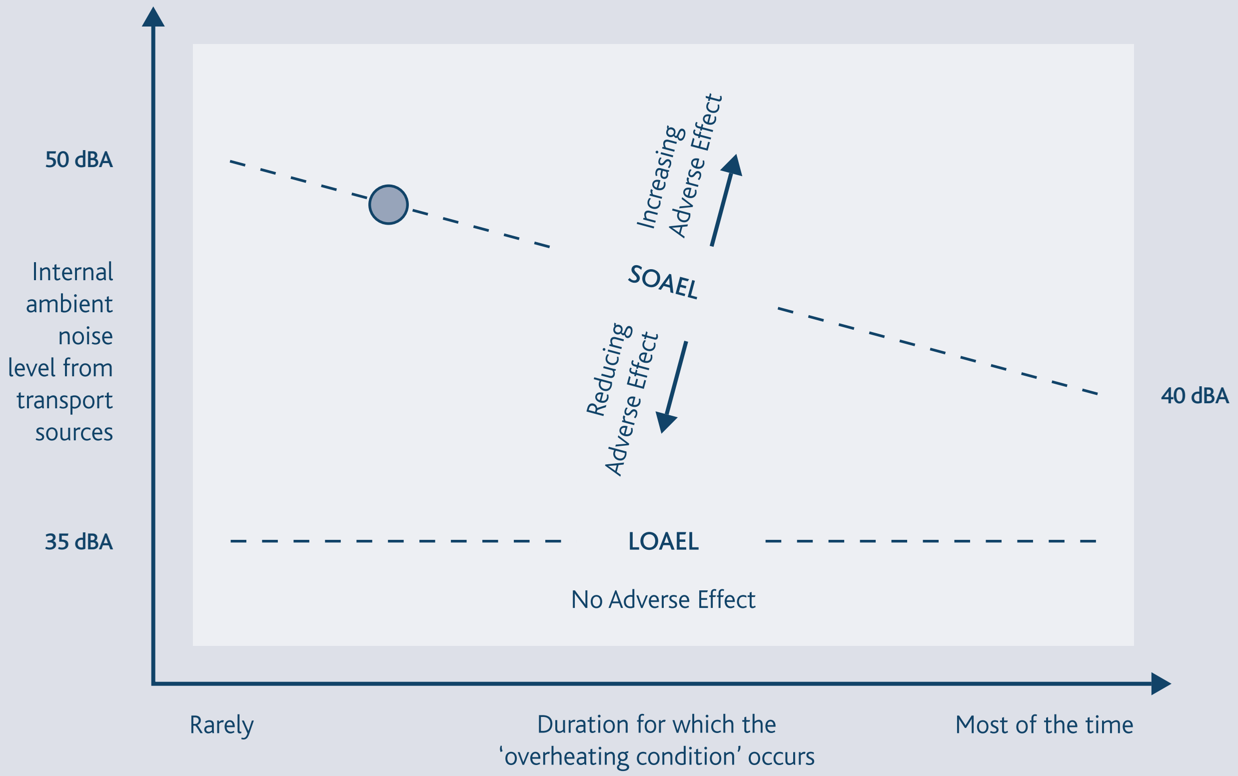


Table B-11 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor B **- Part 4 of 4**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
		South west elevations, bedrooms The overheating assessment indicates a high risk of overheating. Standard opening windows are not considered to be a suitable solution for SW elevations because the higher risk of overheating means that windows are required to be open more often. These elevations incorporate measures to mitigating the noise impact. Bedrooms have plenum windows that are calculated to provide a level difference between outside and in of 19 dB for road traffic noise, based on the measured incident noise spectra. An attenuation of 22 dB is calculated for the typical spectrum associated with L_{AFmax} noise from events. The overheating assessment confirms that the plenum window dimensions are adequate to suitably mitigate overheating (the acoustician should cross-reference assumptions used in the overheating assessment). Thus, while mitigating overheating, an internal noise level of $L_{Aeq,8h}$ 33 dB is calculated (detailed calculations presented in accordance with the detailed method in BS 8233). This value is not more than 5 dB above the lowest category according to Table 3-3, and therefore may be considered "Reasonable" according to ProPG. This sits comfortably on the AVO Diagram shown below. Maximum noise levels from events are calculated to be up to 55 dB L_{AFmax} for the Overheating Design Case. This is significantly below the level of the upper category according to Table 3-3, and is proposed as suitable in this case.	Increasing likelihood of adverse impact, on the basis of Overheating D/C L_{AFmax} level.

Illustration of night-time conditions is shown below:

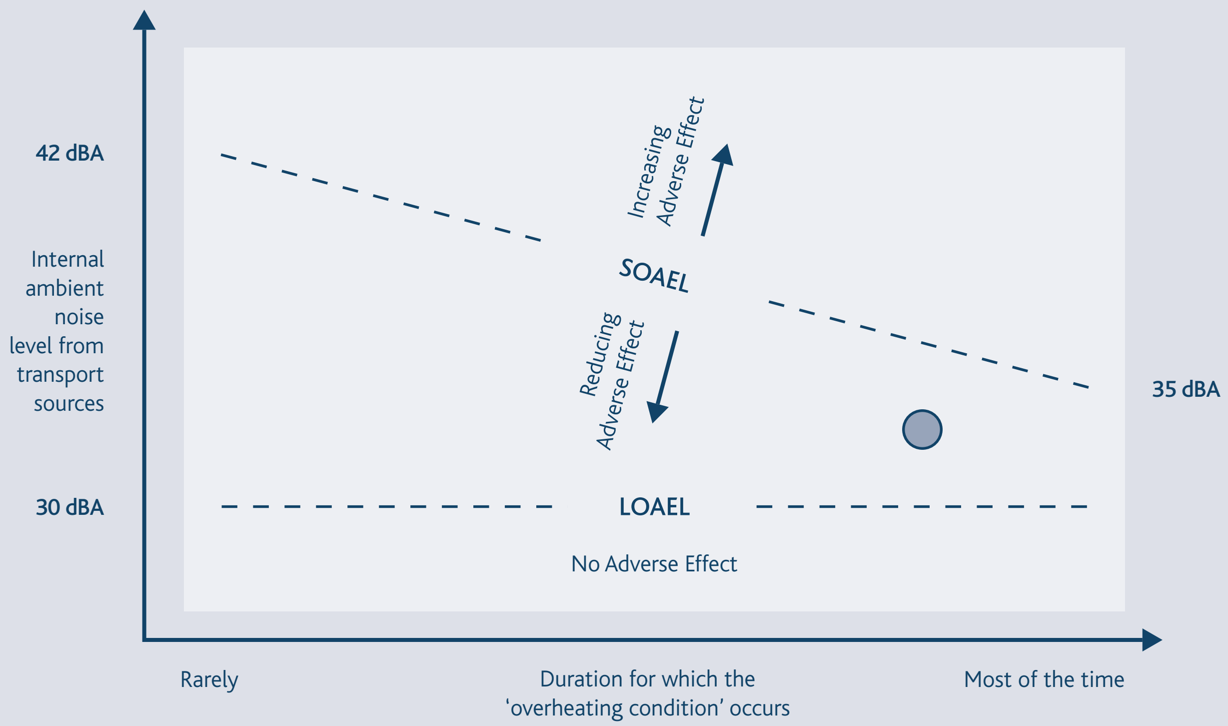
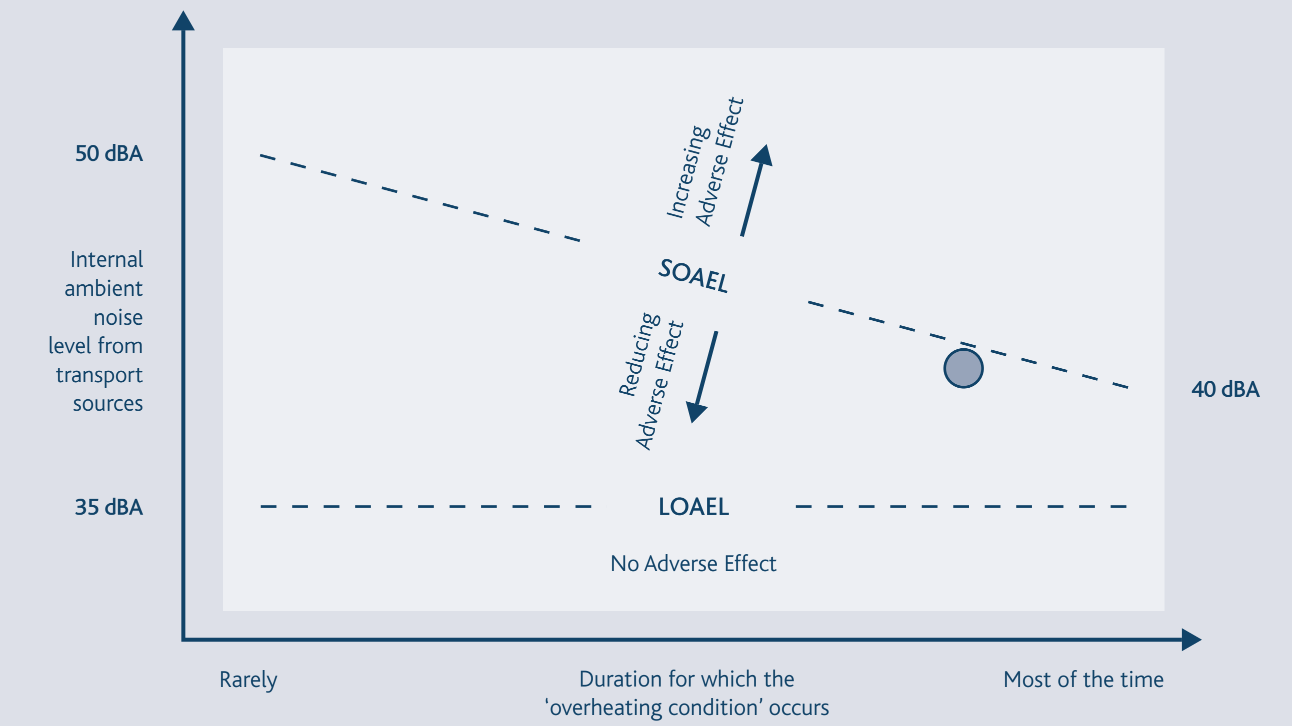


Table B-12 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor C **- Part 1 of 2**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ **64** **Night-time** $L_{Aeq,8h}$ **59** **Overheating design case** L_{AFmax} **87**	High	**Southwest Elevations – Living Rooms and Bedrooms** The overheating assessment indicates a high risk of overheating. Standard opening windows are not considered to be a suitable solution for mitigating overheating. These dwellings incorporate large attenuated vents for mechanical ventilative cooling, provided with an integrated fan. Both living rooms and bedrooms have acoustically attenuated vents (2.25 m high by 1.0 m wide) that are calculated to achieve a level difference between outside and in, in combination with the other façade components, of 23 dB for road traffic noise, based on the measured incident noise spectra, and 27 dB for noise from events, L_{AFmax}. The overheating assessment confirms that the ventilation rates are adequate to suitably mitigate overheating (the acoustician should cross-reference assumptions used in the overheating assessment). An assessment of mechanical ventilative cooling noise is also required in accordance with Table 3-6. Thus, while mitigating overheating, internal noise levels are calculated to be L_{Aeq},16h 41 dB during the daytime and $L_{Aeq,8h}$ 36 dB during the night-time. Internal noise from the overheating design case for events is calculated to be L_{AFmax} 60 dB. Calculations in accordance with the detailed method in BS 8233 are presented (omitted here for brevity). The continuous equivalent levels are considered to be below the significant adverse effect level for all building façade aspects, and therefore suitable for the number of occasions for which vents are required to be open. The noise from events is also considered to be suitable with these mitigation measures, despite being above the lowest observable adverse effect level. Illustration of daytime condition with mitigation is shown immediately below, with the night-time condition illustrated further below.:	Increasing likelihood of adverse impact, but for limited duration. Considered to be below a significant adverse effect for this combination of level and duration.

Table B-12 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor C **- Part 2 of 2**

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 assessment	Level 2 assessment (in line with Table 3-3, with mitigation)



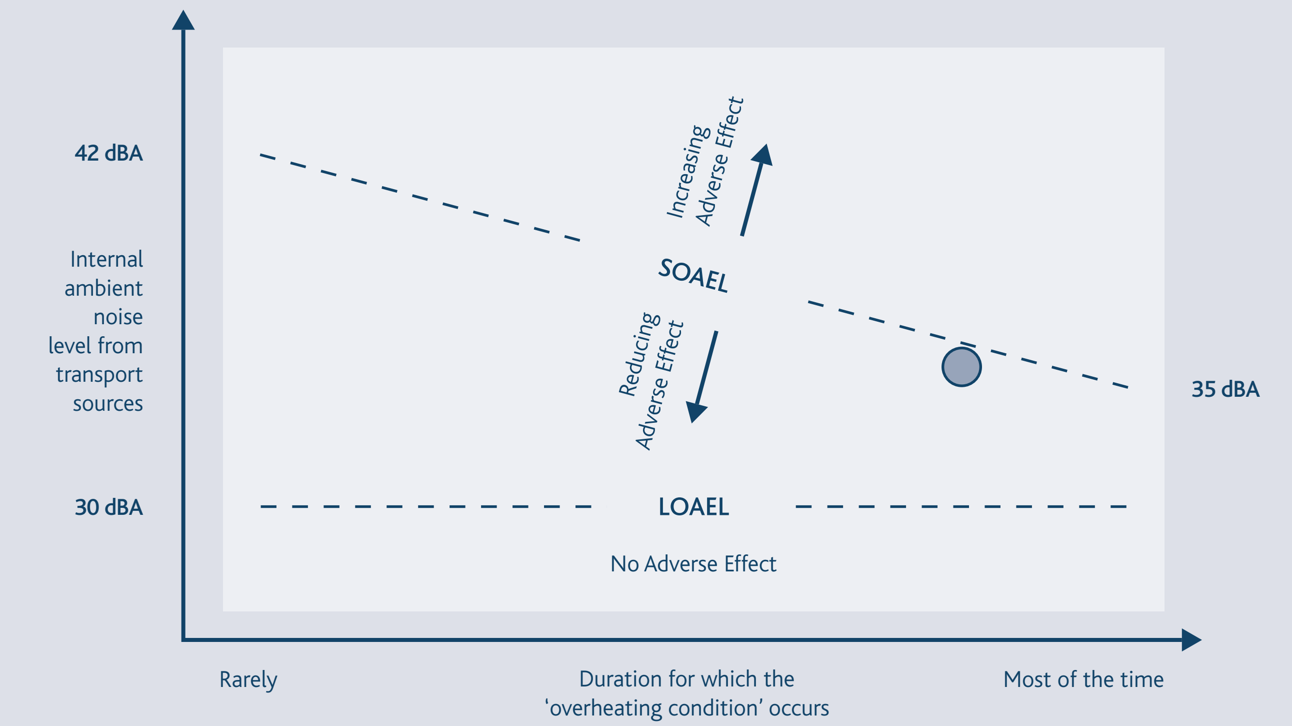


Table B-13 Worked example of Step 3 assessment – considering the effect of potential overheating mitigation strategies on the acoustic conditions – Receptor D

External free-field noise level (dB)	Level 1 risk assessment (in line with Table 3-2)	Notes on overheating mitigation and requirement for Level 2 risk assessment	Level 2 assessment (in line with Table 3-3, with mitigation)
Daytime $L_{Aeq,16h}$ **72** **Night-time** $L_{Aeq,8h}$ **67** **Overheating design case** L_{AFmax} **94**	High	**All Elevations – Bedrooms and Living Rooms** For these noise levels, opening windows are not considered appropriate even for the limited durations of use that are calculated. Windows are still openable for rapid dilution of smells/water vapour/VOCs. Mechanical cooling is proposed to manage thermal comfort in conjunction with the MVHR ventilation system. An assessment of mechanical noise is required, in accordance with Table 3-6.	Noise can be heard, but does not cause adverse impact internally with windows closed.

Summary of Mitigation

B.67 Table B-14 summarises the façade mitigation strategies in the worked example, the level differences achieved and calculated internal levels.

B.68 The minimum performance requirements for the relevant elements of the building envelope are noted, and potential generic products identified.

B.69 For simplicity and clarity, calculations of expected outside to inside sound insulation are made using a single-figure $R_w + C_{tr}$ or $D_{n,e,w} + C_{tr}$ / R_w or $D_{n,e,w}$, and based on a notional room of 3.0 * 2.5 * 2.4 m dimensions, with glazing to 25 % of the façade area and a 0.5 s reverberation time.

B.70 The external wall performance is calculated based on a performance of 63 (-15) dB R_w ($+C_{tr}$), such as a cavity masonry external wall build up.

Table B-14 Summary of minimum element performance requirements and associated level differences achieved **- Part 1 of 2**

Location	External free-field noise levels (dB)	Ventilation Condition: Design	Ventilation Condition: Element performances	Ventilation Condition: Expected Outside-to-inside sound insulation (dB)	Ventilation Condition: Expected internal ambient noise levels (dB)	Overheating Condition: Orientation	Overheating Condition: Room Type	Overheating Condition: Design	Overheating Condition: Element performances	Overheating Condition: Expected Outside-to-inside sound insulation (dB)	Overheating Condition: Expected internal ambient noise levels (dB)	Overheating Condition: Occurrence	Overheating Condition: Level 2 Assessment
A	$L_{Aeq,16h}$ 53 $L_{Aeq,8h}$ 45 Vent D/C L_{AFmax} 63 O'heat D/C L_{AFmax} 72	ADF Sys. 1	Glazing: 31 (-6) dB R_w (C_{tr}) e.g. 4/16/4 mm double glazing Trickle vent: 34 (-1) dB $D_{n,e,w}$ (C_{tr})	$L_{Aeq,T}$ 23 L_{AFmax} 25	$L_{Aeq,16h}$ 30 $L_{Aeq,8h}$ 22 D/C: L_{AFmax} 38	All	B&L	Standard opening windows	See Table B-5	L_{AeqT} 13 L_{AFmax} 13	$L_{Aeq,16h}$ 40 $L_{Aeq,8h}$ 32 D/C: L_{AFmax} 59	N/A	Not required
B	$L_{Aeq,16h}$ 59 $L_{Aeq,8h}$ 52 Vent D/C L_{AFmax} 69 O'heat D/C L_{AFmax} 77	ADF Sys. 3	Glazing: 31 (-6) dB R_w (C_{tr}) e.g. 4/16/4 mm double glazing Trickle vent: 34 (-1) dB $D_{n,e,w}$ (C_{tr})	$L_{Aeq,T}$ 24 L_{AFmax} 27	$L_{Aeq,16h}$ 35 $L_{Aeq,8h}$ 28 D/C: L_{AFmax} 42	NE	B&L	Standard opening windows	See Table B-5	L_{AeqT} 13 L_{AFmax} 13	$L_{Aeq,16h}$ 46 $L_{Aeq,8h}$ 39 D/C: L_{AFmax} 64	Rarely	Increasing likelihood of adverse impact, but for limited duration. Below a significant adverse effect.
						SW	L Sc1	Open windows with sound att. balconies	See Table B-5	L_{AeqT} 17	$L_{Aeq,16h}$ 42	Often	Low end of Increasing likelihood of adverse impact. Below a significant adverse effect.
							L Sc2	Standard opening windows	See Table B-5	L_{AeqT} 13	$L_{Aeq,16h}$ 46	Occasionally	Increasing likelihood of adverse impact, but for limited duration. Below a significant adverse effect.
						SW	B	Plenum windows	See Table B-5	L_{AeqT} 19 L_{AFmax} 22	$L_{Aeq,16h}$ 40 $L_{Aeq,8h}$ 33 D/C: L_{AFmax} 55	Often	Increasing likelihood of adverse impact. Below a significant adverse effect.

Table B-14 Summary of minimum element performance requirements and associated level differences achieved **- Part 2 of 2**

Condition	Location	C	D
	External free-field noise levels (dB)	$L_{Aeq,16h}$ 64 $L_{Aeq,8h}$ 59 Vent D/C L_{AFmax} 78 O'heat D/C L_{AFmax} 87	$L_{Aeq,16h}$ 72 $L_{Aeq,8h}$ 67 Vent D/C L_{AFmax} 83 O'heat D/C L_{AFmax} 94
Ventilation Condition	Design	ADF Sys. 3	ADF Sys. 4
Ventilation Condition	Element performances	Glazing: 38 (-5) dB R_w (C_{tr}) e.g. 6/16/6.8 mm acoustic double glazing. Trickle vent: 40 (-2) dB $D_{n,e,w}$ (C_{tr}) Closed overheating vent: 52(-6) dB $D_{n,e,w}$ (C_{tr})	Glazing: 43 (-7) dB R_w (C_{tr}) e.g. 8/16/9.1 mm acoustic double glazing
Ventilation Condition	Expected Outside-to-inside sound insulation (dB)	$L_{Aeq,T}$ 30 L_{AFmax} 33	$L_{Aeq,T}$ 37 L_{AFmax} 45
Ventilation Condition	Expected internal ambient noise levels (dB)	$L_{Aeq,16h}$ 34 $L_{Aeq,8h}$ 29 *D/C:* L_{AFmax} 45	$L_{Aeq,16h}$ 35 $L_{Aeq,8h}$ 30 *D/C:* L_{AFmax} 38
Overheating Condition	Orientation	SW	All
Overheating Condition	Room Type	B&L	B&L
Overheating Condition	Design	Acoustic vents, mechanical ventilative cooling	Mechanical cooling
Overheating Condition	Element performances	Glazing and trickle vent performances as for ventilation condition Open overheating vent: 33(-4) dB $D_{n,e,w}$ (C_{tr})	As for ventilation condition
Overheating Condition	Expected Outside-to-inside sound insulation (dB)	$L_{Aeq,T}$ 23 L_{AFmax} 27	As for ventilation condition
Overheating Condition	Expected internal ambient noise levels (dB)	$L_{Aeq,16h}$ 41 $L_{Aeq,8h}$ 36 *D/C:* L_{AFmax} 60	$L_{Aeq,16h}$ 35 $L_{Aeq,8h}$ 30 *D/C:* L_{AFmax} 49
Overheating Condition	Occurrence	SW - Often	As required (no acoustic constraints)
Overheating Condition	Level 2 Assessment	Increasing likelihood of adverse impact. Below a significant adverse effect.	Negligible (for external noise, with windows closed)

C Appendix C – sound insulation of a partially open window

Sound Insulation for a Partially Open Window

For the purposes of this guide, the sound insulation is quantified in terms of the difference between the external free-field noise level at the location of the façade and the internal reverberant level in the room. Reference is made to two studies [43, 57] in order to provide an estimate of the typical level difference for a partially open residential window.

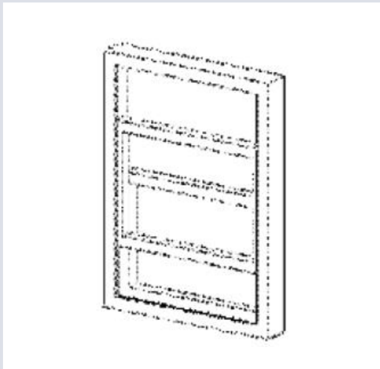
Field Study [57]

Field measurements were made in 102 traffic noise affected dwellings in Switzerland. The study distinguishes between 'open' and 'tilted' windows. No measurements of window size or open area were made, but the images show typical situations.

They measured (free-field) outside-to-inside level differences of 10.0 ± 2.9dB for open windows and 15.8 Open ± 2.7dB for tilted windows. A value of 13dB is consistent with a situation between 'open' and 'tilted'

Open

Tilted



Window Type D-1

Lab Study [43]

Laboratory measurements were made for 14 window types/arrangements with various degrees of opening. The derived Dn,e results for a 0.2m² area of opening are summarised in Table 5-5 of the document. The values for window type D-1 (Sash window with upper section open – see image) have been used to represent a conservative situation. If the area of opening is assumed to be 2% of the floor area of the room, the D2m,nT will be approximately equal to the Dn,e. Window type D-1 has Dn,e,w(C;Ctr)=16(0;0). Applying a 3dB correction between L1,2m and the free-field value suggests an outside-to-inside level difference of 13dB. It is worth noting that hinged opening windows (e.g. types C-3, D-3, E) were found to provide level differences that were 1-2dB higher. Benefits may also be achieved for off-axis, directional sources. However, it was not considered advisable to include these factors when estimating a typical performance.

References

- Part 1 of 4

Ref	Title	Author/Publisher	Year
1	ProPG Planning & Noise – New Residential Development	ANC/IOA/CIEH	2017
2	Using planning conditions to improve indoor environmental quality (IEQ) of new residential developments	Conlan, N and Harvie-Clark, J Acoustics 2018, IOA Proceedings Volume 40, Part 1, p77-86	2018
3	Approved Document F – Ventilation (2010 edition incorporating 2010 and 2013 amendments)	HM Government	2015
4	TM59 Design methodology for the assessment of overheating risk in homes	Chartered Institution of Building Services Engineers	2017
5	UK housing: Fit for the future?	Committee on Climate Change	2019
6	Next Steps in Defining Overheating	Zero Carbon Hub	2016
7	Passive House Planning Package	Passive House Institute	2015
8	Overheating in New Homes	Good Homes Alliance	2019
9	The London Plan	Greater London Authority	2016
10	Noise Policy Statement for England	Department for Environment, Food & Rural Affairs	2015
11	National Planning Policy Framework	Department for Communities and Local Government	2012
12	Planning Practice Guidance (Noise)	Department for Communities and Local Government	2012
13	British Standard 8233:2014 Guidance on sound insulation and noise reduction for buildings	British Standards Institution	2014
14	Guidelines for Community Noise	World Health Organisation	1999
15	Environmental Noise Guidelines for the European Region	World Health Organisation	2018
16	Night Noise Guidelines for Europe	World Health Organisation	2009
17	Aircraft noise effects on sleep: application of the results of a large polysomnographic field study	Basner, M, Samel, A and Isermann, U Journal of the Acoustical Society of America, Volume 119, 5 (Part 1), p2772–84	2006
18	WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep	Basner, M and Mcguire, S International Journal of Environmental Research and Public Health, Volume 15 (3), p519	2018

References

Ref	Title	Author/Publisher	Year
19	Building our Future: Laying the Foundations for Healthy Homes and Buildings White paper	All Party Parliamentary Group	2018
20	How loud is too loud? Noise from domestic mechanical ventilation systems	Harvie-Clark, J, Conlan, N, Wei, W and Siddall, M International Journal of Ventilation	2019
21	Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet	Department for Environment, Food & Rural Affairs	2014
22	Assessing L_{max} for residential developments: the AVO Guide Approach	Paxton, B, Conlan, N, Harvie-Clark, J, Chilton, A, Trew, D Acoustics 2019, IOA Proceedings Volume 41 Part 1	2019
23	Guidelines for Environmental Noise Impact Assessment	Institute of Environmental Management and Assessment	2014
24	Understanding the role of inhabitants in innovative mechanical ventilation strategies	Brown, C and Gorgolewski, M Building Research & Information, Volume 43, Part 2, p210-221	2015
25	Ventilation in new homes – A report of site visit findings	Zero Carbon Hub	2016
26	Why this crisis in residential ventilation?	Hasselaar, E Indoor Air 2008, paper ID 690	2008
27	The relationship between health complaints, the quality of indoor air and housing characteristics.	Hady M, van Ginkel, J, Hasselaar, E and Schrijvers, G Indoor Air 2008, paper ID 153	2008
28	Mechanical ventilation in recently built Dutch homes: technical shortcomings, possibilities for improvement, perceived indoor environment and health effects	Balvers, J, Bogers, R, Jongeneel, R, van Kamp, I, Boerstra, A and van Dijken, F Architectural Science Review, Volume 55, Part 1, p4-14	2012
29	BS 8233:1999 Sound insulation and noise reduction for buildings (withdrawn)	British Standards Institution	1999
30	Guide A – Environmental Design	Chartered Institution of Building Services Engineers	2015
31	Sound Control for Homes	Building Research Establishment	1993
32	BS ISO 17772-1:2017 Energy performance of buildings. Indoor environmental quality. Indoor environmental input parameters for the design and assessment of energy performance of buildings	British Standards Institution	2017

References

Ref	Title	Author/Publisher	Year
33	Transport and Urban Development COST Action TU0901	European Cooperation in Science and Technology	2013
34	BS EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics	British Standards Institution	2007
35	ISO 7730:2005 Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria	International Organization for Standardization	2005
36	Approved Document L1A: Conservation of fuel and power in new dwellings (2013 edition with 2016 amendments)	HM Government	2016
37	Energy Planning — Greater London Authority guidance on preparing energy assessments	Greater London Authority	2016
38	Home Quality Mark Technical Manual	BRE Global Limited	2016
39	TM52 The Limits of Thermal Comfort: Avoiding Overheating in European Buildings	Chartered Institution of Building Services Engineers	2013
40	Standard Assessment Procedure	Department for Business, Energy & Industrial Strategy	2012
41	Housing Health and Safety Rating System	Ministry of Housing, Communities & Local Government	2006
42	Ventilative cooling. State-of-the-art review executive summary	Heiselberg, P & Kolokotroni, M (editors) Energy in Buildings and Community Programme http://venticool.eu/annex-62-publications/deliverables/	2017
43	NANR116 Open-Closed Window Research Report	Department of Environment, Food & Rural Affairs	2007
44	BS EN 1793-3:1998 Road traffic noise reducing devices. Test method for determining the acoustic performance. Normalized traffic noise spectrum	British Standards Institution	1998
45	BS EN 12354-3:2017 Building acoustics. Estimation of acoustic performance of buildings from the performance of elements. Airborne sound insulation against outdoor sound	British Standards Institution	2017

References

- Part 4 of 4

Ref	Title	Author/Publisher	Year
46	Technical housing standards – nationally described space standard	Department for Communities and Local Government	2015
47	BS EN 12758:2011 Glazing and airborne sound insulation. Product descriptions and determination of properties	British Standards Institution	2011
48	Green Book: Environmental Noise Measurement Guide	The Association of Noise Consultants	2013
49	A Review of Residential Balconies with Road Traffic Noise	Naish, D and Tan, A Proceedings of ICSV14	2007
50	Adopting Specially Designed Balconies to Achieve Substantial Noise Reduction for Residential Buildings	Yeung, M Proceedings of Internoise 16, p 1185-90	2016
51	Research and Development of Noise Mitigation Measures for Public Housing Development in Hong Kong - A Case Study of Acoustic Balcony	Hin-Leung Ho, J Proceedings of Internoise 16, p 1199-1207	2016
52	The field performance of partially open dual glazing	Kerry, G and Ford, R D Applied Acoustics, Volume 7, p 213-227	1974
53	Open windows with better sound insulation,	Sondergaard, L S and Egedal, R Proceedings of Internoise 16, p 1173-84	2016
54	Noise control strategies for naturally ventilated	De Salis, M H F , Oldham, D J and Sharples, S Building and Environment, Volume 37, p471-84	2002
55	Methods of Controlling Noise Levels and Overheating in Residential Buildings	Conlan, N and Harvie-Clark, J ICSV 24 Proceedings, p5674	2017
56	A review of ventilation opening area terminology	Jones, B M, Cook, M J, Fitzgerald, S D and Iddon, C R Energy and Buildings, Volume 118, p249-258	2016
57	Differences between Outdoor and Indoor Sound Levels for Open, Tilted, and Closed Windows	Locher, Wunderli et. al. International Journal of Environmental Research and Public Health, Volume 15(1), p149 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5800248/	2018

ACOUSTICS, VENTILATION AND OVERHEATING

Residential Design Guide

January 2020 This document is published by the Association of Noise Consultants

Association of Noise Consultants
19 Omega Business Village, Thurston Road, Northallerton DL6 2NJ
Tel: 0208 253 4518
Email: INFO@THEANC.CO.UK