Glasgow City Council

Tall Building Design Guide

Technical Appendices

Reference: TBDG-ARUP-ZZ-ZZ-RP-10002

02 | 03 July 2024

Job number 302388-00

Ove Arup & Partners Limited
7th Floor
1 West Regent Street
Glasgow
G2 1RW
United Kingdom
arup.com

Whole Life Carbon

Written by Camila Colhado Gallo, Arup

Introduction

This document describes the whole life carbon requirements for tall buildings in the city centre of Glasgow and aims to provide technical guidance and support for applicants.

This report will first provide useful definitions to aid its understanding. It will then provide some context as to why this document is required and how it will help Glasgow respond to the Climate Emergency. Then, it will guide applicants through the carbon related planning requirements for applications of tall building in the city centre of Glasgow. And, finally, it will provide more detail on the carbon calculation methodology, assumptions and deliverables at each planning stage.

Useful Definitions

Throughout this report, the term **Carbon** will be used to cover all greenhouse gases, including carbon dioxide (CO_2). As carbon emissions can be classified in different ways, this section will provide a brief explanation on the classifications to be used for planning applications.

Firstly, it is important to understand that there are two main types of carbon. The first one the most widely known type of carbon emissions and is related to the use of energy and water. This is called **Operational Carbon**.

The second type is the carbon related to ‘stuff’, called **Embodied Carbon**. In a building’s context, consider the carbon expended to make concrete, deliver and install it on site, and then recycle it at the end of the building’s service life (assumed to be 60 years[1]).

Embodied carbon also covers any carbon expended on or by ‘stuff’ during the building’s service life, e.g., facades are expected to be maintained, refurbished and/or replaced over 60 years, and some building service equipment can leak carbon intensive substances (refrigerants) while in use.

Embodied carbon emissions tend to be further categorised depending on when they are expected to happen over the building’s service life, as shown in Figure 1.

The term **Whole Life Carbon (WLC)** is simply the sum of Embodied and Operational carbon.

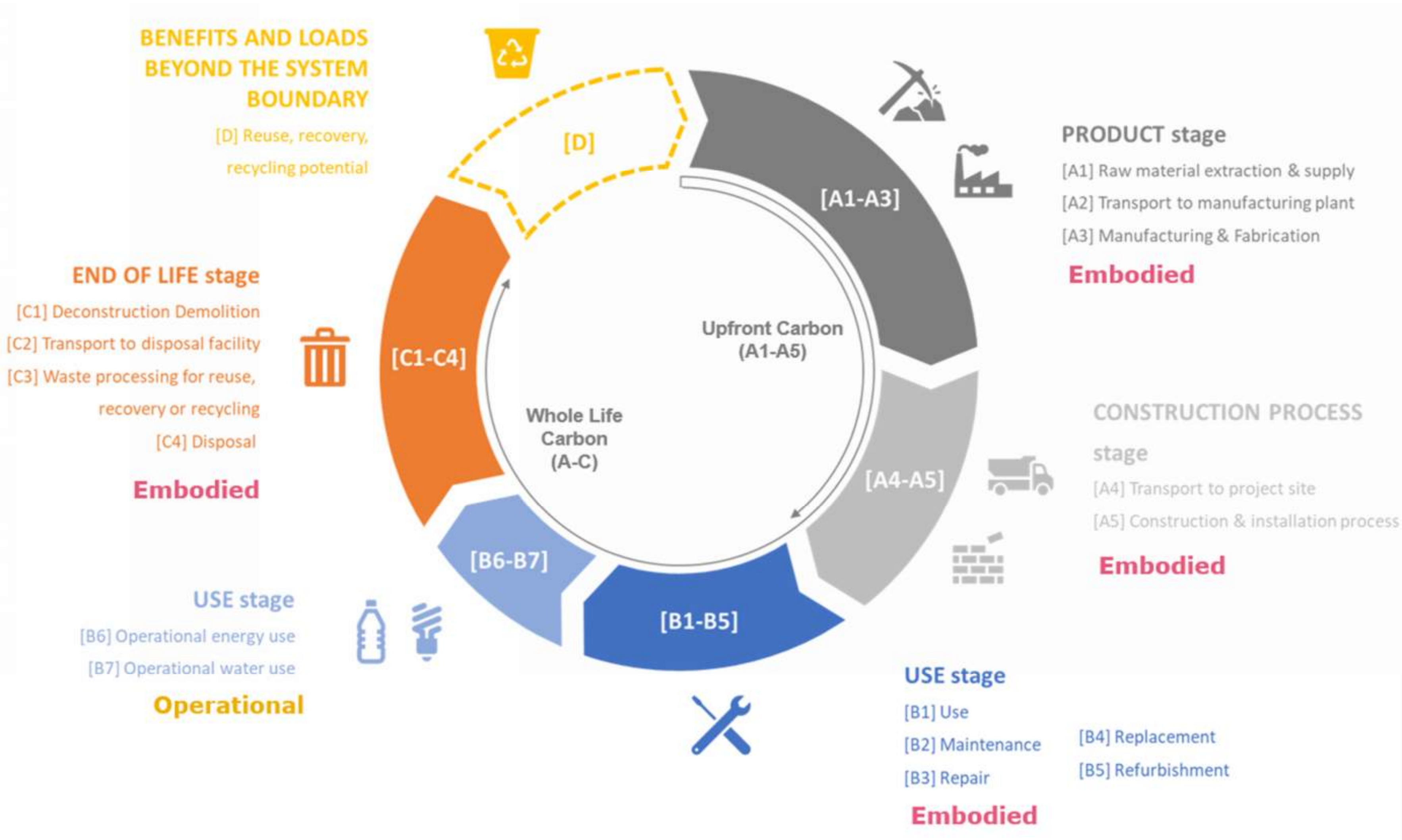


Figure 1 Life Cycle modules according to BS EN 15978:2011 (Source: Mecserve)

---

[1] RICS, “Whole life carbon assessment for the built environment, Version 2,” Royal Institution of Chartered Surveyors (RICS), London, 2023.

Context

As part of the Paris Agreement 2015, 196 parties (including the United Kingdom), agreed to work towards a target temperature increase of no more than 1.5ºC above pre-industrial levels. Severe climate events are predicted to happen if this target is not achieved, such as more frequent and extreme heatwaves, storms, flooding and droughts[2].

As a result, the Scottish First Minister officially declared a state of climate emergency in 2019 and called upon the nation to respond to the challenge of becoming net zero by 2045[3].

Within this context, the built environment is estimated to contribute approximately 42% of the UK's total greenhouse gas emissions.[4] Therefore, the construction industry must respond to the climate emergency and commit to the challenge of reducing their carbon emissions.

Assessing whole life carbon is the first step towards a reduction in the built environment's carbon emissions. While operational emissions of buildings are currently being tackled by many government policies, requirements to calculate and reduce embodied emissions are yet to be widely implemented. As the energy grid decarbonises, embodied carbon will become an increasingly prominent proportion of a building's life cycle emissions, as shown in Figure 2.

The calculation and reduction of carbon emissions for tall buildings is particularly important, as an increase in number of storeys is typically proportional to an increase in embodied carbon, as shown in Figure 3. The main reasons for this increased are discussed below:

Structural demands: tall buildings, which tend to be slender, create a disproportionally higher demand on vertical structures (e.g., core walls or braced bays) and foundations when compared to low and mid-rise buildings. As a result, much more material is required for these elements in tall buildings to provide the same performance as they would in a mid-low rise building.

Façade to floor area: the slender nature of tall buildings also mean that, inherently, the building will have a higher form factor (façade area to floor area ratio) than mid-low rise buildings. This means that more façade will have to be built (and carbon spent) for less occupiable area.

Moving people, water and energy at height: tall buildings require substantial core areas to accommodate a higher quantity of lifts and larger building services. As a result, these core areas, which are very material and carbon intensive, occupy a much higher percentage of the total building area when compared to mid-low rise buildings.

Given the global climate emergency and the impact that tall buildings can have in the environment, carbon related assessments will be required for planning applications of tall buildings in the city centre of Glasgow.

These assessments, which are described in the next sections, cover not only carbon measurement, but also requires applicants to show that alternative options to new builds have been considered and to demonstrate how applicants will minimise the carbon emissions of their projects.

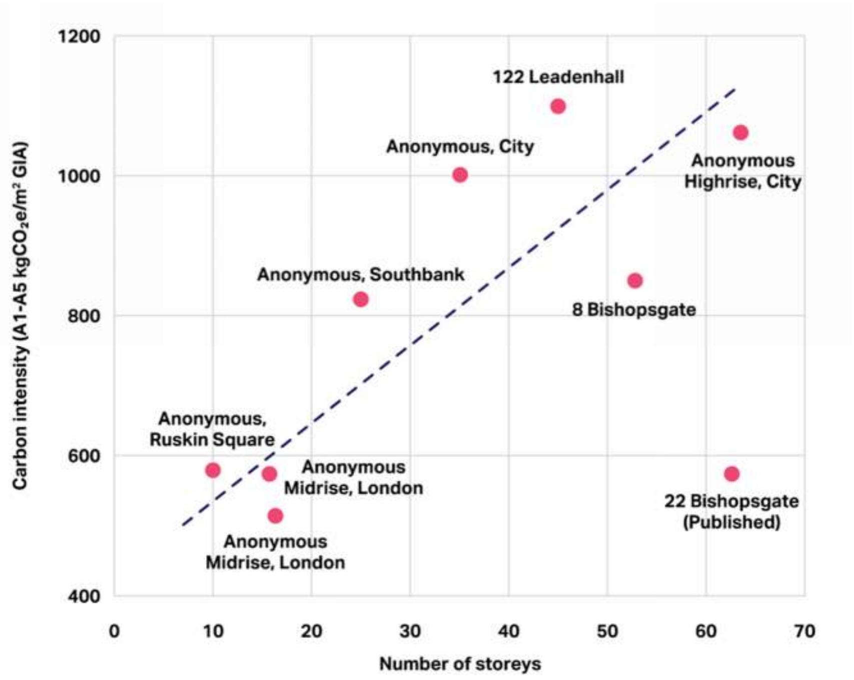


Figure 3 Carbon intensity of tall buildings[4]

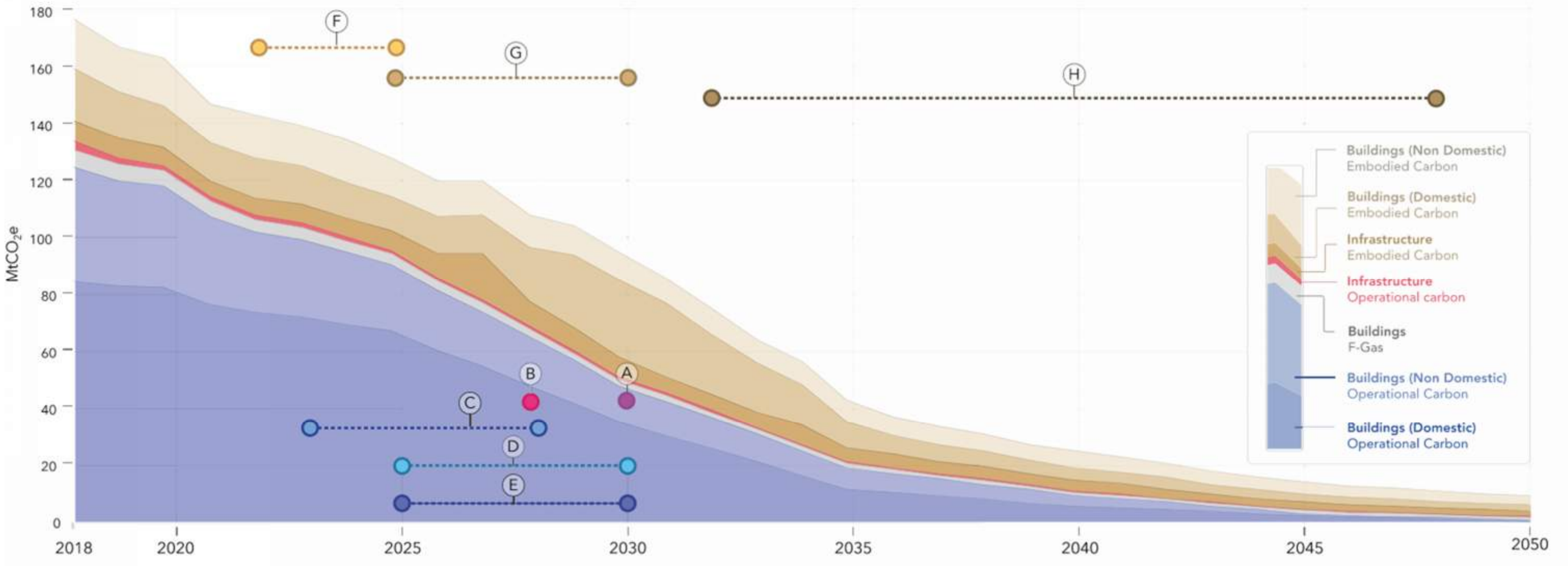


Figure 2 Projected emissions from 2018 to 2050[4]

---

[2] UNFCCC, "The Paris Agreement," United Nations Climate Change, [Online]. Available: https://unfccc.int/process-and-meetings/the-paris-agreement. [Accessed 28 June 2024].

[3] Cabinet Secretary for Net Zero and Energy, "Climate Change", Scottish Government, [Online]. Available: https://www.gov.scot/policies/climate-change/. [Accessed 28 June 2024].

[4] UK Green Building Council, "Net Zero Whole Life Carbon Roadmap – A Pathway to Net Zero for the UK Built Environment, UKGBC, 2021.

B2 Pre-Application Optioneering

The impact that design decisions can have on a project decrease as the project progresses (Figure 5). Therefore, it is crucial that whole life carbon is considered when developing a project's brief, and when considering different options for redevelopment, e.g., new build vs. refurbishment and extension of existing buildings.

Applicants should approach the **B2 Pre-Application Optioneering** process with an open mind and allow for flexibility in their brief to account for the outcomes of this exercise.

Establishing Options

The number and details of the options will vary depending on the project and are to be discussed/agreed during pre-application meetings. However, if a building already exists on site, the options must include **at least one light touch refurbishment and a deep retrofit option**.

Key considerations for early stages should follow the carbon reduction hierarchy presented in Figure 4.

B2 Pre-Application Optioneering: WLC Deliverables

Once the options have been agreed, **whole life carbon calculations should be carried out for each of the options** following the methodology and assumptions presented in the 'WLCA Methodology' section.

The deliverables listed below should be submitted during the pre-application process and used to inform the decision of a preferred option.

- A **Pre-redevelopment audit** should be carried out to inform the optioneering discussion.
- Whole life carbon calculations for each of the options as per 'WLCA Methodology' section.
    - The calculations should be **reviewed by an independent third-party**. Appendix 7 from the COL document has further information on this process.[5]
    - Results should be presented using the COL spreadsheets, which must be completed in full: carbon-options-tool.xlsx (live.com).
    - A **technical note** with the assumptions and methodology adopted for the calculations should be issued alongside the COL spreadsheets.
- A **Pre-demolition audit and a Circular Economy Statement,** if any demolition is to take place on site.

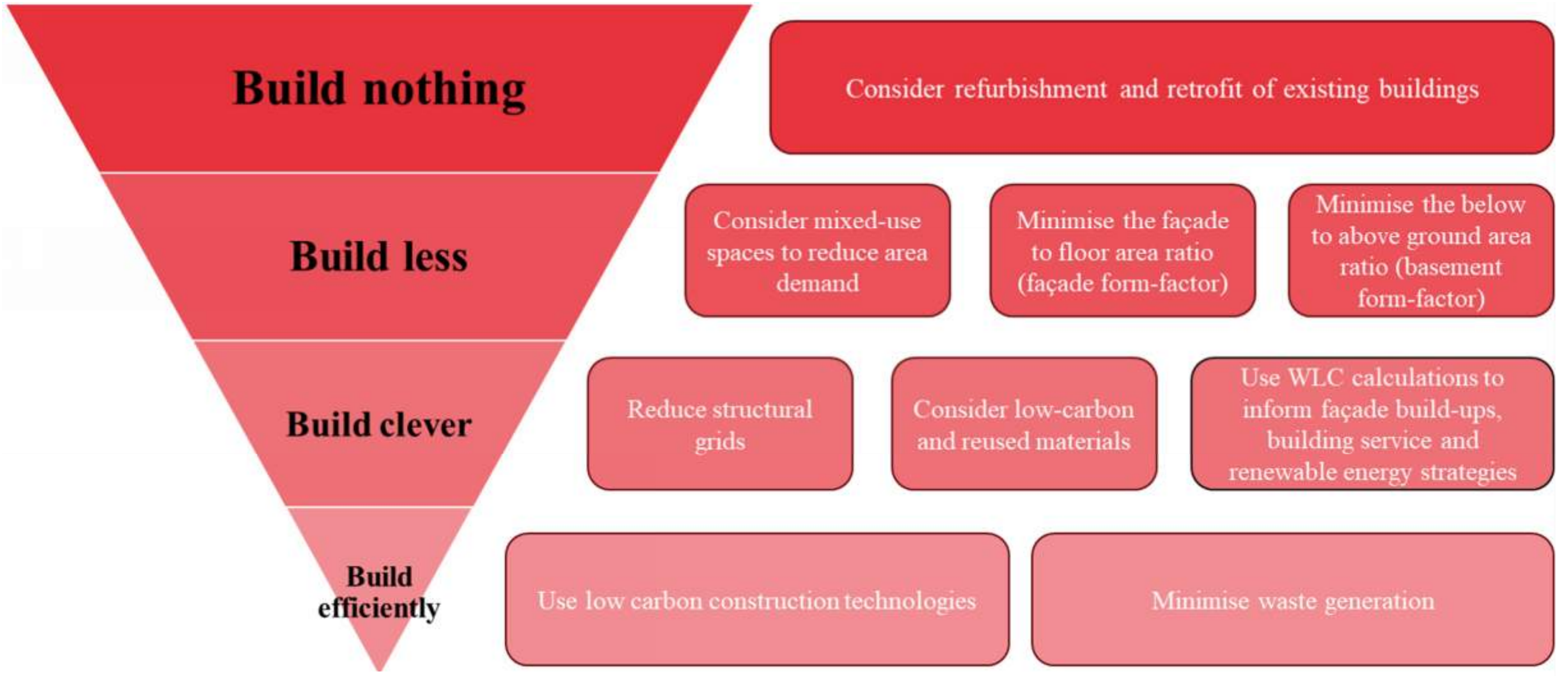


Figure 4 Carbon reduction hierarchy

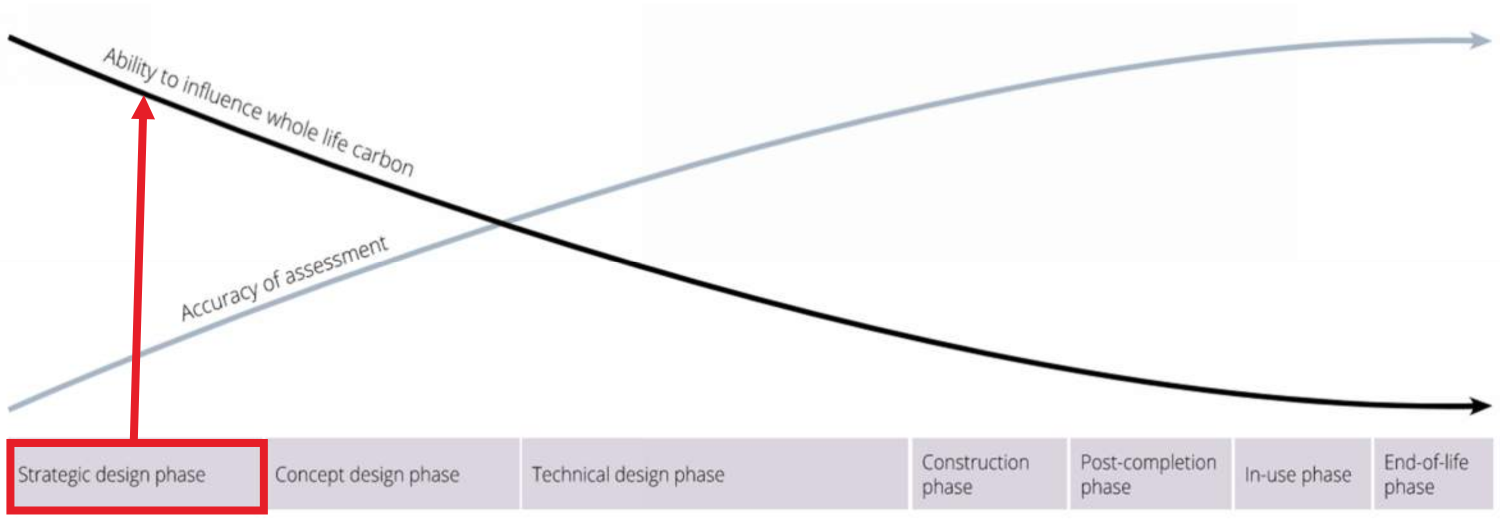


Figure 5 Decisions made during the strategic design phase have the potential to make the most impact in a project[1]

---

[5] City of London Corporation: Carbon options guidance.

B3 Design Development & Testing

The preferred option identified at B2 should continue to be tested during the B3 stage using the carbon reduction hierarchy shown in Figure 4.

Carbon optioneering studies should be carried out for the items below, as a minimum. The findings should be used to inform design decisions and the embodied carbon of the developing design should be monitored regularly.

- Foundation optioneering, structural grids and materiality
- Simplification of load paths, e.g., avoidance of transfer structures through coordination of structural grids and set-backs
- Facade composition and materiality
- Internal finishes strategy - omission of ceiling tiles are encouraged
- Building services strategy

C1 Planning Submission: Whole Life Carbon Assessment

Following the pre-app process, a more detailed whole life carbon calculation of the **preferred option** should be delivered as part of the Planning Application, following the methodology and assumptions presented in the 'WLCA Methodology' section.

This WLCA should be more detailed than the previous assessment delivered during pre-planning and based on design information.

C1 Planning Submission: WLC deliverables

The deliverables listed below should be submitted for Planning.

- Whole life carbon calculations as per the 'WLCA Methodology' section.
  - The calculations should be **reviewed by an independent third-party**. The GLA document has further information on this process.[6]
  - Results should be presented using the RICS 'Reporting-template-building'.[7]
  - A **technical report** should be submitted alongside the RICS reporting template. This report should cover, as a minimum:
    - Assumptions and methodology adopted for the calculations.
    - Contingencies and uncertainty/coverage factors used.
    - Normalised results (per sqm of gross internal area) for A1-A5, A-C (embodied excl. operational) and whole life (embodied and operational with and without grid decarbonisation)
    - Comparison with industry benchmarks and targets as per Section 0.
    - Big ticket items and strategy to reduce the whole life carbon emissions.

---

[6] Greater London Authority: Whole Life-Cycle Carbon Assessments, March 2022.

[7] RICS, "Whole life carbon assessment for the built environment, Version 2," Royal Institution of Chartered Surveyors (RICS), London, 2023.

WLCA Methodology

All WLC calculations issued during the planning process should be based on the latest version of RICS at the time of application and account for all materials and works that will be specified, designed or carried out by the applicant. More specific methodology details for each of the application stage follow in Table 1.

Table 1 Details for WLCA

Topic	Description	B2 Pre-App	C1 Planning
Scope of works	All RICS categories should be accounted for in the WLC calculations, from 0. to 8., including pre-construction demolition (reported under A5) and fit out works (Cat A for offices and fit out by applicant for residential). External works within the project's boundary should be reported in the totals, while those outside the project's boundary should be reported separately.	✓	✓
Results categories	Results should be issued for all life cycle categories (A-C). Module D results should be reported separately.	✓	✓
Results normalisation by area	The carbon results should be normalised using the total gross internal area (GIA) in sqm. For refurbishment/retrofit/extension projects, the full GIA should be used, e.g., new plus retained areas.	✓	✓
Generic data	Generic carbon factors, transport distances, service life and site emissions should be used, in accordance to RICS.[8]	✓	✓
Carbon of structural elements	At early stages of design, the foundations and frame of the building are sufficiently developed to have more accurate calculations. As a minimum, the embodied carbon impact of the substructure and structural elements in the superstructure should be calculated. The design team should be engaged early in the process, so that they can provide the necessary quantities to undertake the calculations.	✓	✓
Carbon of the facade	The embodied carbon impact of the facades should be calculated using the CWCT methodology[9]. If quantities from the design team are not available during the B2 pre-app stage, the carbon intensity per façade area of similar façade types can be used in combination with the building's form factor for the calculations. The design team should be engaged with this process for the selection of appropriate façade types.	As a minimum, carbon intensity and form factor to be used for embodied carbon estimations.	CWCT methodology to be followed.
Use of industry benchmarks in lieu of design information	At early stages of design, some components of the building are often not sufficiently developed to enable carbon calculations. To ensure completeness and avoid underreporting, industry benchmarks ca be used to estimate the potential embodied carbon impact of these components. The assessment should clearly differentiate what carbon is allowed for from benchmarks and which carbon is calculated from project-specific info. Note that these benchmarks are generally for mid-rise buildings. Therefore, assessment of the validity of benchmarks and justified modifications - with transparent reporting of assumptions - is also encouraged.	Allowed except for substructure, structural elements in the superstructure and facades.	Explicit calculations for all building categories are expected. Justification is expected if benchmarks are used for any categories.
Contingency and Coverage	Early-stage contingencies and uncertainty/coverage factors should be used to support completeness of assessment, as per RICS guidance.	✓	✓
Energy and water consumption	Annual energy consumption (split into regulated and unregulated) and water use must be estimated for all options.	✓	✓
Carbon of electricity	Operational carbon calculations must be carried out using the current version at the time of application of the Future Energy Scenarios (FES) falling short excluding negative emissions.	✓	✓

---

[8] RICS, "Whole life carbon assessment for the built environment, Version 2," Royal Institution of Chartered Surveyors (RICS), London, 2023.

[9] CWCT, "How to calculate the embodied carbon of facades: A methodology, Centre for Window and Cladding Technology, Bath. 2022

Whole Life Carbon Industry Targets

The embodied carbon results should be compared against industry benchmarks and applicants should provide a narrative as to how their results compare to these.

The most suitable sets of benchmarks available at the time of assessment should be used and their choice, justified. At the moment of writing, available sources in the UK include GLA[10] RIBA[11] and LETI[12] which may considered by the applicants. If other benchmarks become available or are considered more suitable for Tall Buildings in the city centre of Glasgow, they can be used as long as a justification is provided.

Table 2 Example of industry benchmarks results

Type	Benchmark/ Target	Office	Residential	Education	Retail
Upfront (A1-A5) kgCO$_2$e/m^2 GIA	GLA Current	950	850	750	750
	GLA Aspirational	600	500	500	550

‘Big Ticket’ Items and Continuous Optioneering

Applicants must demonstrate that a robust strategy for continuous whole life carbon reduction has been prepared, as part of the planning deliverables. This strategy should cover the project from design to construction and follow the PAS2080 carbon reduction hierarchy.[13] Additional guidance is provided below:

- ‘Big ticket’ items, i.e., the biggest carbon emitters, to be identified and targeted.
- Carbon reduction measures to follow the carbon hierarchy presented in Figure 4 and include reuse opportunities (from site or donor sites), design improvement, and low carbon materials/construction practices.
- Carbon reductions to be assessed quantitatively.
- Strategy to assess the feasibility of these opportunities and to assist their incorporation into design to be presented.

---

[10] Greater London Authority: Whole Life-Cycle Carbon Assessments, March 2022.

[11] RIBA, “RIBA 2030 Climate Challenge”, version 2, Royal Institute of British Architects, 2021.

[12] LETI Climate Emergency Design Guide: How new buildings can meet UK climate change targets; January 2020 edition.

[13] PAS 2028:2023 Carbon management in buildings and infrastructure; The British Standards Institution, Second Edition March 2023.

Wind Microclimate

Written by Gordon H. Clannachan, Arup

Introduction

Wind microclimate assessment is concerned with the impact of proposed developments on pedestrian comfort and safety. The quality of the wind microclimate can have a significant influence on the public's experience of the public realm and local amenities.

The construction of taller buildings can potentially affect the wind microclimate by deflecting stronger winds downwards to street level. It is important to ensure that wind conditions would be suitable for the various intended activities in and around the site. In addition, the assessment must seek to demonstrate that the proposed development(s) would not have a significant adverse effect on conditions off-site.

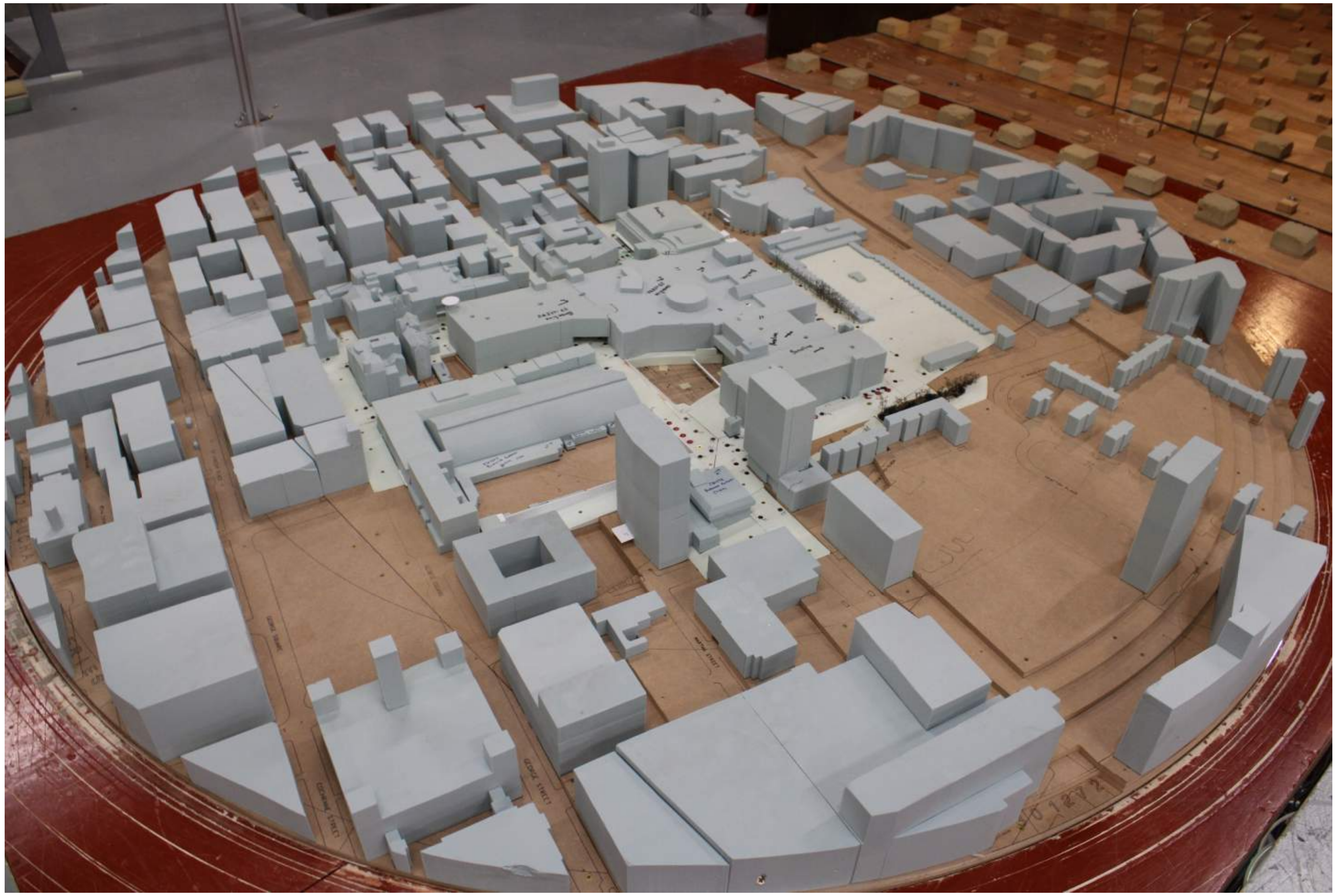
There are different tools available for wind microclimate assessments, namely qualitative desk-studies, computational fluid dynamics (CFD) and boundary-layer wind tunnel testing. The most appropriate method depends on the likely impact of the proposed development based on the following key characteristics:

- Building massing (i.e. shape and height);
- Strength of the local wind climate;
- Expected interaction with surrounding buildings; and
- Sensitivity of the surrounding environment at street level

The main steps of the wind microclimate assessment process are outlined in Figure 6 and these steps are discussed in more detail in the relevant section of this report. Table 3 provides guidance on the appropriate approach based on building height. This does not cover all the project-specific influences, as introduced above. The approach is to be agreed with Glasgow City Council's planning team during the pre-application process, as indicated in Step 2.

Table 3 Recommended approach for wind microclimate assessment

Building Height Above Ground	Recommended Approach
25m or less	Qualitative desk study by an experienced Wind Engineer
Greater than 25m, less than 50m	Quantitative study using either boundary-layer wind tunnel testing OR computational fluid dynamics (CFD)
Greater than 50m	Quantitative study using boundary-layer wind tunnel testing. CFD optional as supplementary tool.



B2 OPTIONEERING

B3 DESIGN DEVELOPMENT & TESTING

Step 1

Preliminary qualitative desk study to inform early massing studies, ground floor layout(s) and public realm proposals.

Step 2

Pre-app meeting with Glasgow City Council Planners to discuss Step 1 and agree methodology for the application assessment (see Table 1)

Step 3

Undertake geographic wind climate assessment to determine site-specific directional and seasonal wind characteristics.

Step 4

Undertake assessment and develop mitigation strategy as required.

Step 5

Pre-app meeting with Glasgow City Council Planners to present the results of the assessment and the mitigation strategy.

Figure 6 Wind tunnel model of Glasgow City Centre (courtesy of Arup from RWDI's wind tunnel facility in Milton Keynes) and 5 step assessment process.

Local Wind Climate

The geographical characteristics of the local wind climate, such as directional and seasonal variations in strength, are fundamental aspects of the wind microclimate assessment.

Quantitative results from wind tunnel testing and CFD must be combined with local wind climate statistics to produce a meaningful probabilistic representation of the wind conditions. This is discussed in more detail in the next section on *Assessment Criteria*.

A minimum of 16 wind directions must be assessed (i.e. at 22.5-degree equal increments). Directional annual and seasonal Weibull parameters have been provided in the adjacent tables to drive a consistent basis for all wind microclimate assessments. These statistics are based on historical wind records from Glasgow Airport and have been adjusted to 'open country' terrain at a reference height of 10m. An appropriate method must be followed to transpose these statistics to the project site, such as ESDU[14].

The transposition must account for the vertical profiles of mean and gust wind speed based on the influence of surrounding terrain roughness. Likewise, the influence of far field topography using ESDU or similar must also be adequately considered.

Near field topographic effects may influence local speed-ups in and around the project site. An assessment must be undertaken to determine whether topographic effects are likely to be significant. Figure NA.2 in the UK National Annex to BS EN 1991-1-4 [15]provides a method for establishing if topographic effects will have a significant influence. Where significant, the local topography must be explicitly represented in quantitative wind tunnel and CFD assessments.

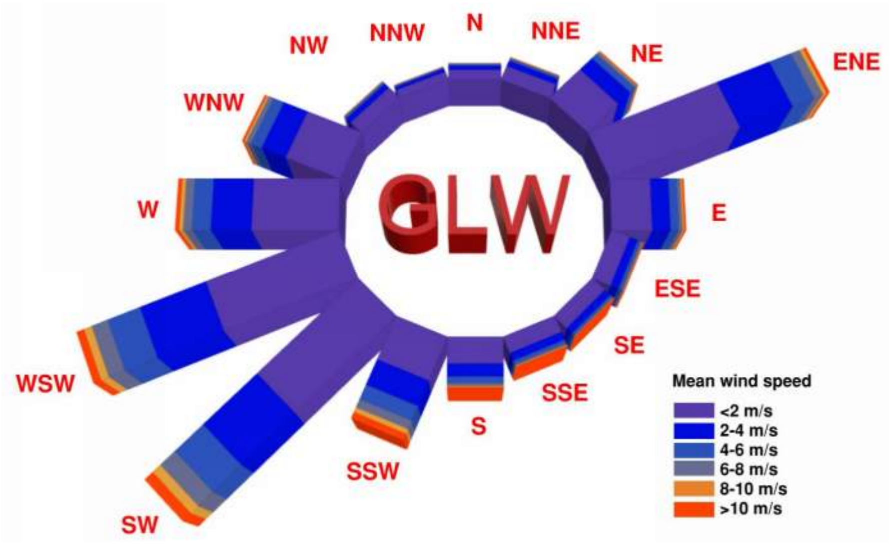


Figure 7 Annual wind rose for 'open country' terrain in Glasgow

Table 4 Weibull Parameters for 'open country' terrain at a 10m reference height in Glasgow

All year																
Wind E of N (deg)	0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5
p	11.85	17.31	47.86	158.79	47.46	21.81	18.86	21.03	32.56	69.47	177.75	174.76	104.26	69.66	16.69	9.88
c	3.22	3.01	3.32	5.31	4.80	4.45	4.46	4.88	5.94	7.26	6.15	4.51	4.59	4.86	3.26	3.19
k	1.49	1.43	1.55	2.36	1.92	1.90	1.98	1.84	2.18	2.04	2.04	1.62	1.76	1.99	1.63	1.57

Spring																
Wind E of N (deg)	0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5
p	14.23	18.42	50.52	204.09	55.96	20.69	16.31	20.66	28.98	57.07	154.40	157.10	97.27	75.68	18.07	10.55
c	4.01	3.89	3.63	6.06	5.67	4.85	4.61	5.42	6.47	6.96	5.91	4.75	4.89	5.32	3.90	3.91
k	1.83	1.77	1.60	2.66	2.03	1.96	1.96	2.18	2.43	2.18	2.17	1.82	1.97	2.29	1.96	2.09

Summer																
Wind E of N (deg)	0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5
p	9.20	15.83	49.84	158.33	38.37	16.74	14.10	17.41	27.87	55.67	163.28	192.97	125.05	89.14	19.06	7.13
c	2.83	2.83	2.92	5.15	4.48	3.58	3.59	4.40	5.27	5.93	5.27	4.04	4.24	4.64	3.22	2.20
k	1.96	1.77	1.60	2.46	2.29	2.03	1.72	1.92	2.60	2.26	2.25	1.92	2.21	2.51	2.39	1.47

Autumn																
Wind E of N (deg)	0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5
p	12.56	17.44	45.32	145.91	52.42	25.26	22.19	22.83	39.11	77.32	183.33	175.85	94.02	58.83	15.95	11.66
c	3.16	2.59	3.16	4.74	4.49	4.61	4.38	4.60	5.81	7.22	6.19	4.66	4.56	4.83	3.21	3.21
k	1.50	1.45	1.45	2.36	2.17	1.82	2.03	1.94	2.35	2.08	2.16	1.89	1.96	2.19	1.66	1.44

Winter																
Wind E of N (deg)	0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5
p	11.43	17.58	45.50	124.27	43.08	24.89	23.23	23.45	34.62	89.42	212.47	172.86	99.99	53.50	13.44	10.26
c	2.82	2.79	3.29	4.95	4.86	4.49	4.81	5.14	6.28	8.36	7.04	5.21	5.21	5.10	3.22	3.20
k	1.45	1.45	1.62	2.18	2.23	2.03	2.06	1.69	2.03	2.13	2.12	1.60	1.69	1.80	1.51	1.63

---

[14] ESDU 01008 Computer program for wind speeds and turbulence properties: flat or hilly sites in terrain with roughness changes.

[15] British Standards Institution, 2010. UK National Annex to Eurocode 1: Actions on Structures – Part 1-4: General Actions – Wind Actions.

Assessment Methodology

Wind tunnel testing and CFD should be undertaken in accordance with industry best practice. It is not the intent of the guidance to prescribe technical requirements for the wind tunnel set-up or CFD models.

A sufficient extent of surrounding buildings must be included. It is recommended to include all buildings within a radius of at least 0.5km from the site. A minimum of 16 wind directions must be assessed.

Wind tunnel testing is constrained by a limit on the number of measurement points. Should localised areas of increased windiness be identified during the assessment, then the density of probes in the area must be increased to sufficiently demonstrate that the windiest conditions have been identified and show the dissipation of these strong winds.

Assessment Configurations

Baseline

The baseline refers to the current conditions based on the existing building(s) on the site and existing surroundings. This forms the basis for assessing the impact of the proposed development.

Proposed Development(s) with Existing Surroundings

Should the proposed development involve a number of buildings to be developed in a phased manner, then the approach to interim phases should be agreed at the Step 2 pre-application meeting.

Proposed with Cumulative Surroundings

All consented developments within the assessment area should be included as part of the cumulative assessment. Information of consented developments is available on Glasgow City Council's planning portal.

Assessment Criteria

Wind conditions should be expressed in terms of pedestrian comfort and safety using the established LDDC Lawson Criteria[16]. The perception of windiness is subjective and depends on a number of factors. The Lawson Criteria set acceptable comfort limits for different activities based on a 5% probability of exceeding defined wind speeds. This wind speed refers to the worst case of mean hourly and gust equivalent mean (GEM).

The categories are listed in order of increasing windiness and their associated 5% exceedance wind speed in Table 5. The terms *Sitting*, *Standing*, *Strolling* and *Business Walking* should be used to describe comfort levels of windiness in the application report.

The Lawson Criteria also includes a set of distress, or safety, criteria for less frequent, stronger wind speeds with an exceedance probability of less than 1 hour per year (0.022%). The categories are described in Table 6. Anything exceeding the *General Public Access* limit would be unacceptable for areas open to pedestrians throughout the public realm. The creation of conditions above the *General Public Access* limit are discouraged but may be accepted in areas with no access to the general public and limit activity.

Table 5 Comfort criteria categories as defined by the LDDC Lawson Criteria

Comfort Range	5% Exceedance Mean or GEM wind speed limit	Description
Long-term Sitting	4 m/s	Reading a newspaper, eating and drinking
Standing or short-term sitting	6 m/s	Bus stops, window shopping and building entrances
Walking or Strolling	8 m/s	General areas of walking and sightseeing
Business Walking	10 m/s	Areas where people are not expected to linger
Uncomfortable	>10 m/s	Uncomfortable for any level of public amenity

Table 6 Distress (or safety) criteria categories as defined by the LDDC Lawson Criteria

Distress Range	0.022% Exceedance Limit	Description
'General Public Access'	15 m/s	Unlikely safety risk to the general public.
'Able-bodied Access'	20 m/s	Less able and vulnerable find conditions physically difficult.
'Controlled Only'	>20 m/s	Becomes increasingly difficult for an able-bodied person to remain standing. Justifiable in spaces with controlled access only, which would not be frequented on windy days.

---

[16] Lawson, T.V., 1990. *The determination of the wind environment of a building complex before construction*; London Docklands Development Corporation.

Defining ‘Significant Adverse Effects’

Identifying ‘significant adverse effects’ requires a detailed understanding of the public realm and different activities being performed in and around the proposed development site. Particularly sensitive amenities, including areas used for outdoor dining and building entrances, must be identified.

Wind conditions expressed in terms of the Lawson Criteria must be compared against the activities to be performed in and around the site. A ‘significant adverse effect’ refers to any instance where the proposed development makes conditions windier to an extent that they would no longer be suitable for the intended activities.

It would be acceptable for conditions to become windier than the baseline if conditions remain within an acceptable range for the activities being performed. If baseline conditions are windier than the respective limits for the activities being performed in the area(s), then the applicant must demonstrate that the proposed development does not exacerbate the issue and make reasonable endeavours to improve conditions within the boundary of the development where possible.

Mitigation

The intention is that early advice from a Wind Engineering Specialist will result in more holistic mitigation solutions. The first approach to mitigate adverse wind effects should be through alterations to the building form. Where this cannot be completely achieved, low-level mitigation options are permitted but must minimise the adverse impact on the public’s experience at street level.

Specific features, such as screens and canopies, required as part of the wind mitigation strategy must be shown on architectural plans and elevations. Where screens are provided as part of the mitigation strategy, the impact on existing buried utilities and extent of likely diversion(s) must be highlighted.

Landscaping, such as trees and planters, can be used to enhance comfort conditions but cannot be used as the sole intervention to mitigate unacceptable safety conditions. Landscaping specifically included as part of the wind microclimate assessment must be shown on the landscape architectural plans. Steps must be put in place to ensure any landscaping relied upon for wind mitigation replicates the scale and maturity as represented in the assessment on Day 1 of the area being opened to the public.

Presenting Results

Quantitative results from wind tunnel testing or CFD must be presented as simple contour plots, indicating the measured comfort conditions in accordance with the Lawson Criteria. Any exceedances of the distress criteria can be identified on the same or separate plots.

Results should be presented for ‘worst season’. In addition, summer conditions can be provided where appropriate for areas that are only intended to be used for certain activities in the summer period.

An example contour ‘dot’ plot is provided in Figure 8 for wind tunnel results, where each dot corresponds to a measurement probe location. CFD results are not constrained by a limit on probe numbers and could be presented as a full contour plot through street level.

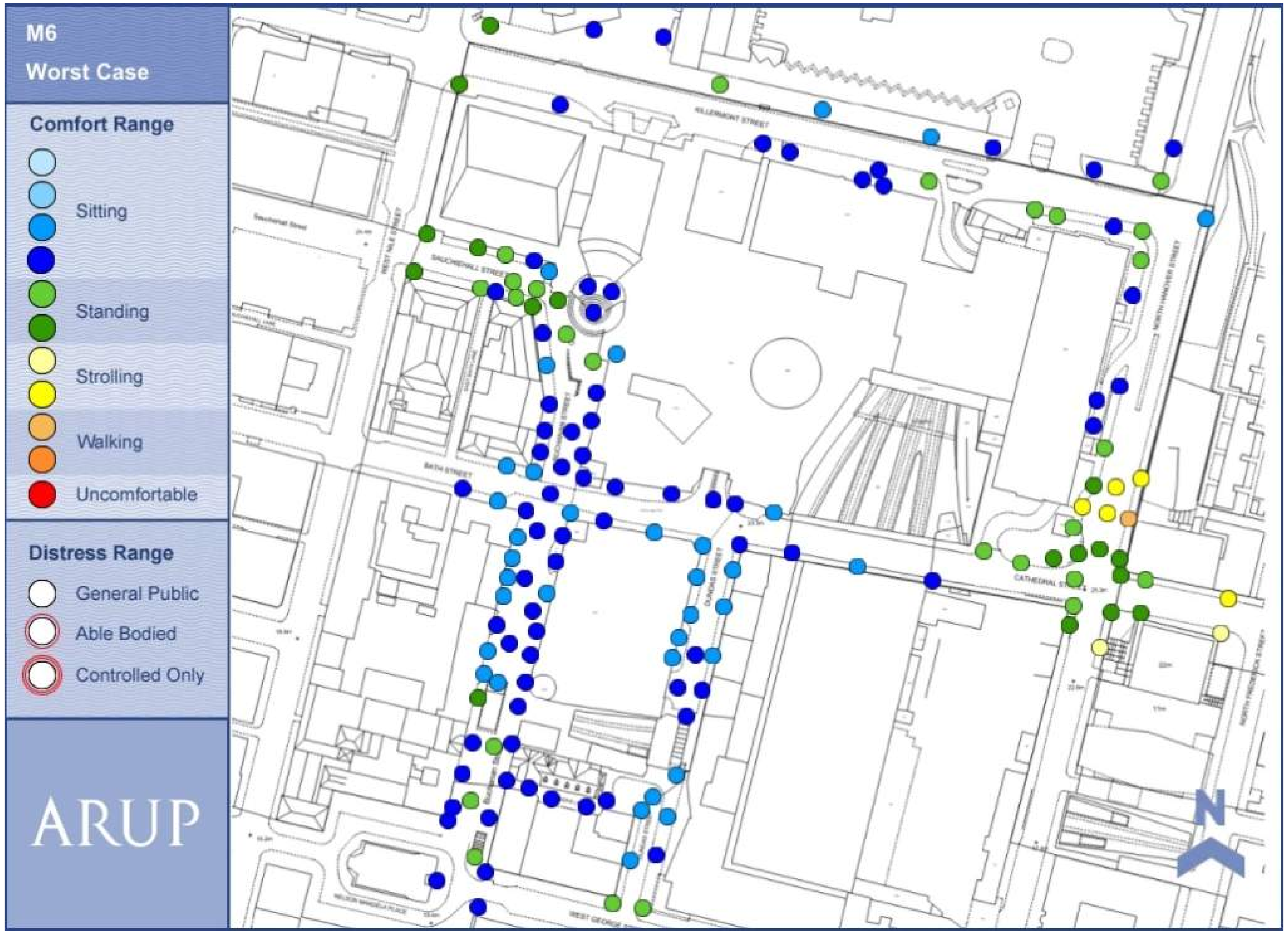


Figure 8 Example presentation of wind tunnel results in terms of the Lawson Criteria.

Sunlight & Daylight

Written by Laura Phillips, Arup

Introduction

Utilising natural light effectively within the planning of a building is crucial to providing a quality environment and achieving a sustainable built environment. The quality and quantity of natural light within a building and in the open space between buildings depends on two key factors: (1) the design of the interior environment, which includes the size of windows, room depth and internal finishes; and (2) the external environment, which relates to orientation, massing, façade design, building proximities and, importantly in the context of tall buildings, the height and form of a building.

Access to daylight and sunlight reduces the need for electric light during daylight hours and effective envelope design can reduce solar gain in summer and utilise heat gains in winter months to make a building more energy efficient and reduce overall energy consumption.

As well as the energy saving benefits, natural light provides psychological benefits for a building's occupants. The colouration of natural light – both the full spectrum qualities unique to daylight and the change of colouration from day to evening – align with our natural body clock and are essential for health and wellbeing. The direct quality of sunlight models form and texture and provides articulation and visual interest within the urban landscape. This helps us acknowledge time passing and to orientate ourselves within our environment.

Occupants appreciate a 'connection' with the external environment. Studies (including by the World Health Organisation and Green Building Council) show that increased access to daylight improves productivity, healthy sleep, recovery from illness and a general sense of well-being.

The amenity that access to natural light provides is as important a consideration for existing occupiers of buildings and spaces surrounding a proposed development to that of the future users of a building. The impact of tall construction should be carefully planned and considered in relation to the context of the site, with the provision and potential appropriate mitigation carefully considered.

Applicants must undertake Sunlight & Daylight assessments in accordance with BRE published document BR209 'Site layout planning for daylight and sunlight' 2022 Edition.

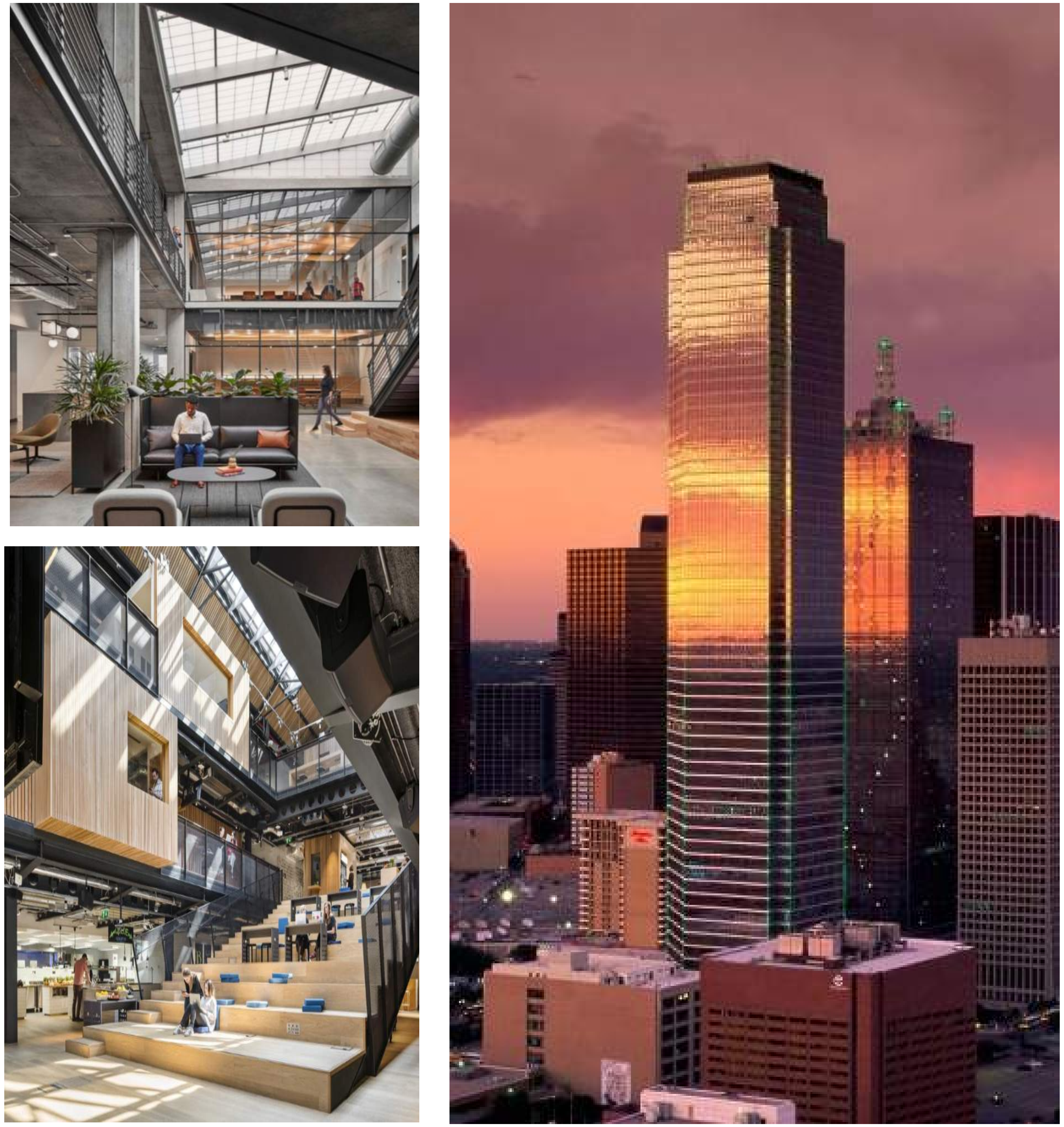


Figure 9 Lit character daylight delivers

Daylight Terminology

Daylight is made up of two sources of light: skylight and sunlight. When considering natural light in the context of new developments, and specifically tall buildings, it is important to understand some basic definitions.

Skylight is the brightness of a given sky under different weather conditions. It is important to recognise that we live in a cloudy climate and, for this reason, most of the natural light that reaches the ground comes directly from the sky and not from the sun. In the UK and Ireland, the sun is typically hidden behind clouds during 70% of daylight hours.

The access to sunlight and daylight are considered separately as:

- **Skylight -** Vertical Sky Component (VSC) as a ratio of the direct sky illuminance falling on the vertical façade at a point, to the simultaneous horizontal illuminance under an unobstructed sky. The maximum value is almost 40% for an unobstructed sky.
- **Sunlight** - Annual Probable Sunlight Hours as the total number of hours in the year that the sun is expected to shine, allowing for average levels of cloudiness for the location in question. The assessment of the probable sunlight hours is orientation dependant and the calculations produce the percentage of annual (APSH) and winter (WPSH) number of probable sunlight hours that a point on a window receives.

Direct sunlight can reflect from a specular surface, such as a glass façade, and this can cause glare. There are two types of glare, as follows:

- **Discomfort glare** causes visual discomfort without necessarily affecting the ability to see.
- **Disability glare** happens when a bright source of light, such as reflected sun on a tall building facade impairs vision where light is scattered in the eye. This is more serious and can impact motorists, pilots or train and bus drivers.

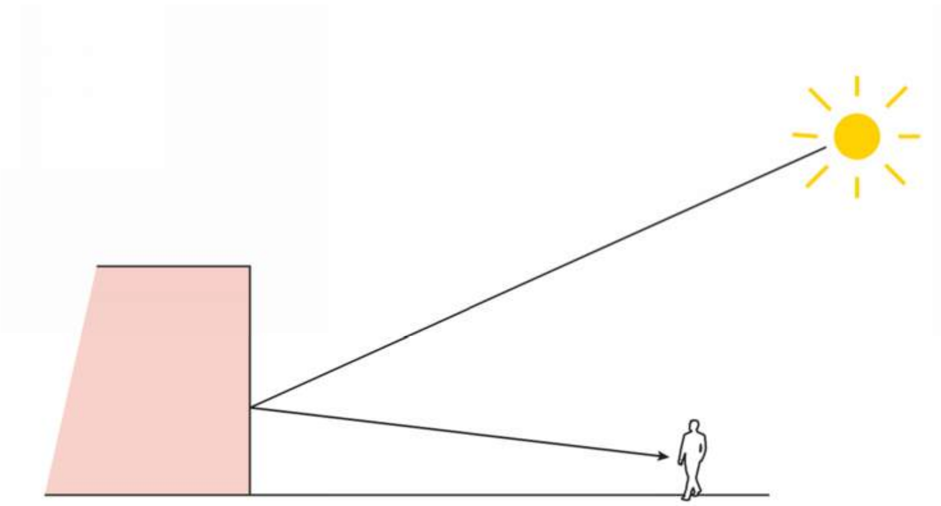


Figure 42: Reflection of low angle sunlight from a vertical façade

Figure 10 Extract from BR209 2022 Edition illustrating glare from tall buildings

Key Design Considerations

In the context of daylight, sunlight and overshadowing there are three key considerations for tall building developments, as follows:

- The distance of the new building from any adjacent building. This could be existing buildings or new proposed buildings as part of a development.
- The overall massing and arrangement and form of massing within the proposal
- The set back of the tall building and how the ground floor levels and street level are considered and resolved.

It is recommended that the following aspects are considered during the **B2 Optioneering** stage of the application process.

Within the city of Glasgow the criteria as defined in BR209 should be viewed in the context of the environmental zoning for a development. Various heights of buildings will be considered within the context of the defined tall building opportunity zones to work with the overall urban townscape.

Each criterion should be satisfied for each type of development zone and in some instances there is greater opportunity to express form, such as taller building within the Metropolitan area type. Within a district development it may be possible to present a series of options on massing and how this has been developed to optimise daylight design could be key to the success of a proposed scheme.

In all developments no matter the zoning area these four key design considerations need investigated early on in the feasibility stage of a proposal. A series of option studies clearly demonstrating how these building facades perform from a daylight perspective should be presented as part of any early planning engagement.

Computational massing indicating VSC (and APSH and WPSH where appropriate) levels for various options should be submitted to inform discussion on daylight access at an early stage. Figure 13 provides an example of such analysis. Any proposed development should considered the cumulative impact of the scheme as a result of multi-phase development or separate construction.

Tall building developments within the city of Glasgow need to consider equivalent VSC analysis to account for the more densely populated areas of the city. This tool assists with looking at initial set backs and height ratios when developing massing for tall buildings. Information can be found in Appendix F of BR209 on setting alternative target values for skylight and sunlight (see extracts adjacent).

As with any new development, consideration should be given to the potential impact of reflected sunlight of glazing, and other proposed cladding materials, along with building form and how this may impact on surrounding building or receptors. Particular consideration should be given to the possible influence on transport infrastructure or safe operation (e.g. Rail/metro, highway and aviation); though should also consider instances where excessive and regular experiences of reflected sunlight could significantly impact the normal operation or enjoyment of a space. While this is true of all new developments, the potential sphere of influence that should be considered greatly increases with tall buildings that protrude above the existing skyline and therefore may need to consider potential receptors at much greater distances from the proposed development site.

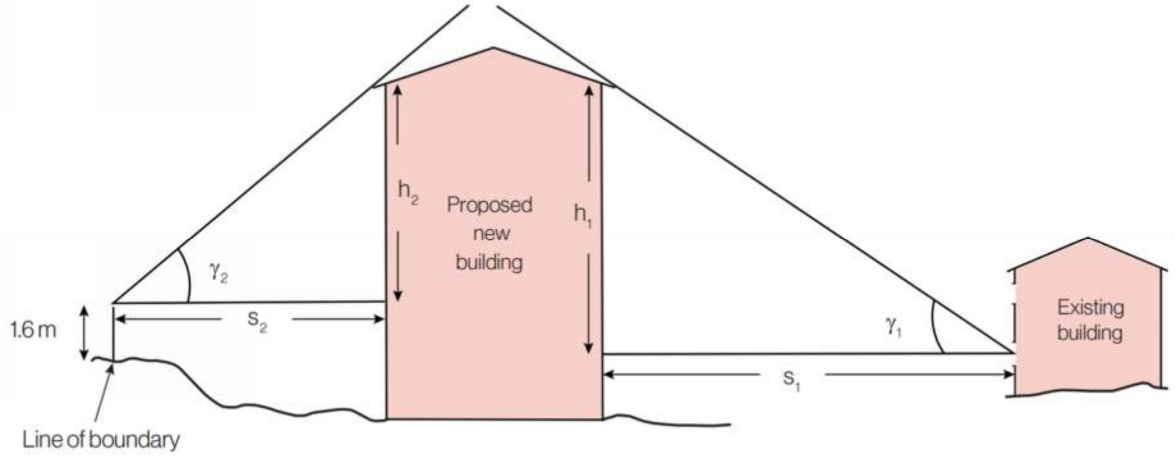


Figure F2: Angles, spacings and heights used in Table F1

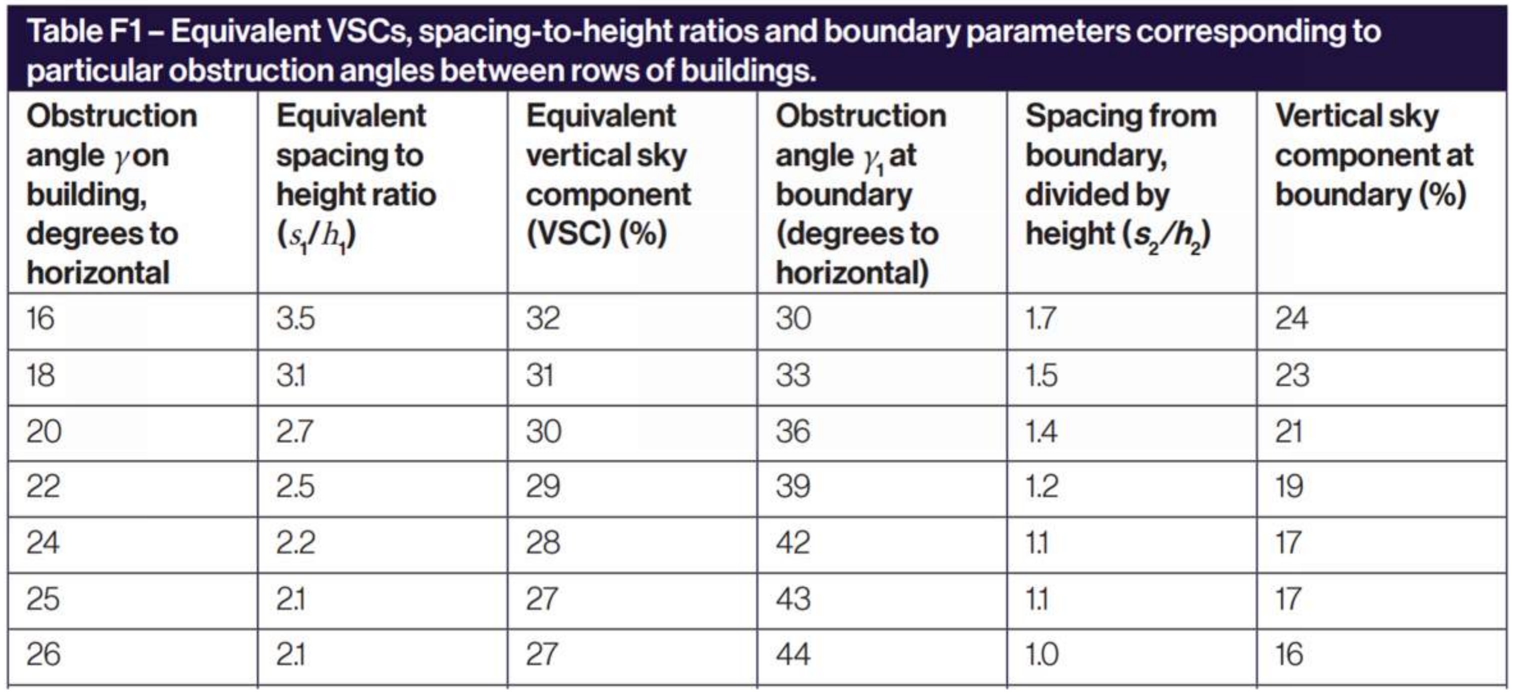


Table F1 – Equivalent VSCs, spacing-to-height ratios and boundary parameters corresponding to particular obstruction angles between rows of buildings.

Obstruction angle γ on building, degrees to horizontal	Equivalent spacing to height ratio (s_1/h_1)	Equivalent vertical sky component (VSC) (%)	Obstruction angle γ_1 at boundary (degrees to horizontal)	Spacing from boundary, divided by height (s_2/h_2)	Vertical sky component at boundary (%)
16	3.5	32	30	1.7	24
18	3.1	31	33	1.5	23
20	2.7	30	36	1.4	21
22	2.5	29	39	1.2	19
24	2.2	28	42	1.1	17
25	2.1	27	43	1.1	17
26	2.1	27	44	1.0	16

Figure 11 Setting alternative target values for skylight and sunlight access – BR 209 Appendix

Assessing Developments

Initial daylight assessment looks at the obtrusion angles, which are measured from the centre of the lowest window. This angle determines if the new development is set back from the existing boundary sufficiently as not to impact surrounding properties. This is referred to as the visible sky angle or angle of obtrusion, if this value is above 65degrees then the building is sufficiently set back and will received good levels of natural light to the façade. In some instance this value may be closer to 40 degrees which would provide a vertical sky component (VSC) of under 27% the recommended guidance for good levels of natural light to a façade. In many city centre environments achieving 27% VSC on lower floors can be challenging. How ground floor spaces are activated and designed including material selection is critical as part of the overall proposal to ensure lower floors of tall buildings do not feel dark and in shadow. It is likely in many instances for built up environments that a development will not meet the initial obstruction angle assessment, if this is the case then a more details analysis of daylight access is required. This can be measured using Waldram Diagrams or more commonly commercially available computational software.

Beyond assessing the amount of skylight a specific point on a the facade of a building will receive, we need to also consider the same for direct sunlight. This is measured in annual probable sunlight hours at peak times of the year in the summer and winter months to provide a predictive understanding of how much sun a façade and the surrounding amenity area will receive within a development over the course of the year The requirement for sunlight will vary depending on whether domestic, or non-domestic, and the value this may provide. Consideration should be given as to whether a use of space or area would reasonably expect to receive direct access to sunlight as a positive contributor to the use and amenity that may be enjoyed.

Overshadowing

It is true that taller buildings cast longer shadows but with careful consideration to placement and form of a new tall building the impact on the surrounding buildings can be minimised. New tall buildings should be massed and orientated to clearly minimize the impact of shadowing on existing public realm and adjacent properties in their vicinity. It is however important to recognise that we live in a cloudy climate and for this reason most of the natural light that reaches the ground comes directly from the sky and not just from the sun. In the UK and Ireland, the sun is typically hidden behind clouds during 70% of daylight hours. When reviewing shadow studies an accurate predictive weather picture needs to be considered, see an example of annual sunlight hours plots in Figure15 which is required to prove any tall building developments are not too greatly impacting this lit character of public space surrounding a proposal and prevent the creation of new dark/shaded public space. The BR209 provides recommendations where 50% of amenity space should receive 2 hours of direct sunlight on 21st March.

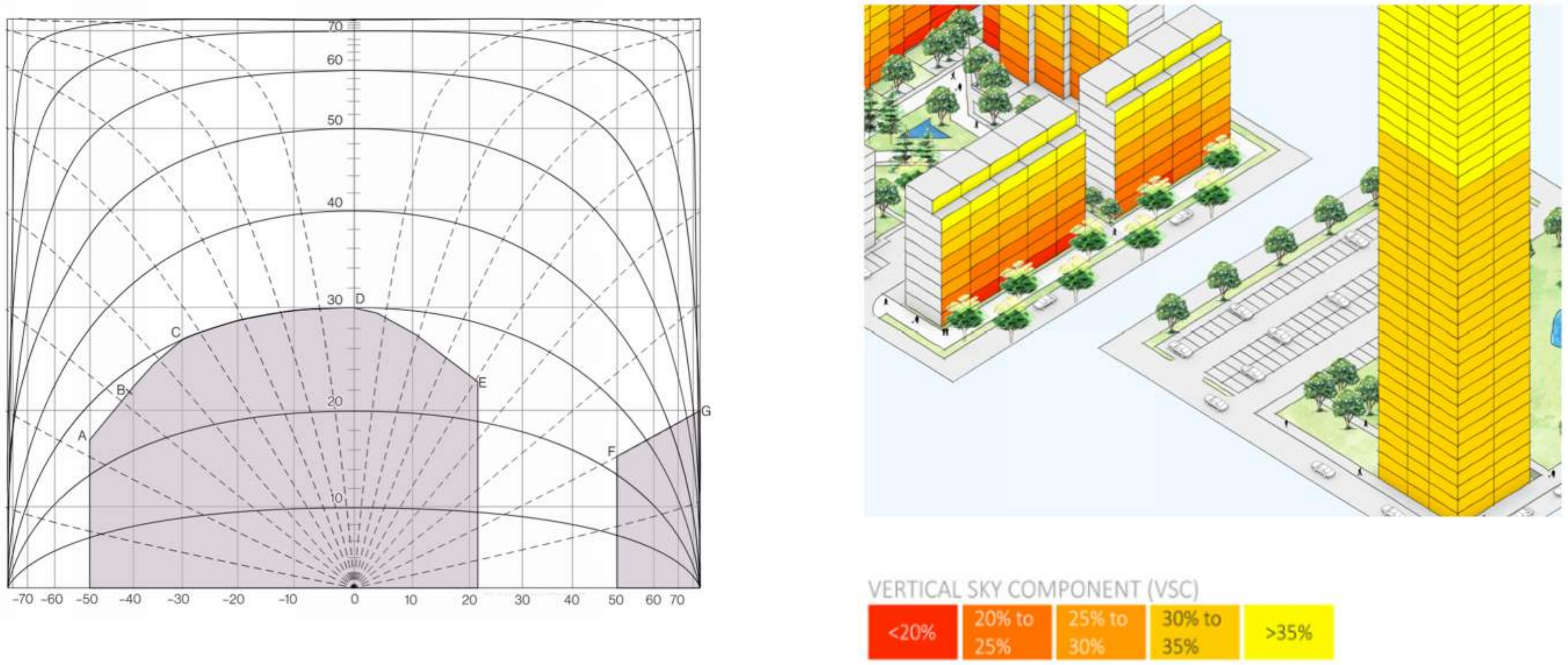


Figure 12 Waldrum Diagram from BR 209 Appendix B and example of computer modelling to plot VSC contours

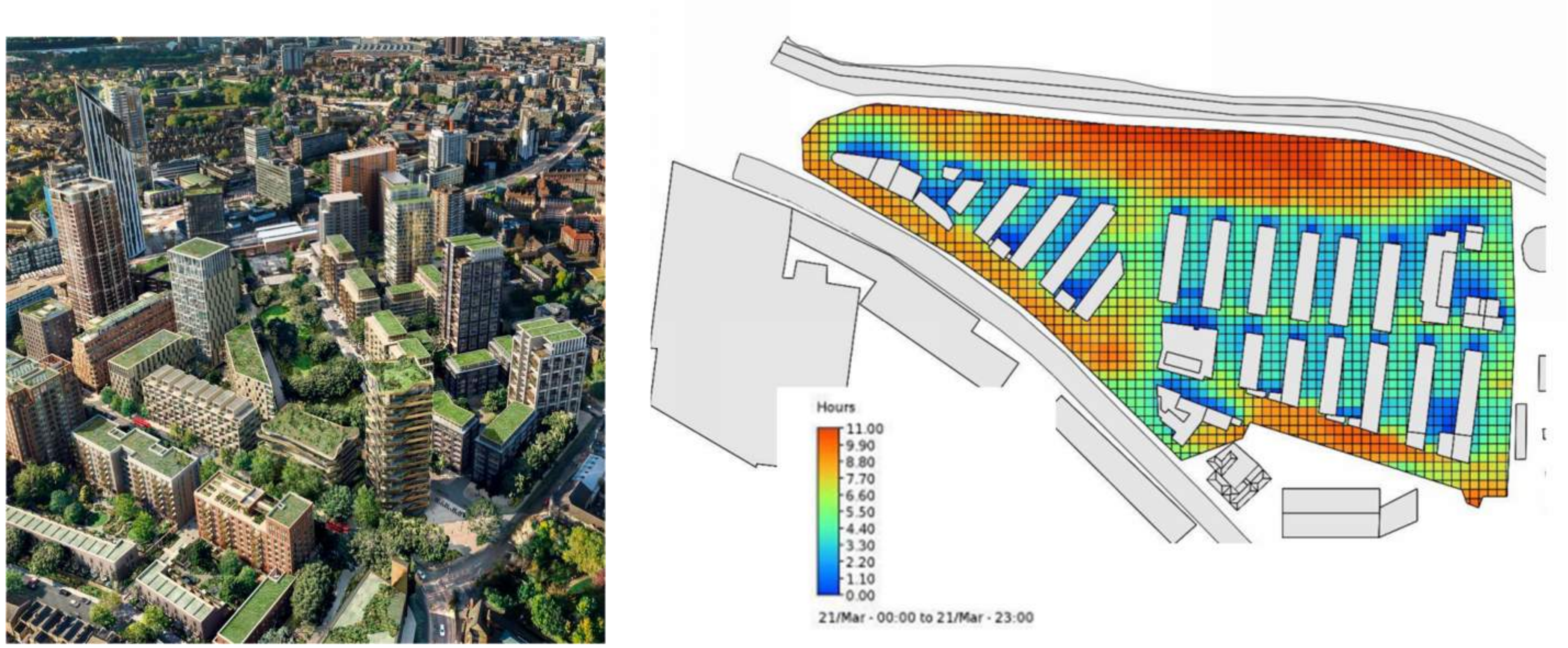


Figure 13 Elephant & Castle masterplan development and corresponding sunlight hour plots for amenity spaces

Smart Buildings

Written by Karen Warner, Arup

Introduction

Smart technology has a key role to play in supporting property owners and operators to manage energy efficiency and understand user needs, to identify and offer new services and provide more granular management information for better reporting and decision making.

A smart building design aims to achieve buildings that perform better, are flexible and easy to change and that communicate more clearly and easily with their users. The recent growth in smart building thinking is in response to the increased ability to have computing at the end device level, the ubiquity and availability of cloud computing, and the reducing price point of both. This model is set to transform the experience of buildings, both new and existing.

The level of complexity inherent in connecting systems and devices (traditionally separated and not connected to the internet), requires a rethink and new approach to avoid the over complicated systems that typically require specialist knowledge to operate.

Using today's technology makes it simpler to extract data from building assets to contribute to better reporting and energy optimisation, as well as potentially contributing to a better understanding of the users leading to new models and services.

Further technology can be leveraged to benefit the wider community impacted by the building's footprint and by linking data and services across buildings to create a sense of place. The ability to access green finance through better evidence of sustainable performance also creates opportunity.

Figure 14 Interaction of people with the building and its systems

Smart Building Fundamentals

To enable solutions to be easily adopted by different buildings and building types and to allow comparison of data across buildings securely, it is essential that foundational elements are consistent across all buildings. The following sections detail the fundamental building blocks of smart buildings that should be prioritised in all projects.

Security

To allow easy exchange of data across building and user systems, use of a converged managed network should be considered. Devices connecting to that network should be capable of supporting minimum network security e.g. Transport Layer Security (TLS), to protect building owners and users from cyber attack. Many devices now support good levels of network security as well as other network fundamentals such as Dynamic Host Control Protocol (DHCP), and Network Time Protocol (NTP). Network connected devices supporting good levels of security should be prioritised.

Openness

Use of open protocols, which support suitable encryption, will facilitate secure data exchange without onerous translation. It is recommended that devices supporting open internet of things (IoT) protocols are prioritised.

Flexibility and Scalability

It would seem obvious that in order to freely use applications across multiple buildings that assets and points should be named consistently and be machine readable, yet this is not normal practice, making data comparisons across buildings and systems time consuming and expensive.

Open-source naming conventions to be used are shown in the recommendations section. Alternatively, a register should be developed showing the mapping of the preferred schema to those used by the project.

Design Considerations

Users

Tall buildings can have a significant impact on the local community, so the development needs to consider enhancing only the building users' experience but also those affected by the building. The building should act as a catalyst to attract people and create a sense of place. The scheme should consider the provision of services and amenities to attract people to the City such as:

- Wi-Fi hotspots
- Wayfinding
- Digital kiosks
- Interactive art
- Living facades
- Community amenity spaces.

Building operations

It is well known that the energy consumption of buildings in use is consistently higher than designed. A system to track and analyse energy consumption and provide building analytics, to optimise building performance should be considered.

Minimum requirements

Use cases

The mandatory use cases for tall buildings are outlined below. These aspects are considered essential given the significant impact tall buildings present to the City centre. Inclusion of these minimum requirements will demonstrate a commitment to the City and its ambitions for its users:

- Energy consumption
- Water consumption

The recommended use cases for tall building are:

- Provision of free Wi-Fi within a 20m radius of the build's footprint for public use.
- Provision of community amenity spaces either in the building or within the free Wi-Fi radius.
- Measurement and display of indoor and outdoor air quality with indicators for acceptable ranges.
- Usage metrics provided through the use of people counters or other means to understand the usage patterns of the building and how this may be leveraged to provide greater community access.
- Percentage of time building amenities have been made available and used by community groups.

Implementation

In order to track and ensure that the operational energy and utilities use of buildings is minimised, it is essential to create a robust metering strategy and to continually monitor and report on energy and water consumption. This approach will enable early intervention for excess consumption.

The following aspects are required to be provided for all developments:

- Energy metering strategy (electrical and thermal) and relationships i.e. how are the meters related to each other and what systems do they serve?
- Details of how data will be made available and reported to building occupants, the wider community and Glasgow City Council to demonstrate that the building is operating within its design limits and contributing to the Government mandated carbon emission reduction targets.
- Measures used to identify and address when energy use fails to meet or improve on the design data.
- The use of grey water, should be explored. Measurement and display of potable water usage compared to design levels and where provided how much potable water has been saved by the use of rain water harvesting should be recorded and displayed.

Network strategy for building systems

A managed, internet protocol (IP) network is required to be provided as a minimum for building equipment and systems related to:

- Building management system (BMS or HVAC control system)
- Lighting control system
- Electrical, thermal and water metering.

Where additional equipment such as indoor air quality sensors or people counters are installed, these should be connected to the same managed network.

All IP capable devices will support minimum network standards including the following:

Network protocol	Description
RFC 2131 & 2132	Dynamic Host Configuration Protocol (DHCP) – A network management protocol used to dynamically assign an IP address to any device on a network so it can communicate using IP.
RFC 8446	Transport Layer Security (TLS) – Protocol v 1.3 that provides end-to-end security of data sent between applications over the internet, where a server and client would use "keys" to unlock encrypted communication.
RFC 5905	Network Time Protocol (NTP) v 4 – Protocol used to synchronize clocks on computer networks with a server that provides an accurate time (e.g. from atomic clock as a time source) to clients on the network. This is important, as datasets can only be interpreted when they are synchronized to the same time source.
RFC 2460 & 3596 & 4443 & 6106	Internet Protocol v6 (IPv6) – Latest version of the communications protocol providing the identification and location for computing devices on the internet. Since the eventual exhaustion of available IPv4 addresses and increasing quantity of IoT devices, this is becoming the standard for modern IP devices.
DNS	Domain Name System (DNS) – Protocol to match IP addresses to a corresponding human readable name. Large numbers of IoT devices and their queries on DNS can challenge the network and also be subject for possible cyber security attacks. Proper DNS filtering is crucial for efficient and secure IoT device communication on a network.

Naming conventions for assets and points

It is strongly recommended that open-source naming conventions, such as those identified below, are used in all developments.

- The Building Device Naming Schema – for assets (https://github.com/theodi/BDNS/blob/master/BDNS_Abbreviations_Register.csv)
- The Digital Building Ontology – for points (https://github.com/google/digitalbuildings/tree/master/ontology)

Failure to standardise on naming conventions leads to unnecessary rework to make comparisons across datasets, so this is fundamental to achieving a smart building.

Protocols

Most building systems now support the use of open protocols to enable integrations with other systems. Use of the following protocols should be prioritised for systems:

Communication protocol	Description
BACnet	Communication protocol for building automation and control based on the ASHRAE, ANSI, ISO 16484-5 standard, designed to allow communication of building automation and control systems and their associated equipment.
DALI 2	Network based protocol for lighting in building automation specified by technical standards IEC 62386 and IEC 60929.
LON	Local Operating Network (LON) is a standardised (ANSI/CEA-709.1-B) device communication and automation networking platform built on a protocol created by the Echelon Corporation for networking devices over media such as twisted pair, power-line, fiber optics, and RF.
KNX	Standardised (EN 50090, ISO/IEC 14543, OSI-based network communications protocol for building automation designed to connect any building systems over the same network over ethernet, bus, powerline or RF topologies.
Modbus	Modbus TCP/IP data is sent over a standard TCP/IP stack with serial implementations of Modbus RTU over RS 485.
MQTT	Message queue telemetry transport is an ISO standard (ISO/IEC PRF 20922) publish/subscribe 'lightweight' messaging protocol for use on top of the TCP/IP protocol.