Sustainability in Design e-book

HOW TO BUILD GREENER: THE ROLE OF PASSIVE DESIGN

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1. INTRODUCTION

In 2013, the UK government published Construction 2025: industrial strategy for construction – government and industry in partnership, which set ambitious targets for the construction industry. It stated that by 2025 we should achieve:

- 33% lower costs – through a reduction in the initial cost of construction and the whole life cost of built assets;
- 50% faster delivery – with a reduction in the overall time, from inception to completion, for newbuild and refurbished assets;
- 50% lower emissions – via a reduction in greenhouse gas emissions in the built environment;
- 50% improvement in exports – with a reduction in the trade gap between total exports and total imports for construction products and materials.

While these targets seemed ambitious at the time, and even more so in 2021, the drive to reduce carbon emissions throughout the built environment has gained considerable traction in the intervening years.

On an international scale, in 2016, 196 parties signed the Paris Agreement, which aims to limit the global temperature rise during this century to 1.5°C above pre-industrial levels. To help achieve this, in 2019 the UK government amended the Climate Change Act and committed to reducing the UK's total carbon emissions to net zero by 2050.

The government's 2017 industrial strategy was built around four Grand Challenges, including the Clean Growth Challenge which led to a mission to at least halve the energy use of new buildings by 2030.

In response, RIBA has developed its 2030 Climate Challenge to help architects meet net zero whole life carbon for both new and retrofitted buildings by 2030. RIBA's Climate Challenge was formulated in direct response to the Green Construction Board's recommendations on how to meet the government's energy mission.

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2. SUSTAINABILITY CHALLENGES FOR THE CONSTRUCTION SECTOR

The construction industry has some specific sustainability challenges:

- Buildings are a major source of carbon emissions (according to the UK Green Building Council, the construction industry is responsible for around 40% of the UK's carbon emissions)
- Buildings are also a major source of energy consumption (about 50% of the sector's emissions are from buildings in use);
- Buildings create urban heat islands.

We can address these challenges by:

- Supporting 'long life, loose fit and low energy' ideas;
- Choosing sustainable, locally sourced materials;
- Recycling more and re-using waste materials;
- Building and retrofitting better-insulated homes and offices;
- Implementing passive methods of heating and ventilation where possible;
- Applying these principles to cities as well as individual buildings.

In this e-book I will outline a number of strategies to consider when designing more sustainable buildings.

3. AN INTRODUCTION TO BIOCLIMATIC DESIGN

Bioclimatic architecture is concerned with the design of buildings and the spaces around them based on local climate.

It aims to deliver both thermal and visual comfort, by making the best use of natural resources such as the sun, wind and rainwater for heating, cooling and lighting buildings.

Although developed as an architectural concept in the mid-20th century, bioclimatic design is embedded within traditional regional architecture: for example, the thick-walled stone-built Mediterranean homes built around a central courtyard.

Contemporary examples of bioclimatic design typically focus on shading, louvers, balconies and cantilevers. Other design elements include inclining the roof to get higher ceilings, achieving better air movement and improving thermal comfort.

Others focus on the building's orientation and the movement of the sun with the addition of carefully placed sky gardens, balconies and shading.

Paxton House was renovated by alma-nac to create 43 dual-aspect apartments. The homes are arranged in couplets with each one enjoying an angled south-facing balcony with a north-facing window on the other side. Shared amenities including a roof-top garden deliver not only a sense of community for residents, but also an enhanced sense of space.
Image: © Jack Hobhouse 2021

4. THE PASSIVHAUS PERFORMANCE STANDARD

Passivhaus (Passive House) is an energy performance standard for buildings that has been adopted throughout the world. Developed in the 1990s, the principle suggests that traditional heating or cooling systems are not essential. Instead, thermal comfort is provided by measures such as: shading, pre-cooling of supply air, night purging, natural ventilation, air-tightness, mechanical ventilation with heat recovery (MVHR), insulation, avoiding thermal bridges, passive solar gain, and exploiting internal heat sources.

Although Passivhaus adopts the principles of passive or bioclimatic design, it takes them much further as it imposes strict limits on insulation, air tightness and energy consumption which includes hot water, lighting, electricity consumption by appliances, space heating, fans and pumps.

The 2019 Stirling Prize-winning Goldsmith Street in Norwich demonstrates how Passivhaus principles can work alongside thoughtful design. Designed by Mikhail Riches, the 100% social housing development is the largest Passivhaus-certified scheme in the UK.
Image: © Tim Crocker 2021

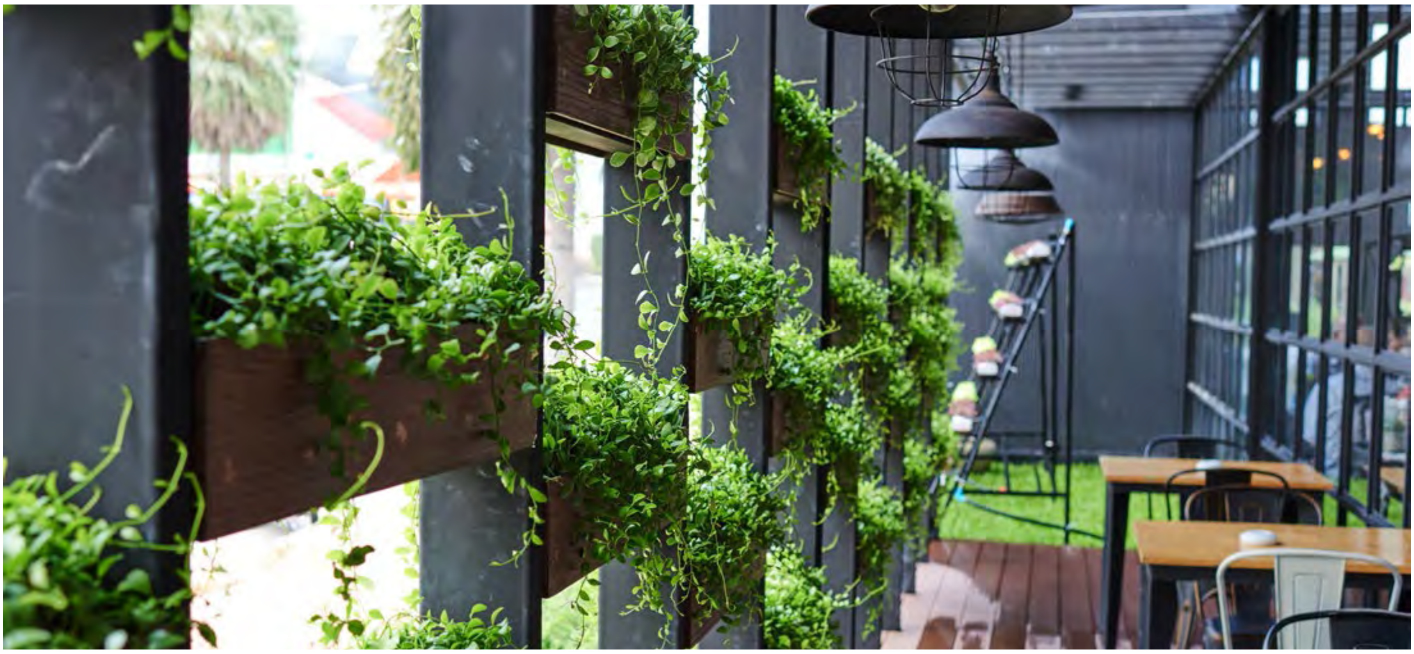
5. THE IMPORTANCE OF THERMAL COMFORT

Thermal comfort is an essential element of building design. The American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE) defines thermal comfort as "the condition of mind which expresses satisfaction with the surrounding thermal environment and is assessed by subjective evaluation."

Generally, a human body's internal temperature is about 37°C. During the day, the body loses or gains heat depending on physical activity.

When designing any building, the main aim should always be to maintain thermal comfort of the occupants. By achieving a comfortable temperature through passive design techniques, there is less need for additional heating or cooling methods. Even though thermal comfort is a subjective issue, from a design perspective, there are standard values that architects can follow.

The Chartered Institution of Building Services Engineers (CIBSE) has prepared a guide which prescribes the thermal comfort conditions and ideal temperatures for different types of buildings and functions.



6. CONTEXT, CULTURE AND CLIMATE

Before thinking about how a building should look or what materials should be used, it is important to consider the three C's: context, culture and climate.

- What are the typical weather patterns for this location? You'll need to consider average rainfall, humidity, wind strength and direction, minimum and maximum temperatures.
- What other buildings are close to the plot and are any new buildings planned?
- Will your new building cause over-shadowing? Or will it be over-shadowed by others nearby?
- What are the habits, traditions and lifestyle of people living in this region?

Once you have a clear understanding of the building's local environment then it's time to move onto other elements.

7. THE KEY ELEMENTS OF PASSIVE DESIGN

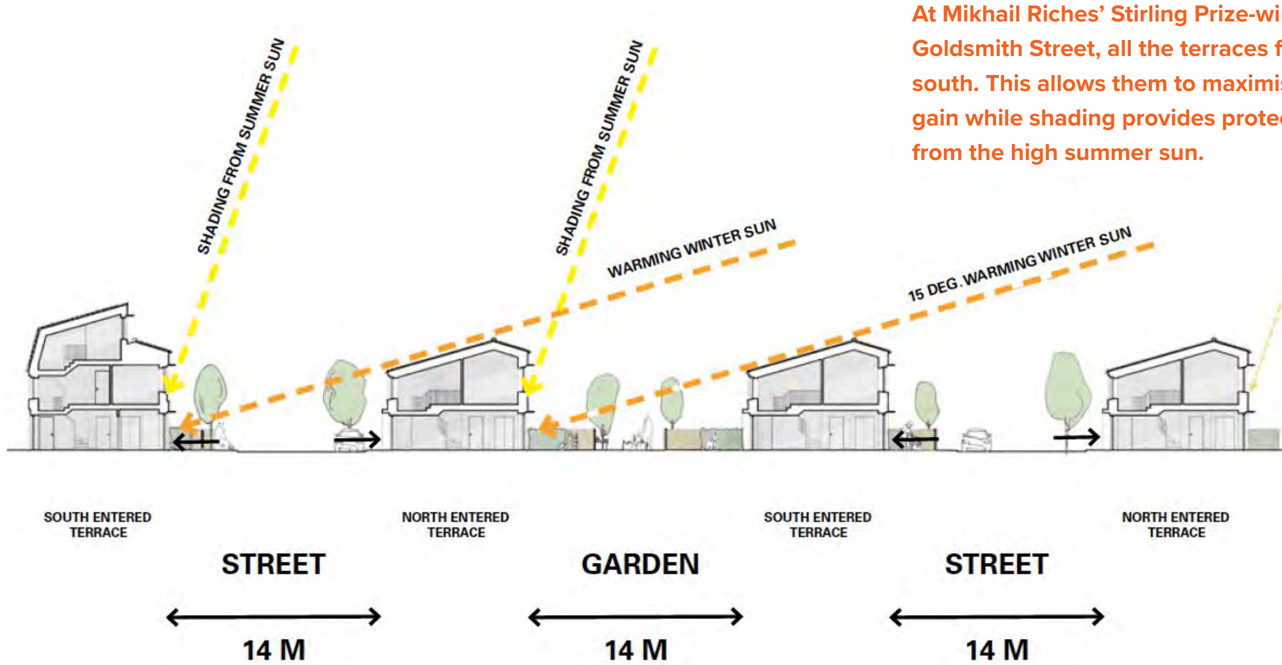
Outlined below are some of the major elements of passive design. These factors will all affect occupant thermal comfort and therefore the building's sustainability.

Sun studies and building orientation

The first thing to consider with any building is its orientation. Wherever possible, a building should be positioned to make the best use of the sun as it moves throughout the day, to benefit from the sun's natural warmth and light while also avoiding overheating.

Once this is achieved, then you can consider the layout of the building's interior. Some spaces require direct daylight, while other spaces can suffer from overheating. Wet areas, laboratories, offices, circulation areas etc. should usually face north whereas living spaces such as bedrooms and living rooms should face south.

By orienting a building within these rules and making these decisions right at the start, you will require less equipment to achieve thermal indoor comfort through either mechanical or electrical heating or cooling.



At Mikhail Riches' Stirling Prize-winning Goldsmith Street, all the terraces face south. This allows them to maximise solar gain while shading provides protection from the high summer sun.

Natural ventilation

Natural ventilation is the movement of air throughout the building without any need for mechanical strategies such as fans and extractors.

Natural ventilation can be achieved with openable windows and doors to benefit from the prevailing winds. There are different types of natural ventilation including cross flow ventilation, stack effect ventilation and atria ventilation.

For successful natural ventilation, the higher the ceiling levels, the better, as the air becomes cooler at the occupants' head level.

To achieve optimum indoor thermal comfort in high rise buildings in hot climates, it is best to locate the service cores in the hot end of the building. In addition, creating transitional spaces such as sky courts, raising the building from the ground floor, and using wind and shading ducts and inclined roofs that chase the movement of the sun will all help to prevent over-heating. These principles apply to both residential and non-residential buildings.

For high rise buildings in cold climates, the opposite is true. The building itself is more sealed or insulated and the service cores are usually placed in the centre. This allows more daylight to penetrate into spaces where its presence is fundamental.

Elements such as sky courts and shading ducts play a less important role in cooler climates, whereas building orientation, wind analysis, building shape and introducing renewables such as wind turbines remain significant factors to be considered to achieve thermal comfort.

Designed by brp, the central atrium at APRA House has high electric windows to draw out warm air during the summer months. Meanwhile, the roof extends over the southerly glazing to offer shading from summer sun, whilst allowing the lower winter sun to enter deeply into the space benefitting from the solar gain.
Image: © brp architects

Shading systems

Shading systems such as louvers, balconies, shaders and overhangs can be incorporated into your building façade design in several ways, using a range of different materials. Your choice of overhangs, balconies, and even the size of your openings will impact the thermal comfort within the building.

To help you work out the optimal size and angle of your shading device, there are a number of websites which have solar angle calculators to help you. One example is from the solar electricity handbook.

Some mechanical louvers are controlled by the movement of the sun. These shading systems can also be integrated into the façade in such a way that they not only block the sun but also provide privacy for the building users.

Integration of vegetation

Adding plants and vegetation both inside and out will affect the air quality in a building. Medium and high-level vegetation outside will act as a buffer zone by breaking the wind and will also prevent over-heating by preventing direct sunlight getting into the building.

In addition, using vegetation inside or on the building will increase the air quality, releasing more oxygen into the air and reducing carbon dioxide through photosynthesis. The use of trees and plants indoors can also improve indoor conditions by decreasing the temperature and increasing humidity levels.

When integrating natural vegetation into a building, it is also worth considering biophilic design principles. Biophilic design is not only concerned with the air quality within a building, (although improved air quality is one benefit of following biophilic principles). It considers human connectivity to the natural environment through nature, space and place conditions and the beneficial impact on human health and wellbeing.

Designed by JRA, an important design element of 33 Central was the landscaped roof garden featuring 9,000 plants from more than 55 native species. With a BREEAM Excellent rating, the building not only offers a flexible modern office space but is also a fine example of sustainable design and construction.
Image: © Hufton & Crow

Water collection

When designing sustainable buildings, rainwater collection is another fundamental design decision which is often overlooked. Rainwater should be collected, purified and used for grey water in the building. Systems can be a combination of passive design solutions (pitched roofs, etc.) and mechanical solutions for harvesting the water and pumping it back into the building.

Fife Architects designed Iron Mill Bay House to perform as efficiently as possible in terms of energy and impact on the environment. The team created a highly insulated house using renewable energy sources including an air source heat pump and a rainwater harvesting system.

Image: © Keith Hunter

Façade design and smart materials

Choice of materials is one of the most critical elements of sustainable design. Availability and performance are the main factors to consider and recyclable, energy efficient materials with low costs should be the first choice.

The heat exchange between the building and outdoors depends on the materials used on the façade. In order to prevent heat gain or heat loss, the building envelope should be thermally insulated. If the building is properly insulated, the need for electric and mechanical cooling will be reduced.

In addition, the effects of weather in different climates will affect material choices. High temperatures cause rapid deterioration on surfaces; high humidity causes mould growth; and high winds cause sand erosion.

Thermal mass

It is also important to consider thermal mass—the ability to store heat energy—when selecting materials for the building envelope. Thermal mass within the envelope prevents extreme temperature changes in the building and makes the internal conditions comfortable and moderate.

Some materials like concrete and brick have high thermal mass, meaning that more heat energy is required to change the temperature of the material. Typical buildings in the UK are made from brick which keeps the heat in and the cold out. While brick and concrete both have a high thermal mass, they also create considerable CO2 emissions in their manufacture.

When considering material choices for sustainable buildings, it's important to consider both the thermal mass and the carbon footprint of the material. For more information, the BRE website includes a comprehensive guide to sustainable products and materials.

8. ARE PASSIVE METHODS ENOUGH?

While passive design strategies can go a long way to help meet sustainability targets, they are not always the most effective solution. For example, high rise buildings will require mechanical equipment for air conditioning units and for lifts etc. For lower rise buildings however, the careful application of passive strategies can often be enough.

There is no 'one size fits all' approach and you may therefore need to look at different options to meet your sustainability requirements and targets.

To work out the impact of different approaches to sustainable design, you can use simulations to compare options for balconies, storey heights, louvres and shaders. You will often need to use a combination of different passive strategies to achieve the best results and simulations will help you achieve the optimum outcome in terms of energy efficiency, cost, comfort and style.

When applying passive strategies to densely populated urban areas, there are more challenges to consider. For example, you may have limited options for sun orientation in the city, and although glass facades have different reflecting and absorption values, they can reflect from each other and create an urban heat island effect.

9. TOOLS TO HELP YOU DESIGN GREENER

There are many software programmes on the market to help designers apply passive design techniques and understand the thermal characteristics of a building.

Examples include ANSYS Fluent, Bentley Hevacomp, AECOsim, EnergyPlus (EERE), Ecotect, Graphisoft's Archicad and EcoDesigner STAR, SAP, Vectorworks Energos, Insight, Project Solon and so on. Software ranges from stand-alone applications through to complex spreadsheets resulting in different user experiences, outputs and outcomes.

Key questions to ask are:

- How easy is the software to use?
- How well does it integrate, or can it collaborate with other software?
- Can it render high quality images?
- Can it render in real time?
- Can it do native thermal simulations?
- Does it do daylight analysis?

For all Archicad users, the software includes the Energy Evaluation palette as well as EcoDesigner Star.

Energy Evaluation enables architects to monitor and control all architectural design parameters that influence building energy performance at the click of a mouse. This includes performing reliable dynamic energy evaluation at all stages of the design process. And, as it's already integrated into Archicad, there is no need to import or export data.

Graphsoft's EcoDesignerSTAR enables multiple energy simulations.

The energy performance of the building once it is in use must also be considered. Archicad contains a full catalogue of building materials that you can use confidently within your analysis. They include properties relating to environmental sustainability, helping you to make choices that will address concerns related to the impacts of global warming and the project's carbon footprint.

Energy Evaluation can be used in the early stages of design to carry out simulations before the full building has been modelled. These include the orientation of the building, number of openings, the size of the openings and more. It can also be used later during the project to carry out thermal analysis and check areas such as the thickness of insulation.

By using Graphisoft's integrated EcoDesigner STAR, users can take multiple reports from the same model and compare changes and revisions to help inform and explain design decisions. They can also prepare their model to get certifications from third-party simulation software.

EcoDesigner STAR also offers:

- BIM Geometry and Thermal Property Data Export
- Thermal Bridge Simulation
- Expert Building Systems Settings
- On-Site Renewables
- Building Energy Simulation Using Standard-Compliant Analysis Engine
- Energy Performance of Thermal Blocks
- Building Energy Performance Rating Comparative Calculations

However, if you choose to use a different software for certifications, then it is also straightforward to export directly from Archicad to third party software.

Comparing energy balances by building usage with EcoDesigner STAR

Thermal bridge analysis with EcoDesigner STAR

10. CONCLUSION

There is no doubt that the ambition to create more sustainable buildings and to reduce energy usage throughout the built environment is challenging.

However, by adopting the strategies outlined above, we can work towards designing buildings that are both environmentally friendly and comfortable.

As a result, we will successfully reduce both energy consumption and energy costs of the building, increase air quality and improve user satisfaction and productivity.

11. USEFUL RESOURCES

ASHRAE (The American Society of Heating, Refrigerating and Air conditioning Engineers):
https://www.ashrae.org/home

Biophilic Design:
https://www.terrapinbrightgreen.com/reports/14-patterns/

BRE (Building Research Establishment):
https://www.bregroup.com/

BREEAM – independent third-party certification scheme of the assessment sustainability performance:
https://www.breeam.com/

CIBSE (Chartered Institution of Building Services Engineers):
https://www.cibse.org/

CCC (Committee on Climate Change) Housing Fit for the Future:
https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/

CLC (Construction Leadership Council) Net Zero Carbon Industry Initiative workstream:
https://www.constructionleadershipcouncil.co.uk/workstream/net-zero-carbon-workstream/

CLC (Construction Leadership Council) and GCB (Green Construction Board) Buildings Mission 2030:
https://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2019/05/GCB-Energy-Mission-Report-300419-FINAL.pdf

Construction 2025 Industrial Strategy:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf

Future Homes Standard:
https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings

Government industrial strategy Grand Challenge Missions:
https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions

Government Project Speed 2020:
https://www.gov.uk/government/news/pm-a-new-deal-for-britain

Passivhaus Trust:
https://www.passivhaustrust.org.uk/

RIBA 2030 Climate Challenge:
https://www.architecture.com/about/policy/climate-action/2030-climate-challenge

Solar Electricity Handbook and calculator:
http://www.solarelectricityhandbook.com/solar-angle-calculator.html

UK Green Building Council:
https://www.ukgbc.org/climate-change/

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