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Article

Climate Based Façade Design for Business Buildings with Examples from Central London

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Abstract: There is a disconnection between commercial architecture and environmental thinking, where green features can be included as part of a strategy for gaining approvals and marketing projects, but those features are not reviewed after completion and occupation of the building and knowledge is not shared. High levels of air conditioning are still considered unavoidable. Elaborate double skin façades and complex motorized shading systems are adopted; often masking an underlying lack of basic environmental thinking. This article returns (in principle) to the physics of comfort in buildings and the passive strategies which can help achieve this with a low energy and carbon footprint. Passive and active façade design strategies are outlined as the basis of a critical tool and a design methodology for new projects. A new architectural sensibility can arise based on modeling the inputs of sunlight, daylight and air temperature in time and space at the early stages of design. Early but sound strategies can be tested and refined using advanced environmental modeling techniques. Architecture and environmental thinking can proceed hand in hand through the design process.

Keywords: climatic design; day-lighting; façade design; shading; solar heat gain; cross disciplinary; design workflow; nearly zero carbon; business buildings

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1. Introduction

This article brings together passive design thinking and the urban business building, which can be the building block of a compact city served by public transport. The business building of the paper's title is a multi-story building, most likely for office or institutional use. Both the design and its dense occupation reflect the high value of the land on which it sits.

The starting point is that while all buildings should be targeting a net zero energy profile, the majority of city buildings are dressed in cladding (whether traditional or highly glazed) which ignores orientation and passive solar design thinking. A fabric first approach to façade design can help reduce air conditioning loads.

A series of façade design strategies are reviewed, the results of which can form both a critical tool and a design methodology for new projects.

Examples shown in case studies of recent buildings and projects primarily from central London; links are made to other climatic conditions to encourage a cross fertilization of ideas to and from this focus.

A notional design sequence is set out to indicate how climate based façade thinking can be incorporated into the accelerated design processes common today.

2. Context and Literature Review

2.1. Environmental Design in Architecture

Reyner Banham pioneered in foregrounding the role of environmental systems in architecture [1]. The systems he foregrounded, however, were principally the energy intensive mechanical systems of air supply and air conditioning. The air conditioned sealed container was already the predominant mode of North American commercial architecture. Strong structural frames allowed large expanses of glass which together were seen as signs of the technological age.

From Louis Kahn came the concept of servant and served space and separately the playful influence of Archigram led to Piano and Rodgers' design of the Pompidou Centre in 1977 and the continuing work of Richard Rodgers and his partners.

In Britain, the need for air conditioning was not so apparent with its milder climate. In "*The Selective Environment: an Approach to Environmentally Responsive Architecture*" [2], the role of the r as a modifier of climatic conditions was made pre-eminent. The façade would filter sunlight, daylight and fresh air from the exterior as appropriate according to the variation of the seasons either by the actions of the occupant's or by mechanical means. The effect was intended to significantly reduce the energy budget for the buildings designed. In the earlier "*The Architecture of Energy*" [3], the environmental opportunities of covered atria as thermal buffer zones mediating outside temperatures and facilitating natural ventilation were presented. For low energy performance to be achieved in practice it is helpful if the narrow definition of comfort criteria is relaxed somewhat within working spaces as well as buffer spaces, allowing temperatures to fluctuate somewhat, especially in summer [4].

The commercial sector adopted the fashion for atria as dramatic social spaces but often without the buffer zone thinking, imposing the more narrow comfort criteria which are standard in the industry.

The European Buildings Energy Performance Directive states that new buildings in the European Community should be by 2020 "*Nearly Zero Energy Buildings*" [5]:

> "*... The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.*"

Definitions of "energy balance" for a lettable building under this concept requires energy used for heating, cooling, and lighting (but excluding unregulated energy use for computers and equipment) to be matched by on or near site renewable energy [6]. This "unregulated energy use" will, however, still need to be sourced and paid for. In addition, this usage may impact the thermal energy balance of the building and in summer lead to additional cooling requirements. In addition, the energy balance definition should allow for some weekly as well as seasonal climatic fluctuation; an array of energy storage batteries should be provided in a Net Zero Energy Building to smooth out the variations in heating/cooling required and the intermittent availability of renewable energy. Larger fluctuations can be achieved by importing or exporting to the electricity grid.

In parallel with this initiative, "*Net Zero Energy Buildings*" [7] catalogues a series of buildings which generate energy at or near the building in question through Photovoltaic (PV) panels. The case studies are well supported by technical explanation and performance data. A typical characteristic of the buildings identified, however, is that they are in the low density edge of town locations and supported by generous car parking arrangements.

2.2. Façade Design Research Trends

A strong international research network gathers annually under the umbrella of the Energy Forum with a conference called "Advanced Building Skins" [8]. To stand out in this environment, research initiatives often propose highly intricate dynamic façade concepts which would require building managers to invest considerable knowledge, skill and time to maintain the optimum tuning of systems to the fluctuations of the weather as well as the specifics of the local microclimate. Maintenance of dynamic systems is an additional responsibility for which many facilities managers may not be trained. The same dynamic systems are often proposed as an addition to an over glazed façade.

The Advanced Building Skins conference strongly promotes the idea of Building Integrated Photovoltaic (BIPV) panels. The advantage of on-site generation is that little energy will be lost from the point of supply to the point of use. Not only installed at roof level, PV panels are becoming part of an increasing number of façade systems. Because of the improved financial efficiency of the systems there is less need for them to attempt to be optimally oriented towards the sun, which is in any case a moving target. Indeed, a vertical surface may gather more solar radiation in winter and this may be an advantage.

PV panels can be incorporated seamlessly into façades as a direct substitute for opaque cladding materials in floor zone, spandrel and core areas. The additional cost of the installation is thus offset by the cladding materials which would otherwise have been used (often of high quality). It is shown elsewhere in this paper that the amount of clear glazing needed in façades is less than is often provided.

A substantial trend in both research and practice is the use of double skins in façade assemblies [9,10]. A double skin provides a buffer zone for management of thermal extremes and an acoustic and wind protected zone which can support opening window panels. If movable blinds are located in this zone, solar heat gain can be excluded from the building interior. In winter, the same solar heat gain can be retained within the cavity as an insulating layer between the colder air outside and the building interior.

Since this is an additional investment in the cost of the façade, it merits additional scrutiny as to where and when it can be of most benefit.

2.3. Legislation and Marketing Initiatives

Environmental assessment methods such as the Building Research Establishment Environmental Assessment Method (BREEAM) [11] and Leadership in Energy and Environmental Design (LEED) [12] have been an important force in bringing attention to many environmental issues within the development industry. The industry, however, has become wise to these initiatives, prioritising “easy wins” in the point scoring systems over the longer term benefits which may carry short term costs. The value of the ratings of these systems is most pronounced at the stage of marketing the project; post occupancy management is only recently being included as of importance within these systems. There is a sense that the systems promote green features ahead of green thinking.

The UK Building Regulations propose target (carbon) emissions rates for new buildings other than dwellings in Part L2A [13]. This target is regularly reviewed and the target made more onerous. In addition, recommendations are made for maximum glazing percentages.

2.4. Climatic and Passive Design

A scientific approach to passive design was set out by Olgay in 1963 [14]. The work contains many charts, graphs and data; the architecture referred to, however, is in the main, low in density and unremarkable in design. Passive design thinking, which evolved from this, tailors building form, orientation, day-lighting and ventilation strategies to the individual site and its microclimate.

Architecture, whether formal or vernacular, when studied globally, reveals many climatically specific responses [15,16] to shading and daylight, ventilation and breeze and thermal capacity. Cross fertilisation of such thinking is informing passive design today. The extent of similarity and difference between climatic regions can inform practice which is increasingly globalised. The definitions and boundaries for these climatic zones, for the purpose of an architectural article coalesce around the characteristics of the indigenous architecture as well as approximate latitude bands and temperature/humidity profiles. With London as a focus, a building type with a need for cooling and a climate expected to change over the lifetime of buildings designed today, reference is made to warmer climates, in the tropics and the desert, where markedly different architectures have evolved.

2.4.1. Temperate Climate

London is at a latitude of 51 degrees North, and Britain is classified as a Marine Mild Winter Climate (Cfb) meaning temperate, without a dry season, with a warm summer, under the Koppen climate classification system [17]. Although there is a significant seasonal change due to the high latitude, winters are warmer than comparable latitudes due to the warming effect of the Gulf Stream ocean currents. This may become destabilized with substantial volumes of cold fresh water from Greenland’s melting ice cap being discharged into the path of this current; the benign thermal flywheel effect could then potentially be significantly reduced. Summers are expected to be hotter and drier; and winters generally warmer and wetter [18]. In addition, like other major cities, London is also subject to an Urban Heat Island effect where temperatures in the city can be significantly higher than in the adjoining countryside [19,20].

Despite the seasonal temperature variations, but because of high occupational densities and deep plans, many of London’s business buildings are in net cooling mode for much of the year. The potential of a warming climate indicates that more attention should be made to manage cooling loads, the most obvious being due to solar heat gain through extensive glazed areas.

A possible source of ideas can be found by looking at warmer climates and the architectural responses indigenous to those areas.

2.4.2. Tropical Humid Climate

Tropical humid climates, straddling the equator and extending towards the Tropics of Cancer 23 degrees North and of Capricorn 23 degrees South are much less affected by seasonal change caused by changing solar geometry. Seasons are mostly distinguished by being wet or dry, although the timing of these seasons is less predictable than in the past.

In addition, the temperature does not vary substantially over the daily cycle, limiting the opportunity for night time cooling, unlike in desert climates.

Passive design in the tropics relies on the shading of spaces and façades from the heat of the sun and harnessing cooling breezes through appropriate parts of the building. Circulation systems in buildings such as hotels and educational establishments can be thermally open, shaded from sunlight and where possible cooled by local breezes. The extent of fully enclosed (and frequently air conditioned) space is thus kept to a minimum.

Building orientation if predominantly facing north and south can allow for façade shading to exclude the heat from direct sunlight during the middle of the day whilst allowing generous glazed areas to admit reflected light into interiors. East and west façades should be provided with much less glazing, as low angle sun in the early morning and late afternoon can transmit substantial heat gain into building interiors. The relatively consistent seasonal solar geometry allows for simple rules of thumb to inform the location and shading of glazed elements in building façades.

2.4.3. Desert Climate

Many hot dry regions can be found some distance from the equator (in the Middle East, North Africa and in Australia, for example) where a significant seasonal climate can be experienced, due in part to the change in solar geometry. Clear skies bring substantial solar radiation (and heat gain to building interiors if not managed) in daytime and a steep drop in night time temperatures. Daytime temperatures can often exceed 40 °C.

Traditional development in hot, dry regions has clustered buildings close together so that shaded spaces can be created between them for streets and courtyards; streets have been oriented to suit prevailing winds and “windcatchers”; passive down draught cooling systems to bring breezes into the interior especially at night time together with thermal mass to smooth out temperature swings over the daily cycle.

Much of this has been lost in more contemporary development with typically wider streets and standalone buildings. However, passive solar design is being re-evaluated and traditional techniques can be enhanced with new technical knowledge and systems, as can be seen at the Masdar development in Abu Dhabi (see Figure 1).

Figure 1. Shading by adjoining building, façade modelling and limited glazed openings, Masdar, Abu Dhabi, Foster and Partners.

Improved façade design, which will exclude most sunlight and introduce reflected light, will lead to savings in mechanical equipment and the associated space requirement as well as reducing electricity bills over the years of operating the building.

Diffuse and reflected light can be harnessed by building design to reduce the reliance on artificial lighting; traditional Arabic architecture has evolved many techniques (in particular, the mushrabaya screen) which can be adapted to newer design solutions. Solar geometry tends to be more complex (and subject to more seasonal variation) than in the Tropical regions as the proximity to the equator is usually not so great; hence, the need for smaller glazed areas and the interest in dynamic shading systems. Care should be taken in desert regions to avoid the effect of sand storms rendering intricate systems less movable over time.

Several desert regions are rich in fossil fuel energy reserves; restraint in the use of these can help reduce global warming. These same regions are blessed also with abundant solar energy; the opportunity for generating substantial renewable energy exists.

2.4.4. Changing Climates—Mitigation and Adaptation

Design for mitigation of climate change often aligns with low energy building design which has a more immediate connection with clients and users' interests.

There is a need to consider adaptation measures, which may be needed more incrementally over time as the extent of climate change in specific areas becomes clearer. Pioneering research in this area adopts a spectrum of climate scenarios with which to test the future proofing of live projects [18]. Façade design can be based on a robust chassis on which additional shading devices can be fixed in the future as the economic case for them becomes more pressing.

Climate data for design prediction needs to be at least up to date and methodologies for forecasting future climate are reviewed in a recent paper [21].

2.5. Low Energy Building Design Strategies

Low energy design (helping mitigation of climate change) should aim first of all to reduce building energy consumption for heating, cooling and electric lighting. In larger commercial buildings (especially deep plan buildings) there is a greater need for cooling than heating over the seasonal cycle. This is in part due to high occupancy rates and in part due to artificial lighting loads.

Day-lighting and passive ventilation design set limits on the depth of buildings at around 13.5 m. Deeper buildings have to be lit and ventilated by atria at this spacing or rely full time on artificial systems. For deep buildings with air conditioning the influence of the façade on the performance of these buildings is less because of the reduced surface area per unit of floor space accommodated. A typology of building shapes and related environmental systems is indicated graphically in Figure 2 below.

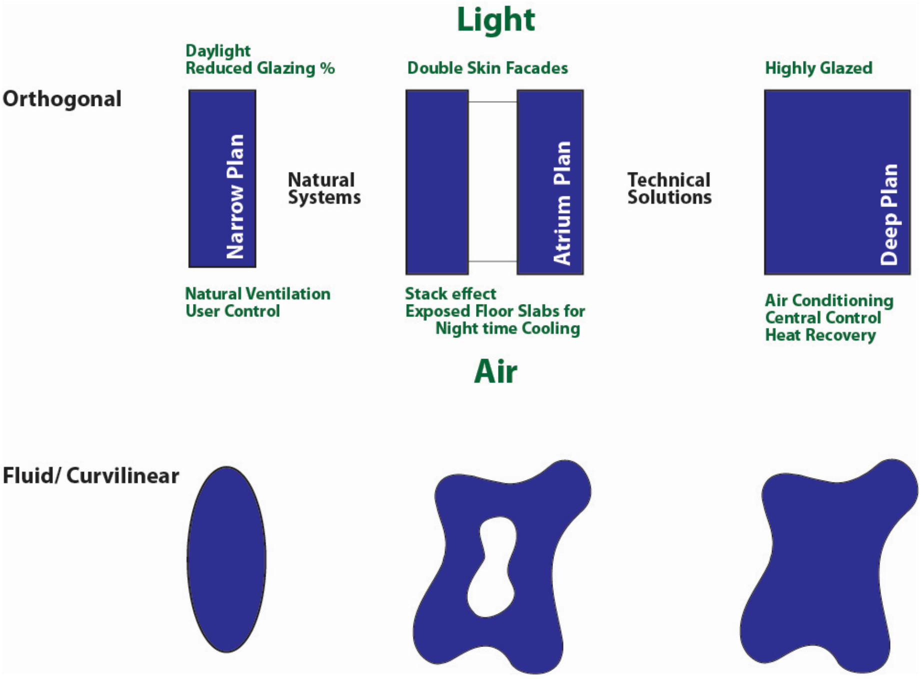

Figure 2. Typology of environmental systems and spaces (workspace).

Building form which has been designed substantially for natural lighting will generally be supportive of natural ventilation strategies. Narrow depth plans with courtyards or atria can support combinations of single sided and cross ventilation. Deeper plan areas or more densely occupied areas will benefit from mechanical ventilation and/or air conditioning. Chilled beams and ceilings provide cooling (through the use of water as a transfer medium) without humidity control. Chilled beams can save space in floor to floor height and can work in conjunction with the exposure of structural thermal mass in moderating and delaying temperature swings which can be cooled with night time air ready for the next day.

Natural ventilation requires façade openings in the form of windows, panels or grilles. In taller buildings or buildings in urban environments, a buffer zone is sometimes formed to protect these openings from driving wind, rain, temperature extremes and external noise. This can be done in the form of a glazed screen or double skin façade which also serves to screen the visual complexity of windows and grilles.

This type of thinking is still at an early stage in the commercial market which has up to now favoured sealed buildings and air conditioning or mechanical ventilation.

2.6. The Role of Daylight in Buildings

Everyone agrees that light is a fundamental ingredient of good design, but agreement on the amount and quality of light, both natural and artificial, that makes good design is less easy to find. Daylight is also an important contributor to the reduction in the need for artificial lighting with its associated energy costs and contribution to heating loads. Façade design has a big role to play in both of these issues.

Climate Based Daylight Modelling (CBDM) challenges the industry's reliance (through BREEAM and LEED among others) on the Daylight Factor and its "Standard Overcast Sky" as a design standard [22].

> *"Practitioners encounter guidelines and recommendations for target DF values that they know are likely to result in over-glazed buildings with excessive solar gain and/or heat loss."*

CBDM measures absolute illuminance from both sun and sky, direct and indirect light as a dynamic simulation in time from regional climatic datasets. Although a more sophisticated an analytical system [22],

> *"... Development of more accessible, user-friendly CBDM applications will be needed, with an inevitable compromise between precision/flexibility and ease-of-use."*

Urban quarters which work well for public transport and the pedestrian are likely to, at the same time, restrict access to sunlight and daylight to their buildings because of their proximity to one another; this effect varies throughout the day and throughout the seasons. Light available to building interiors is likely to have a higher proportion of reflected light than in less compact areas. Access to sunlight and daylight on building façades can be assessed using environmental software such as IES and Ecotect [23,24]. This reduced access to light contradicts to some extent the otherwise accepted view that glazing percentages in commercial buildings are too high.

For buildings with specific needs, light can be introduced from above (north light only if required), from the side (windows) and from reflected sources such as window reveals, light shelves, light scoops, *etc.* As Rafael Moneo states [25]:

> *"... What stands out is the importance attributed to light, the true protagonist of the compact architecture."*

As these strands of thinking come together it becomes clear that the façade of a building within the scope of this study should introduce more (day) light into the building but less (solar) heat.

3. Façades: Climatic Design Principles and Strategies

3.1. Glazing Percentage and Orientation

A better combination of glass and solid, shading and reflectance, view and solar control is required from mainstream building design if a significant reduction in carbon emissions and an improvement in occupant comfort and productivity is to be achieved. Internal blinds are no defense against the heat of the sun as that heat will have already entered the buildings' thermal zone; the heat reflected back towards the glass will be retained within the building (this powerful effect is popularly known as the greenhouse effect and is not always welcome in workplace interiors).

Solid façade elements give scope for good insulation levels which will help reduce extremes of heat and cold influencing the heating and cooling loads.

If there is to be less clear glass then how should it be distributed within a building enclosure? The desire for full height glazing in all areas should be subject to the strongest scrutiny. The view of the underside of office desks from outside benefits no one. Circulation areas and meeting rooms, if they could be defined are areas where more generous glazing can be appreciated. This is a difficulty created by the speculative nature of property markets where no options are ruled out but space is lacking in any definition.

East and West façades are the hardest for which to manage solar heat gain as the low angle sun in morning or evening is not controlled by horizontal shading. South facing façades (in the Northern hemisphere) can admit good quantities of light even if there are projecting external shading systems; much of this daylight will have been reflected and the direct heat of the sun reduced. North facing light is weaker and more even in its distribution.

In conclusion, buildings are more climatically designed (and hence, more likely to be energy and carbon efficient) when their façades are specific to their orientation. Buildings may, in fact, have primary façades which welcome daylight and sunlight and secondary façades which restrict this, adding directionality to the way the building addresses its surroundings. Although well known to many, it is surprisingly rare in recent practice. Façades with larger amounts of glass should have measures in place to manage the exposure to the extra light and heat (and associated fluctuations of these) which will result. This is analogous to wearing sun cream if you intend to spend long periods in the sun.

3.2. Double Skin Façades

A double skin façade provides a minimal depth glazed thermal buffer zone for the moderating of fluctuating thermal conditions between inside and outside. Many variations of this idea have been developed in terms of the size of the compartments and the environmental operation of the system, which can be free flowing (gaps between glass panels), motorized automatically or with local override. The internal façade line can be fully or partly glazed and may be sealed or incorporate opening windows. The cavity is an ideal thermal position to incorporate blinds and shading systems [26].

European examples will tend to be associated with narrow plans and the opportunity to open windows behind this screen, which will have screened air flow and traffic noise. UK and U.S. examples, however, will more likely wrap sealed buildings with a double skin façade and their mechanical systems may be engaged with the import and export of air to and from the buffer zone.

A new type of cross disciplinary design team is emerging where building physics specialists work alongside façade specialists (who may be consultants or may be façade contractors); architectures may specialise in this field to join teams such as this. An account of the elite design groups who have the skills and/or potential to maximise the benefits of double skin façades is given by Trubiano in an earlier issue of this journal [27].

What is missing is much sharing of knowledge of performance post occupancy in this fast growing field. Projects are marketed with an array of green features and excellent BREEAM or LEED ratings (and this will help gain planning and financial approvals). Visualisations with blue and red arrows will show the route that air is expected to take but seasonal or daily control strategies are rarely published and comparisons of similar façades with different orientations would be of value. Are the double-skin façades wrapped all the way round primarily for visual consistency or are they effective in each orientation but under different control regimes?

The additional investment in two layers of material of high embodied energy (aluminium and glass) may suit some clients with high profile projects but it is not clear that wider dissemination of this system is a good use of resources.

The customisation of the intricate web of digitally driven environmental systems in double skin façades and mixed mode ventilation systems is an art in itself; a new breed of facilities manager may evolve to bring together the opportunities presented by innovative design and the community of building occupants who may have differing views of comfort in buildings [28].

Without wider sharing of good practice (currently inhibited by commercial confidentiality), the potential benefits of these exciting developments may not be matched in practice over time.

3.3. Glazing Coatings and Specifications

In the time when fully glazed façades were the norm, specialist glazing was the only line of defense against solar heat gain. Sophisticated glazing assemblies (double and triple glazed) together with specialist coatings have been developed to control heat gain while maximizing the transparency of the window system. Low-e glass will help retain heat in the interior of the building if this is required.

These glass assemblies still have an important role to play but are not enough in the context of very low energy buildings where physical solar shading should be provided before the summer sun's rays reach the façade and a reduced glazing percentage is the simpler method of maintaining indoor conditions.

3.4. Shading and Reflecting—Static and Dynamic Systems

Static shading devices range from overhangs and deep reveals within more solid walling systems to maintenance walkways and lighter filigrees of projecting louvered aluminium. Solar shading can also be of folded metal providing an opaque projection still within the work "package" of a curtain wall specialist. Such projecting devices can often hang over the building boundary and not sacrifice the opportunity to maximize the commercial value of a site.

More lacey constructions of perforated or twisted metal can contribute to a decorative effect informed by the new conditions of digital fabrication. Such "veils" continue the analogy of the curtain (wall) which has been part of the language of façade design since structural frames freed this part of a building from load bearing responsibilities. In some cases, they link back to the two directional shading devices of the Middle Eastern mashrabiya tradition.

Horizontal shading systems can double up as "light shelves". The shelf effect enables reflection and diffusion of daylight deeper into the interior of the building. The light reflected from the top of the sky is brighter than that of a lower angle.

Dynamic shading at its simplest includes movable shutters, external blinds and awnings; the traditional hand operated moving systems which have been used in warmer countries for generations. Robust designs for these products have evolved to deal with wind, rain and the heat of the sun.

Roller Blind systems are now available with motorized controls which can be programmed by the BMS to be deployed in multiple zones to suit the varying patterns of solar exposure. These blinds are programmed to be retracted on the onslaught of extreme conditions of wind and rain. Tilting louvers can also be operated by motorized systems.

More substantial shutter systems based on folding, sliding, or folding and sliding elements are options based usually on the size of window module. These can operate in the horizontal plane or sometimes in the vertical plane. The shutter material may take advantage of the ease with which metal sheets can be perforated to allow for some transparency and air flow. Blinds which are fixed in position but can be rotated by pre-programmed motorized systems are well established in the market.

Complex moving elements are found in the Al Bahar towers recently completed in Abu Dhabi. Here, an origami like arrangement of folding panels based on a hexagonal geometry makes reference to the region's Islamic patterns. As an (otherwise highly glazed) elliptical tower, a wave of open panels can track incrementally across the curved surface providing changing scenery at different times of the day [29].

This is a field of innovation and experimentation where different methods of solar shading are being invented and patented and different aesthetic solutions are being tried and tested.

3.5. Building Integrated Solar Energy Systems

If parts of the façade are not needed for day-lighting the interior, are there other uses to which the surfaces in question can be put?

The cost and efficiency of PV solar generation of energy has decreased significantly in recent years. Not only installed at roof level, PV panels are becoming part of an increasing number of façade systems with issues of efficiency and aesthetics coming to the fore. The advantage of on-site generation is that little energy will be lost from the point of supply to the point of use.

A study has shown that energy generated on east and west façades (in conjunction with south and on the roof) can contribute to a smoother energy generation profile over the day with a closer match to the demand than if panels were all optimally orientated. This study was based on unobstructed façades, different to those of the compact urban quarters of this study. An exploration of solar access of the different façades at design stage may lead to an adoption of BIPV on an exposed façade and at upper levels on more shaded façades. An aesthetic logic for this could be sought [30].

The same study indicates an approximate ratio of the maximum energy which can be generated in Northern Europe compared with Southern Europe of 50% for an equivalent installation; notwithstanding this, the direct substitution of quality surface materials in a building façade for PV panels is an attractive financial possibility. PV panels may also be incorporated within double skin façades as shading devices within a glass assembly.

4. Case Studies

The value of the preceding sections of the paper lies both in helping support design strategies and as a critical toolbox in reviewing completed buildings from both an environmental and an architectural viewpoint.

Projects have been chosen for short reviews as case studies based on the context of the urban settings, the general nature of the business spaces provided, their potential for influencing other projects, and differing approaches to embedding environmental thinking within a variety of design positions and their design quality as perceived by the writer. The projects are reviewed within the context of the previous discussion.

Two of these projects are in the Kings Cross railway land development. This large scheme fits the criteria for a well-designed dense and connected urban quarter with a strong pedestrian priority.

4.1. Ropemaker Place, London

Ropemaker Place is located on the boundary of the City of London's financial district and the London Borough of Islington (where a general planning height restriction of 30 m applies). The building steps up in height form the North (LB Islington) to 20 stories at the South East corner where it faces the 30-storey tower known as City Point and its open plaza. The surrounding streets are narrow and the building is well connected to public transport, London buses, London Underground and the upcoming Crossrail link, all at Moorgate.

As a deep plan building for the London financial market, the design of Ropemaker Place by Arup Associates has taken a strict approach to limiting solar heat gain.

The percentage of clear glazing is very low. The building is clad principally in opaque insulated glass panels with coloured inserts of varying pattern across and up the façades. Projecting "windows" are arranged above desk level in long rows, which are then bookended by opaque glazing.

The projecting windows are angled to restrict the entry of sunlight: on the south elevation, the window is tilted downwards with a hood like canopy at the top, whereas on the east and west façade's the window glass is angled laterally towards the North with solid ends facing the South (Figures 3 and 4). These latter windows appear in serrated rows of strip windows within the flat expanses of opaque glazing. This angled window treatment is stated to reduce solar heat gain by 27% from an equivalent flat façade.

The rigorous exclusion of sunlight supports the low energy strategy for this deep plan building; the occupants may miss the amenity of the sun's rays reminding them of the daily cycle.

The substantial opaque areas of the façade could have been an opportunity for energy generation; however, an artist designed array of subtly changing coloured panels is the preferred solution. The use of glass as a design feature for the opaque cladding is highlighted in The Architects Journal [31] for its relatively high embodied energy; it seems that the new architectural thinking is camouflaged to fit with the expectations of the market.

The author was a member of the design team for this project as part of his work with Arup Associates.

Figure 3. South facing inclined windows, Ropemaker Place, London, Arup Associates.

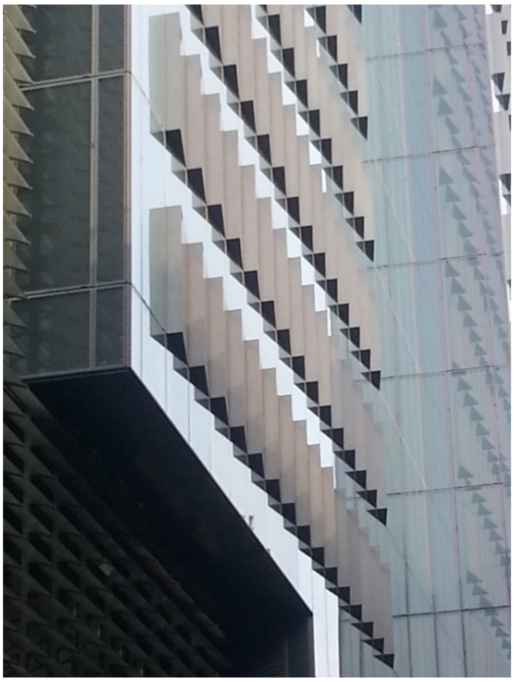

Figure 4. Serrated windows on East façade (West façade similar), Ropemaker Place, London, Arup Associates.

4.2. One Pancras Square, Kings Cross, David Chipperfield Architects

This commercial building makes a powerful historic reference to the cast iron age while acknowledging the benefits of a reduced amount of glazing to the building's interior. Cast iron column casings form an apparent structure at an interval more frequent than the regular steel frame underneath (see Figure 5). The columns are in the round as a portico on the prominent southern elevation and on the east and west half round as part of a beam and slab arrangement which shades the glazing whose percentage is reduced in the process (Figure 6) [32]. This percentage is approximately 40% consistently around the main floors of the building. Two Pancras Square has been newly completed and no performance data is expected at this stage.

Figure 5. South facing portico with cast iron columns. One Pancras Square, London, David Chipperfield Architects.

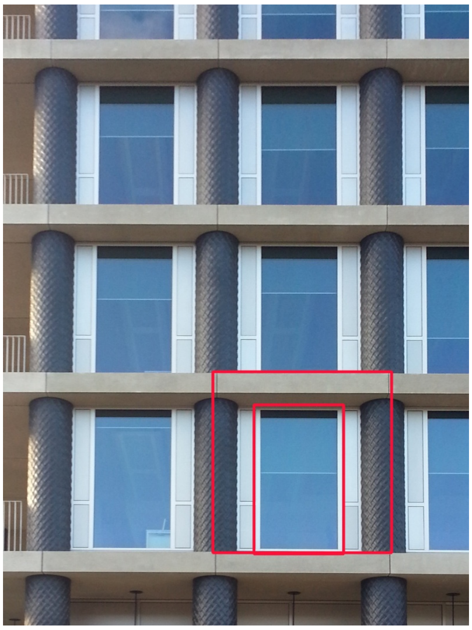

Figure 6. Typical façade detail showing glazing percentage. One Pancras Square, London, David Chipperfield Architects.

4.3. Two Pancras Square, Kings Cross, Allies and Morrison

This is a building by a practice which has adopted a contextual approach from its inception. A modern tripartite composition of solid and void achieves the reduced glazing percentage indicated in the paper in a polite and restrained manner. The exposed east façade will later be part of a tall urban street as the adjoining site development gets underway (see Figure 7). Allies and Morrison were the architects of the master plan for this development [33,34] which combines density with a traditional network of streets working with the existing conditions and features from the railway and canal era.

Figure 7. Two Pancras Square, London, Allies and Morrison (**right**) with One Pancras Square (**left**).

The almost imperceptible incremental increase in window size rising up the building can be seen as an aesthetic transition from the 6 m wide column spacing at ground level to the thinner pergola-like framing at roof level 3 m apart. A daylight driven response would plan for more daylight at the lower parts of the building where shading by adjoining buildings will be more evident. An example of this can be seen in the north elevation of the CH2 building in Melbourne, an urban ecological building of which a successful performance review has been carried out and published [35].

The glazing percentage varies from approximately 50% at the lower level (see Figure 8) to 60% at the top of the building. Two Pancras Square has been newly completed and no performance data is expected at this stage.

Figure 8. Typical façade detail showing glazing percentage. Two Pancras Square, London, Allies and Morrison.

4.4. Kings Place, London, Dixon Jones

This landmark building houses music venues, gallery and conference space, a canal side bar and a restaurant underneath commercial offices currently occupied by the Guardian newspaper among others [36]. A five-storey height, wave-like projecting glass screen shields the building from traffic noise while presenting a consistent front to the adjoining major new development (see Figure 9). The screen, which is thermally open at the bottom and at the top, allowing warm air to disperse due to stack effects, faces west whilst also wrapping round the south west corner into part of the south façade (see Figure 10). This screen allows a more highly glazed inner façade than would otherwise be justified in low energy terms. Other façades are composed of punched window openings in a more traditional manner (see Figure 11). The building shows how environmental thinking can be incorporated into a powerful urban and architectural composition [37].

Figure 9. Kings Place, London, Dixon Jones (West Elevation).

Figure 10. Close-up of double skin façade, Kings Place, London, Dixon Jones.

Figure 11. North West corner, showing differing façade system facing North, Kings Place, London, Dixon Jones.

On visiting the site on a sunny winter morning, almost all of the internal blinds on the south façade were in the down position; even the fixed cavity shading did not limit the penetration of the low angled winter sun (see Figure 12).

Figure 12. Blinds in drawn position, South façade, Kings Place, London, Dixon Jones.

4.5. Education Executive Agency and Tax Offices, Groningen, UN Studio

This building is not in a dense urban context and has significant provision of underground car parking. It is included here because it demonstrates an incremental adjustment to solar orientation and shading within and around a curvilinear building outline. This would be difficult to conceive, let alone analyze and calculate without recent advances in three-dimensional modeling, parametric software and computer power [38]. A composition based on two ellipses; the pointed spandrel projection increase and decreases incrementally as the façade faces from east to south and to west in particular at the same time as the window height is raised and reduced again. The top surface of the projecting overhang is able to reflect light (minus the solar heat gain) into the interior, acting as a light shelf.

The project is a sophisticated example of parametric design thinking incorporated into a curvilinear building. UN Studio is a research led practice which makes strong connections between environmental led design and parametric form finding [39].

4.6. 101 Bishopsgate, London, KPF

This building (see Figure 13) is highly glazed on three façades facing the North, East and West, whilst the south face of the building is occupied by lifts, toilets and stairs which shield the office space from the southern solar heat gain. These core elements are in part clad in a building height array of PV panels, showing that façade areas that are not required to act as windows can generate renewable energy at the point of source for building users. The cost of these panels can be offset by the cost of the cladding which would have been required if the PV panels were not there. In this case, development of the adjoining site to a similar height may in the near future obstruct the solar access of these panels during the middle of the day.

Figure 13. PV panel cladding at lift cores, 101 Bishopsgate, London, KPF Architects.

4.7. White Collar Factory Old Street, London, AHMM

In Derwent London's and AHMM Architects' "White Collar Factory" concept [40], a looser and more robust approach to housing innovative enterprises is emerging. The cost of building and accommodating business is moving from the (formerly suspended) ceiling to the façade, where opening windows and shading/screening devices are included as part of a reduced percentage of overall glazing. Exposed structure at ceiling level can contribute through its thermal capacity to the flywheel effect of smoothing out temperature changes over the daily cycle in conjunction with night time cooling. Changes in computing patterns are leading to a reduced emphasis on under floor cabling as Wi-Fi enables a more fluid and mobile way of working.

The construction of this project was at the foundation stage at the time of writing.

5. Implementing Climatic Based Façade Design

The façade is not just the thin zone outside where the architect is encouraged to package a predetermined interior floor space and present it in its external surroundings. The façade should modify the interior environment, significantly lightening the air conditioning (or other mechanical system) loads, whilst admitting daylight, limiting solar heat gain, controlling glare and managing privacy. In order to do this, glazing can be arranged in appropriate ways to respond to the cardinal points of the compass and the surrounding buildings. Wall surfaces not actively in use as windows can be clad with PV panels and help generate electrical energy.

Effective climatic design requires a set of environmental objectives which are agreed with the client and the design team from the earliest stages of a project. An up to date template for task management in the complex procurement and digital collaboration world incorporating key sustainability checkpoints now exists in the form of the RIBA Plan of Work 2013 [41]. Within this framework, the right issues can be identified at the right time and a proactive contribution from the key specialists can be expected. Allowance is made for sharing key data at the right time and supporting the commissioning and handover stage more effectively.

These check points include identifying during concept stage and confirming during design stage a seasonal control strategy and considering resilience in response to future changes in climate. For British practice, the Part L analysis should commence early so that environmental thinking is part of the decision making process and not a response to an already confirmed design.

An example of how climatic based design thinking (focusing on the façade design) can be incorporated into the design sequence for an urban business building can be seen in Table 1.

Robust design based on Table 1 can be embedded in the project before a full team is appointed and before the more frontloaded and accelerated Building Information Modelling (BIM) activity is too far advanced. Environmental software such as IES or Ecotect can be used to support these early stages. Façade design can be then tested in more detail and refined using such software in parallel (and off the critical path) during a design development phase. A variety of approaches to incorporating environmental design within the new shared digital environment are reviewed in detail in BIM Design [38].

Table 1. Design sequence for embedding environmental thinking within early façade design ideas (Environmental and climatic activities highlighted in green).

1	Building form	Review the plot boundaries, surrounding buildings and context and planning restrictions
		Review orientation, access to sunlight and daylight, shading from adjoining buildings
		Will additional light and ventilation routes be introduced via an atrium or courtyard?
		Develop initial building form based on the above
2	Energy balance	Formulate an initial view of the relative importance of heating and cooling, sunlight and daylight over the seasons, based on building form and expected occupancy
3	Orientation, glazing %	Study visibility, principle direction of arrival, entrance positions, clients profile
		Review and analyse which surfaces of this building volume will be illuminated by the sun, at what times/seasons, at what frequency and for how long?
		Review and analyse how much daylight is accessible to these building surfaces, both directly and indirectly
		Based on the above, is there a reason for increasing the glazing % above recommended amount (40%) for any (or all) of the elevations?
		Should the proposal have directionality with primary and secondary façades?
4	Glazing concepts	Develop glazing concepts for the building and its individual façades based on the above
		Incorporate solar shading and/or double skin façade concepts as appropriate responding to orientation and solar access.
5	Vertical differentiation	If sunlight and daylight are less accessible at lower levels of the façades should the design be adjusted to suit this?
		Is there an opportunity to harness solar energy on the various façades, and is this more pronounced at upper levels of the building?
6	Detail of glazing concepts	Consider extent of solar shading and /or operation of any double skin façade system proposed. Review solar angles at winter/summer/mid-season. Review energy implications of solar heat gain to energy balance in these three seasonal conditions.

6. Summary and Conclusions

The set of issues identified and examined in this paper can be used both as a tool for critical evaluation of buildings and as part of a design methodology for new projects.

Post occupancy testing, however, of double skin façades, in particular, is urgent and results should be published in order to help improve practice. It can then become clearer whether these systems should be adopted for specific orientations or more generally around buildings and if so, how they can be customized for the different orientations.

Architectural and sustainable strategy must go hand in hand in the design of the façades of buildings, and both passive and active design thinking should inform this process. In addition to facilitating views and the appearance of the building, each façade (and each part of that façade) can contribute to daylight, solar control, energy generation, insulation and/or thermal buffering according to its exposure to sunlight and daylight over the daily and seasonal cycles on a three-dimensional grid. In addition to the façade systems which automatically open and close vents and blinds according to the weather, each part of the façade plays its part in several aspects of building physics according to where it is.

Using advanced modeling techniques, the relevant design information can be made available and early ideas tested; the challenge is to invent new aesthetic systems to effectively use that information.

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Conflicts of Interest

The author declares no conflicts of interest.

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