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**Table 1** Summary of research on natural light controls and guides systems

| **System** | **Object/Methodology** | **Location** | **Building** | **Major findings/limitations** | **Ref.** |
| --- | --- | --- | --- | --- | --- |
| Lightshelf/Anidolic | The system was simulated through Radiance in a prototype that responds to a deep office space typology for different seasons of the year and hours of the day. The system was compared for illuminance and glare performance. | Israel | Office | This system protects the lower areas near a window from direct solar radiation and it also reduces the contrast between the light levels generated in the vicinity of the window and those at the back of the room. The anidolic ceiling offers high levels of illumination in quantitative terms. However, qualitatively, care must be taken over solar angles where the reflection hub may cause glare. Errors in the size or orientation of the hub may cause undesired reflections, even when the system’s performance is good. | [49] |
| Lightshelf | Traditional adaptations of tropical /sub tropical buildings to high ambient irradiance from high elevations are outlined. Some examples of optical systems designed to improve daylighting in tropical buildings are discussed. | Tropics | Office | The lightshelves are a good device for shading and natural lighting. | [50] |
| Lightshelf and blind | In the lightshelf zone, first the existing venetian blinds were relocated to the middle of the window height, and then the interior lightshelves were installed on the upper half of the windows. The measurement was performed under overcast sky condition with electric lights off and all venetian blinds retracted. To study the effect of the subdivided window on occupants’ use of blinds and electric lighting, the data was gathered on blind positions and electric light usage. | Wisconsin | Office | The results suggest that in identical environmental conditions, occupants whose workstations were located within the lightshelf zone demonstrated a lower window occlusion than those who were located in the area with conventional windows. Additionally, occupants in the lightshelf zone used less electric lighting than those in regular window design area. | [51] |
| Lightshelf | The impact of ceiling geometries on the performance of lightshelves was investigated using physical model experiments and radiance simulations. | Sub-tropics | Office | The geometry of both the ceiling and the lightshelves plays a very important role in their performance. The best ceiling is one which is curved in both the front and the rear of the room and the best lightshelves are curved and bevelled. | [52,53] |
| Prismatic glazing | The reduction electrical energy consumption was investigated using a prismatic glazing unit consisting of two panes with interlocking, horizontal prismatic ribs with a triangular cross-section and a prism angle of 90º. | North or south latitudes between 30º and 60º | Office | This heightened penetration and uniformity of light reduces electrical energy consumption for cooling as it offers a significant improvement in the thermal comfort of the users during the summer months. | [61] |
| Prismatic glazing | This study estimates the technical potential for energy savings available from vertical daylighting strategies and explores additional savings that may be available if current dPOE research culminates in a successful market-ready product. | Chicago | Office | Results indicate that fully functional dPOE coatings, when paired with conventional vertical daylight strategies, have the potential to reduce energy use associated with U.S. commercial electric lighting demand by as much as 930 TBtu. This reduction in electric lighting demand represents an approximately 85% increase in the energy savings estimated from implementing conventional vertical daylight strategies alone. | [64] |
| Hologram | The development and production of HOE's for controlling and directing the radiation of the sun which gives a broad scale of applications with high potential of energy saving and increase of comfort. | Dortmund (Germany), Southampton (UK) and Athens (Greece). | Office | A shading device with HOEs is a highly innovative system allowing “transparent shading”. The view to the outside is nearly not affected, but the beam radiation is inhibit to penetrate the building. In combination with an automatic control system the energy consumption for cooling, heating and illumination in buildings can be reduced. | [66] |
| Hologram | This paper describes the potential application of solar control HOE applied as either a fixed plate or tracked solution. The single-element hologram focuses light, spectrally splits it and diverts unwanted infrared heat away from the solar cells. | UK | Greenhouse | The temperature in a greenhouse could be reduced by as much as 6.1 degrees if holograms were added to 62% of the glass. | [69] |
| Anidolic | The subject of this article is building energy saving on electrical lighting by anidolic integrated ceiling (AIC), compared in different daylight climates. The objective was to quantify the energy savings of AIC for a range of locations where such AIC has yet to be applied. | Singapore and Sheffield | Office | Computational simulations show that more than 20% of energy for electrical lighting can be saved. The energy savings are quite similar for both locations, with 21% for Singapore and 26% for Sheffield. Therefore, it is valid to conclude that AIC is a universal remedy to improve daylighting and energy efficiency in deep buildings. | [74] |
| Anidolic | The article gives a description of the anidolic systems, as well as an overview of their luminous performance, assessed experimentally within the framework of IEA Task 21. | Greece | Office | On an overcast day, the daylight factor, measured at the back of a room, increased by 1.7; this allows for a reduction in electrical energy consumption for lighting of a third. Furthermore, measurements of visual comfort recorded that, with an overcast sky, the Anidolic ceiling offers better quality illumination than conventional glazing. | [76] |
| Anidolic | All south-facing office rooms within the LESO solar experimental building in Lausanne (Switzerland) are equipped with a given type of ADS. | Lausanne (Switzerland) | Office | With Anidolic lighting systems, lighting power densities can be reduced by at least 4 W/m2 with no significant impact on visual comfort and efficiency; even a 3 W/m2 reduction is a realistic possibility. | [77] |
| Anidolic | The present paper describes in detail the anidolic collecting system as a part of the comprehensive daylighting system. | Madrid (Spain) | Non-residential  buildings | The daylighting system minimizes on solar incidence which means an appropriate behavior for virtually any time of year during working hours. Moreover the controlled aperture angle reduces reflection losses. | [78] |
| Louvre | This research is aimed at exploring the influence of external dynamic louvres on the energy consumption. | Abu Dhabi-UAE. | Office | The results showed that the potential energy savings when using the dimmers was merely 24.4%, 24.45% and 25.19% in the south, east and west-facing facades, respectively. The proposed system of dynamic blinds together with the gradual light reduction strategy meant energy savings of 34.02%, 28.57% and 30.31% in a southern, eastern and western orientation, respectively. | [93] |
| Louvre | In this paper a ray-tracing method is developed to describe the global solar transmittance of louvre shading devices. The paper assesses the influence on the cooling demand and peak cooling power of a south oriented office cell when using different models and approaches to simulate the performance of exterior louvre shading devices. | Belgium | Office | Best results are achieved by implementing solar radiation weighted monthly averages allowing to estimate the cooling demand and peak cooling power within 3%. | [94] |
| Louvre/blind | The optimized automatic control strategies of slattype blinds were developed to efficiently adjust the solar radiation through the window, which can improve both energy efficiency and visual comfort by taking into account cooling, heating and lighting energies as well as the glare phenomena. | Daejeon City, South Korea | Office | When the double-sided blind was used alongside the controlled light dimmers, an energy saving of 24.6% could be achieved when compared to the baseline case, and simultaneously glare could be avoided. In the second stage, the control strategies of slat angle and up/down control logic were developed to fully remove glare and improve the energy efficiency. As a result, an energy saving of 29.2% could be achieved whilst glare was reduced to just 0.1%. | [95] |
| Louvre | The effect of the louvre shading devices applied to different facades of a building at different latitudes was studied. | Mexico (Mexico), Cairo (Egypt), Lisbon (Portugal), Madrid (Spain) and London (UK) | Office | The results showed that the integration of louvre shading devices offered thermal comfort inside a building and could lead to significant energy savings, compared with a similar building without this type of shading devices. | [98] |
| Louvre | This study examines the effectiveness of installing a controlled semi-silvered reflective louvre system in the clerestory portion of a direct solar (north) facing facade system in a deep cellular office space. | Melbourne, Australia | Office | The reflective louvre system can increase working plane illuminance by up to 70% on a clear day. However this system did not generate reasonable savings in costs and presented the disadvantage of creating contrast. | [99] |
| Louvre/blind | Methodology for a combined lighting-daylighting numerical simulation of an office space with an advanced window system incorporating motorized reflective blinds between the two panes. | Montreal | Office | The energy savings using the methodology presented for the particular window system with integrated blinds may exceed 75% for overcast days and 90% for clear days, compared with the case of an office space with no daylighting /dimming control. Also, proper control of the blinds blocks direct solar radiation and reduces glare. | [101] |
| Blind | This study aims to find out whether the environmental performance of a building can be improved by the application of an automated Venetian blind in comparison to a manual or motorized Venetian blind and whether occupants may feel discomfort by the application of an automated Venetian blind in the summer season. | Seoul, Korea | Office | The potential energy savings and the comfort enhancement when using the automated blind was confirmed. | [120] |
| Skylight | The main aim of this article is to determine a suitable shape for lightscoop skylights, whose main characteristic is a vertical opening oriented in the opposite direction to the solar trajectory, in order to ensure maximum illuminance on the work plane within a room. | - | Museum or library | The curved shape produces an increase of average daylight factors close to 3.5% compared with the rectangular shape, while the sawtooth shape produces a decrease of average daylight factors close to 3.5% in a room under overcast sky conditions. | [127] |
| Skylight | This study reviews a concept to understand the passive behavior of solar radiation in the form of light and heat that falls on, interacts with, and is emitted from a skylight system in a single-story building. The study method is theoretically based on descriptive analysis to assess design requirements. | Malaysia | Single-story building | Skylight systems are inappropriate for direct application in the tropics to balance the thermal and lighting loads. Therefore, these systems should be integrated by using shading, glare protection, proper use of reflective surfaces, reflectors, prisms and multi-pane, using splaying and wells for skylight, as well as double-layered roof system, and taking advantage of different geometries, roof angles, orientations, and complicated roof profiles. | [128] |
| Skylight | A model to estimate daylight factor was investigated and validated using experimental hourly inside and outside illuminance data of an existing skylight integrated vault roof mud-house in composite climate of New Delhi. | New Delhi (India) | House | Through the study and validation of a model used to estimate daylight factors, showed a potential yearly saving in electrical energy for lighting of 973 kWh/year. This saving is equivalent to 1,526 kg/year of CO2 emissions. | [131] |
| Sawtooth | The experimental results and the specific analysis of thermal energy savings carried out to analyse energy efficiency in a building with a sawtooth system installed. | Almeria (Spain) | University | Simulations have shown that, the needed annual thermal loads required to obtain comfort conditions are lower into MEDUCA (Model Educational Buildings for Integrated Energy Efficient Design, contract BU 1006/96) courtyard than in a conventional sawtooth roof. The loads values are different depending on monthly requirements. | [132] |
| Light pipe | In this research, a remote source lighting system (RSL) is introduced to illuminate the enclosed lift lobbies. The system composed of prismatic light pipe and optic fiber to address the problem of limited headroom. | Hong Kong | Highrise commercial and residential | This lighting system can solve the energy consumption problem in the lift lobby in terms of renewable energy use and natural lighting application. The prismatic light pipe can work in both clear and overcast sky conditions. However, there are limiting factors that affect the performance of it such as orientation, solar azimuth angle and angle of incident light. | [136] |
| Light pipe | The aim of this study is to illuminate a windowless room via a light-pipe and dimmable electronic ballasts. | Istanbul (Kadikoy) | Office | Approximately 30% saving was achieved by the proposed controller implementation. In summer, the energy saving from the lighting system will be even higher. | [137] |

**Table 2** Comparison between the different systems of control and guidance of natural light

| **Category** | **System** | **Climate** | **Location** | **Criteria for the choice the elements** | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Glare protection** | **View outside** | **Light guiding into depth of room** | **Homogeneous illumination** | **Saving of energy** |
| Side-lighting systems | Light shelves | All climates | Vertical windows | Depends | Yes | Yes | Yes | Yes |
| Prismatic glazing | All climates | Vertical windows, skilights | Depends | No | Depends | Depends | Yes |
| Mirrors and holograms | Temperate climates/All climates | Skilight, glazed and roofs | Depends | No | No | Yes | Depends |
| Anidolic ceiling | Temperate climates | Skylight | Depends | No | No | Yes | Yes |
| Louvres and Blinds | All climates | Vertical windows | Yes | Depends | Yes | Yes | Yes |
| Top-lighting systems | Skylight | Hot climates, sunny skies | Skylights | Depends | No | Yes | Yes | Yes |
| Roof monitor | All climates | Roofs | Depends | No | No | Depends | Yes |
| Sawtooth | All climates | Roofs | Depends | No | No | Depends | Yes |
| Light pipe | All climates, sunny skies | Skylights | Yes | No | Yes | Yes | Yes |