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# Prediction of energy savings with anidolic integrated ceiling across different daylight climates

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**Abstract**

The subject of this article is building energy saving on electrical lighting by anidolic integrated ceiling (AIC), compared in different daylight climates. This particular device collects diffuse daylight with an anidolic external collector and channels it into a reflective ceiling plenum. The exit apertures located at the rear of the room will discharge the daylight to the deep and gloomy zones of the room and thus reduce demand for electrical lighting. This paper analyses the savings on building energy for different locations. Two cases were studied with Singapore representing a location of high sun altitude and high building density, while Sheffield representing a location of lower sun altitude and moderate urban density. The performance criteria Daylight Autonomy (DA) was used to quantify the energy saving, after the AIC was integrated into the default ribbon window façade of a standard office room. 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.


*Keywords:* Architecture; Anidolic integrated ceiling; Daylight Autonomy; Standard General Sky

## 1. Introduction

It is widely known that electrical lighting in office interiors can make up for 30% of the total building energy consumption. The poor window design is to be blamed, which causes daylight to reach the interior insufficiently and in a non-homogeneous manner. The building regulations require an evenly distributed illuminance of 300–500 lx, but the illuminance levels of standard rooms always show a trend of over-provision of daylight near the window while under-provision towards the rear of the room. As distance from the window increases, the more dependent the space is on the light reflected from the surrounding material surfaces. But most of the time, the walls, floors and furniture are of low reflectance, thus making the rear part of the room appears gloomy and too dark to perform visual tasks. The stark contrast between the bright window and dark rear area is also likely to create discomfort glare. As a result, occupants tend to pull on the curtains and switch on electrical lighting. This situation is commonly found in the office and the prolonged usage of electrical lighting will inevitably result in high-energy consumption. The application of advanced daylight systems can help to reduce the energy consumption in buildings [1]. Apart from energy consumption, indoor daylighting is also a concern for human well being and performance. Studies have shown that daylight in the interiors contribute to human well being [2] and productivity in schools [3]. Besides, the provision of windows also allow for outside view, giving people a sense of security and orientation [4]. The classification of Daylight Systems for Buildings by the International Energy Agency (IEA) provides a very good overview of such systems, along with a checklist of features to assist in the selection process [5].

## 2. Anidolic integrated systems

This paper deals with an advanced daylight re-direction system, which comprises of an external collector integrated in the upper part of the façade, followed by a reflective ceiling duct and an exit aperture in the rear part of the ceiling. The profile of collector and exit aperture follows the anidolic non-imaging

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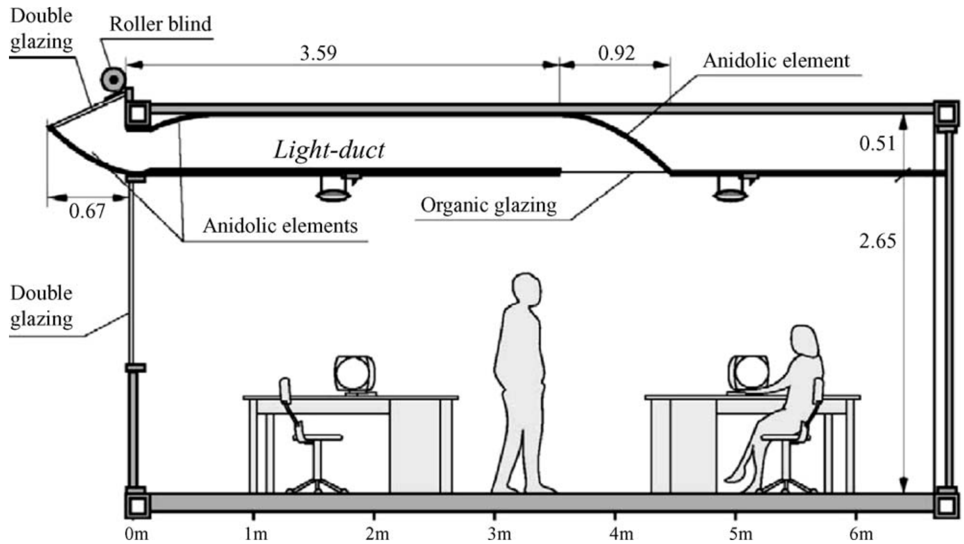


Fig. 1. An example of anidolic integrated ceiling given by Scartezzini and Courret [7].

optics to optimize light control [6]. This system is also known as anidolic integrated ceiling (AIC) because it is integrated into façade and ceiling. The reflectance of the inner surfaces exceeds 90% in order to minimize losses through absorption of light inside the system. Measurements of a built system at the Solar Energy Laboratory (LESO) of the Swiss Federal Institute of Technology of Lausanne show a significant increase of Daylight Factor in deep areas of a room and energy savings of around 30% [7,8] but the performance in other locations is not known. This paper has adopted the successful AIC, as depicted in Fig. 1.

AIC is usually designed to capture the diffuse sky light, but other types that try to channel and re-distribute direct sunlight have also shown promising results. For instance, an enlarged external collector could also acts as shading device to diffuse sunlight directly into the room without going through an anidolic ceiling [9] And yet another version proposes a new type of anidolic ceiling comprising of several light pipes with many exit apertures [10]. Anidolic zenithal openings have also proven to improve the daylight autonomy more than shed lights [11].

## 3. Methodology

The objective was to quantify the energy savings of AIC for a range of locations where such AIC has yet to be applied. In order to study the universal feasibility of AIC, two locations with different daylight climate and building density had been selected, mainly Singapore and Sheffield, UK. The daylight of the former location is characterized by predominantly cloudy skies with high sun altitude as well as high vertical obstructions through high-rise buildings. Sheffield's built environment, on the other hand, is mostly low-rise and the daylight climate is characterized by clearer skies with lower sun altitudes. These two locations represent two extreme test conditions and it would be interesting to observe if AIC also performs differently.

However the AIC has neither been found in Singapore nor Sheffield. Since it was not possible to quantify the performance through measurements, computational simulation was used to predict the performance. This brought along other challenges. The basic requirement of the simulation was to obtain an accurate representation of the daylight climate, which is mainly determined by the sky type and sun altitude. Through the International Daylight Measurement Programme (IDMP) the best fit sky types have been determined for many locations and the data for Singapore and Sheffield was used in this study [12]. Additional information on the average height of the vertical obstructions in Singapore and cities in the UK [13] was also taken into considerations.

Usually Daylight Factor (DF) or Vertical Daylight Factor (VDF) is used to express daylight performance, but neither quantifies energy savings. Therefore, this study used the Daylight Autonomy (DA) instead, which expresses the percentage of time over a user set period of time where the illuminance level at a particular point exceeds a certain minimum. This threshold depends on the local codes of practices, but in our case we assumed a minimum office building's requirement of 300 lx at any working hour of a year. A DA of 100% means that a building interior has sufficient daylight over the specified period, and therefore would not require electrical lighting, which results in great energy savings.

The common DA calculation is usually based on the assumption of an overcast sky, which would be too simplified as it would not help to differentiate the two daylight climates. Alternatively the Virtual Sky Dome (VSD) method [14] was used to represent the IDMP data for use in standard lighting simulation software.

The DA of a room using AIC alone is not very convincing and thus, it is compared against the DA of a reference room without AIC. The difference between them quantifies how much more working time would be covered by daylight and in turn how much energy on electrical lighting could be saved.