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Case Studies in the Development Towards
a Daylighting Roadmap

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ABSTRACT
Through the International Energy Agency (IEA) Task-31 Daylighting in the 21st Century a subtask has been organized to undertake the development of a Daylighting Design Roadmap. This project will attempt to unfold a path as to how we may approach and provide support for daylighting at the various project stages of a design. Although this roadmap is in its preliminary stages, the authors have examined several case studies of daylighting projects. This paper outlines an initial overview of a daylighting design roadmap by reflecting on several aspects of the case studies. An attempt is made to provide reasonable guidance of parameters which could be analyzed at various stages in a project. The roadmap gives reference to several design tools and simulation programs acknowledging that the process can be selective in targeting results to particular circumstances. Voids of information and methodology in the construction of the daylighting roadmap, at this stage in the project, are also acknowledged. It is expected that this initial paper on the subject, will provide awareness and hopefully generate a contribution from other experts in the field.

INTRODUCTION
As stated by the IEA Task 31 Subtask-B committee the setting for a daylight design roadmap is to provide “an experienced team with the skills and tools to translate a building brief into a set of quantitative performance targets that must then be met as the design process proceeds.” It is believed that if a methodology was available to design teams that we would be much closer to our task goal of making daylighting designs the preferred solution for all buildings. The objectives as set out by the task group are:

• To define and characterise the key design and performance metrics, indices and criteria that must be considered in successful daylighting solutions.
• To create performance benchmarks that highlight the range of expected daylighting performance.
• To make explicit the key architectural integration concepts and daylighting-related decisions that must be made within the building design process if successful designs are to be realized.

The resulting products expected from these objectives are:

• An organized set of design metrics for daylighting and a set of performance criteria for each of several different building types
• A simplified design process roadmap that identifies the key issues that must be addressed by the design team and the key metrics that must be considered
• An organized set of performance benchmarks that illustrate and quantify the degree to which effective daylighting designs can reduce building energy use.
• A sensitivity analysis that provides designers with a sense of the range of performance inherent in daylighting solutions and with the potential impacts of occupant behavior on daylighting performance.
• Guidelines for designers for proper use of tools to determine performance, emphasizing the limits of applicability and degree of uncertainty in results generated by tools. (with Subtask C)

THE DEVELOPMENT OF A ROADMAP
Before a project essentially gets into the problem solving or design stage there is a crucial stage of pre-planning or programme development of the project (Figure 1). This initial stage is probably the most important in regards to setting the goals and targets for a daylighting building. A case for daylighting is demonstrated in terms of annual energy performance for a set interior lighting level. This is accomplished via the ENERGY-10

![Figure 1 The Pre-planning or Programming Stage of a Building Project](image)

**Figure 2** Efficient strategy ranking - Energy-10 (Balcomb, 1998)

**Figure 3** Life-cycle energy of electric lighting (Bradshaw, 1993)
(Balcomb, 1998) software program, against 12 other energy strategies which could be implemented into a building (Figure 2). At this point in time the design is a 'shoebox' for the selected building type and no specific design exists. The evidence for a daylit building is supported through numerical means. Additional arguments from a life cycle energy analysis point of view may further substantiate the use of daylight (Figure 3). For every single Watt of useful lighting to a space it takes 98 Watts of energy to produce it!

CASE STUDIES
The following studies are examples of daylight taking on a primary role in the project brief requirements. Unlike the typical approach taken up by electric lighting consultants, each space was designed first to achieve optimal daylighting performance. Only after achieving a daylighting scheme was the design development of electric lighting considered. It was further realised that the electric lighting layout and control strategy was designed in terms of complimenting the daylighting concept. Several benefits of this altered approach to lighting design are recognised through the provided case studies.

Case 1: Brainstorming Concepts
The cross-sections as shown in Figure 4 illustrate a before and after solution with regards to daylighting concepts. Unfortunately the 'before case' is a quite typical solution in Australian building. This brain-storming for a pre-determined proportion and volume office design occurred very early in the lighting consultation stages of the project. In hindsight and in reference to developing a 'roadmap' such tasks may be considered after a pre-planning or project brief/programming phase. At this stage, the possible locations of window openings, daylight distribution systems, glazing material and type, etc. are considered together with the electric lighting concept.

Figure 4 Possible lighting concepts for a pre-designed office space

Case 2: Selective Analysis
A specific area is often selected for the analysis of a lighting design (Figure 5). This 'analysis area' represents a general zone where daylighting together with electric lighting can be investigated with the intention that findings will be related to others areas. The
present case demonstrates the reuse of an existing building where formerly the clerestory portions (non-solar facing) have been blocked off. A requirement of this project was to selectively introduce daylighting through the clerestory, minimizing glazing area while optimising energy efficiency. This is considered electric light reduction as well as heat transfer. The concepts relied upon the integration of an electrical lighting system with daylight dimming control.

The analysis of the area utilises a combined daylighting and electrical lighting program (Lumen-Micro). A possible worst case condition for a non-solar facing clerestory is

![Floor plan highlighting investigated area and its cross-section](image)

**Figure 5** Floor plan highlighting investigated area and its cross-section

![Computer daylighting analysis of a selected area](image)

**Figure 6** Computer daylighting analysis of a selected area
modelled in conjunction with a selective double glazing. The glazing has a Shading Coefficient of 0.4 with a $\tau v / S. C. = 1.53$ (visible to shading coefficient ratio). Ratios of 1.2 or greater are preferred for the maximization of visible light to heat transfer (Sullivan et.al., 1993).

Figure 6 illustrates the results for all four rows of clerestory (A) versus only two rows of glazing at the clerestory (B). The location and glazing dimensions were also investigated. The overall result to the building was a 60% reduction in glazing installation and costs. Option B is preferred over A because the interior lighting level will be supplemented and regulated with the dimming control of the electric lighting system. The electric lighting consumption is reduced from 18 W/m$^2$ to a maximum of 8W/m$^2$ through the clerestory. An average annual electric lighting consumption with the selected daylight system is on the order of 3W/m$^2$.

**Case 3: Integrated Lighting Design**

This last example intends to emphasise a revolutionary concept from traditional lighting practice. It is the paradigm of designing for daylighting first while the electric lighting layout complements recognised zones of simulated daylit configurations. Here the primary solution of the lighting layout is not solely designed for night-time.

An existing space is to be converted into an architecture studio. Again, optimum daylight is desired and a brain-storming process occurs increasing zones of uniform daylighting into the space. Figure 7 illustrates a section looking towards the west facing wall with its existing windows and proposed clerestory and skylight openings.

![Section A-A](from west)

Figure 8 illustrates several results of work plane lux levels under a partly cloudy sky. Result 8A is modelled for the space unaltered. This can be compared to 8B which includes the clerestory and skylight proposed. Finally, 8C illustrates the 12:00 condition where distinctive daylighting zones are recognised and can be complimented with the electric lighting layout and its control strategies.

**CONCLUSIONS**

Several important aspects are discovered through the problem solving of daylighting solutions for various case studies. These could contribute to 'best-practise' guidelines for analysing and optimising daylight design in buildings. In summary, the following points should be considered in the development of a Daylighting Roadmap:
Numerical evidence, substantiating the value daylight has for the particular building is necessary at the pre-design or project brief stage.

Brain-storming concepts or a catalogue/checklist of daylighting possibilities are needed at the preliminary design stage of a project.

Figure 8 Various daylight levels of the space under different conditions

Computational tools, calculation methods/charts, or rules of thumb need to be implemented at the early stages, providing results under extreme sky conditions (overcast, partly cloudy, or clear sky).

Selective design decisions, considering the brain-storming concepts, through investigation, need to be made. (ie. optimising opening sizes, location and/or glass type etc.)

A decision-making process which considers the pros and cons of a daylighting concept is required.

The previous case studies all designed for daylighting first, while acknowledging as well as designing the electric lighting to coincide and compliment with daylighting control. This is a revolutionary thought to most consultants who often have the electric layout completed before a glass opening, shading device or control system is considered. We need to introduce the new paradigm - integrated daylighting design - into the market place by emphasising the above strategies through a roadmap.

REFERENCES