# Helping the design team better visualize energy and its interactions with the help of physically accurate graphical representations


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## ABSTRACT

*It is no secret that architects understand visual representation better than numerical formats. As climate engineering consultants on design teams, it is imperative that design concepts are conveyed in a way that improves the fundamental understanding of the energy concepts and their interactions with various aspects of design. This paper demonstrates through examples, the impact of enhanced graphical communication with the design team, how it results in a better understanding of the energy concepts by the architects, and the design implementation involving building users and operators.*


## INTRODUCTION

The involvement of climate engineering consultants is often misunderstood to be limited to the energy and daylighting analysis in the design phase. It is equally important for the consultants to ensure a holistic understanding and implementation of the energy design concepts right through building construction. It is imperative for the information exchange between design team members to be precise and devoid of any 'information noise'. Thoughtful and accurate graphical representation is a powerful tool in this kind of assistance. This paper broadly categorizes examples of graphical representation into three areas – context orientation, design influence and physical sensation of energy for building occupants. The impact of this awareness on user behavior is briefly demonstrated.

Multiple examples of enhanced visual representation from practice, such as energy and carbon benchmarking, climate analysis and its comparison with locations familiar to the design teams, various design strategies to effectively achieve the energy balance and incident solar radiation with related shading strategies based on different orientations and façade types are demonstrated in this study.

## INTENT AND OBJECTIVES OF ENHANCED GRAPHICAL COMMUNICATION

The primary objective of the enhanced graphical communication in the context of construction industry is to provide accurate information in a concise manner targeted at a specific audience with an ability to be absorbed in an appropriate amount of time based on the design phase and decision making intent.

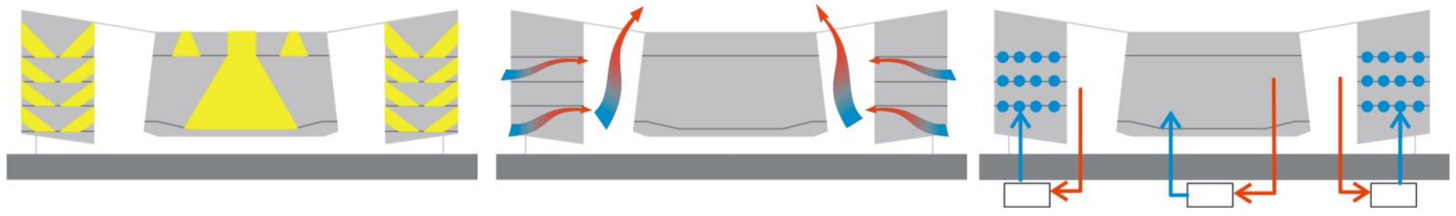

*Figure 1 (a) Daylighting penetration in the space. (b) Natural ventilation concept. (c) Radiant heating/cooling concept.*

For example, illustrating a climate concept for a competition project presents itself with a unique challenge - the information needs to be self-explanatory so that the judges will be able to decipher it in a matter of the few seconds available to them. In a contrasting example, for an end of phase design report - as a reader can afford to spend the required time to understand and absorb – visual communication needs to be able to deliver detailed information such as the fundamentals of a climate concept or basic physics behind the working of any specific component in the design. Figure 1(a through c) illustrates conceptual diagrams using schematic key sections of a building made for a design competition while Figure 2 shows key results of an exhaustive study involving complex design issues, operating modes and rigorous thermal simulation.

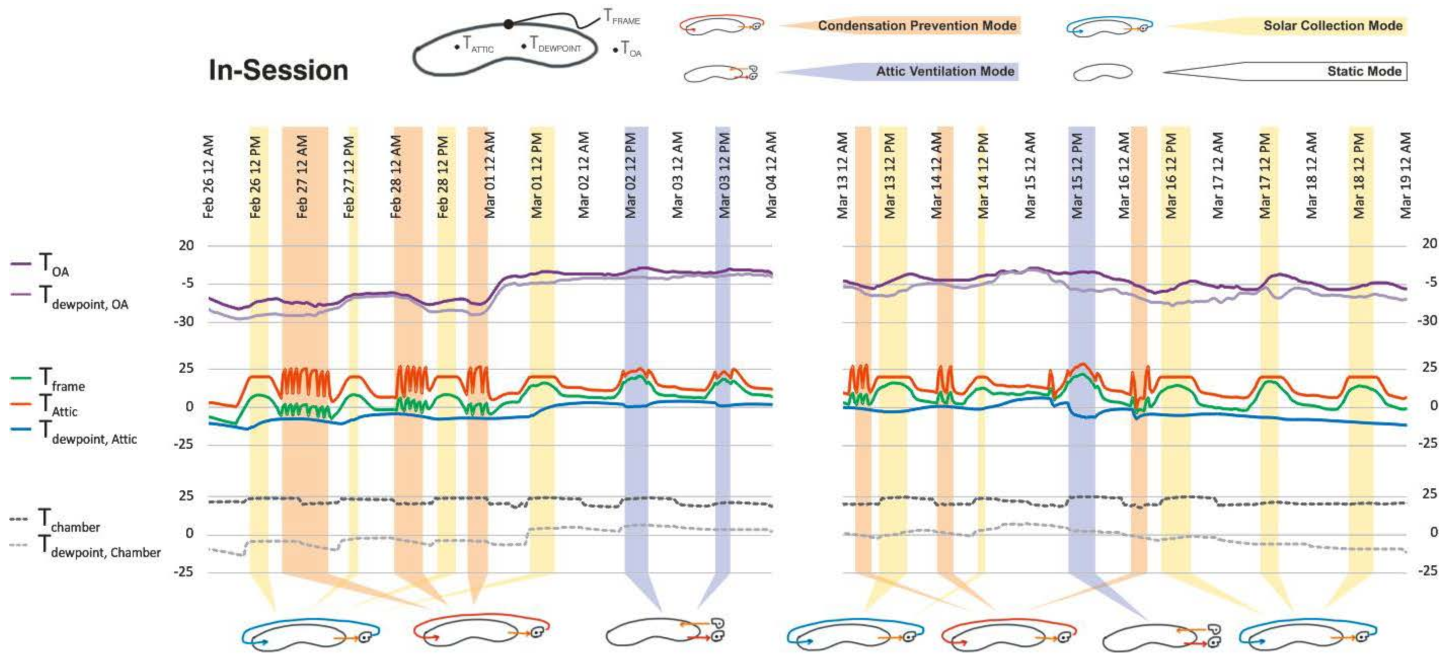


*Figure 2 Hourly, daily and weekly variation in outdoor temperature/weather conditions and the corresponding switching between different mechanical operation modes.*

## PROCESS

In order for the 'integrated design process' to be successful and efficient, it is essential for every team member to accurately interpret information. One way to ensure that the graphical format is clear enough to be understood by a variety of collaborators is by getting inputs from colleagues who come from varying professional backgrounds such as engineering, architecture and liberal arts. For a design driven consulting firm, the toolbox includes design thinking for concept generation and integration, simulation models, custom software, tailored engineering analysis and physical experiments used to develop and validate new ideas. It is equally important then, to effectively communicate the products of this toolbox with rest of the design team for implementation in the actual buildings.

### Context Orientation

Context orientation for the purpose of design communication means careful selection and demonstration of precedents and relevant facts related to a project or a study. The intent is to provide a framework for benchmarking and goal setting, highlight challenges and opportunities by filtering out irrelevant information and provide a clear direction for discussion and design thinking on the subject. Figure 3 shows the examples of energy and carbon benchmarking where instead of proposing only a target number, the project potential in relation to the current building stock is provided with an emphasis on 95 percentile and a very aggressive 'PassiveHaus'[1] standard – all in one graph. Heating, cooling and other electric loads are shown separately in the graph as different design strategies can influence each of these energy uses almost in isolation.

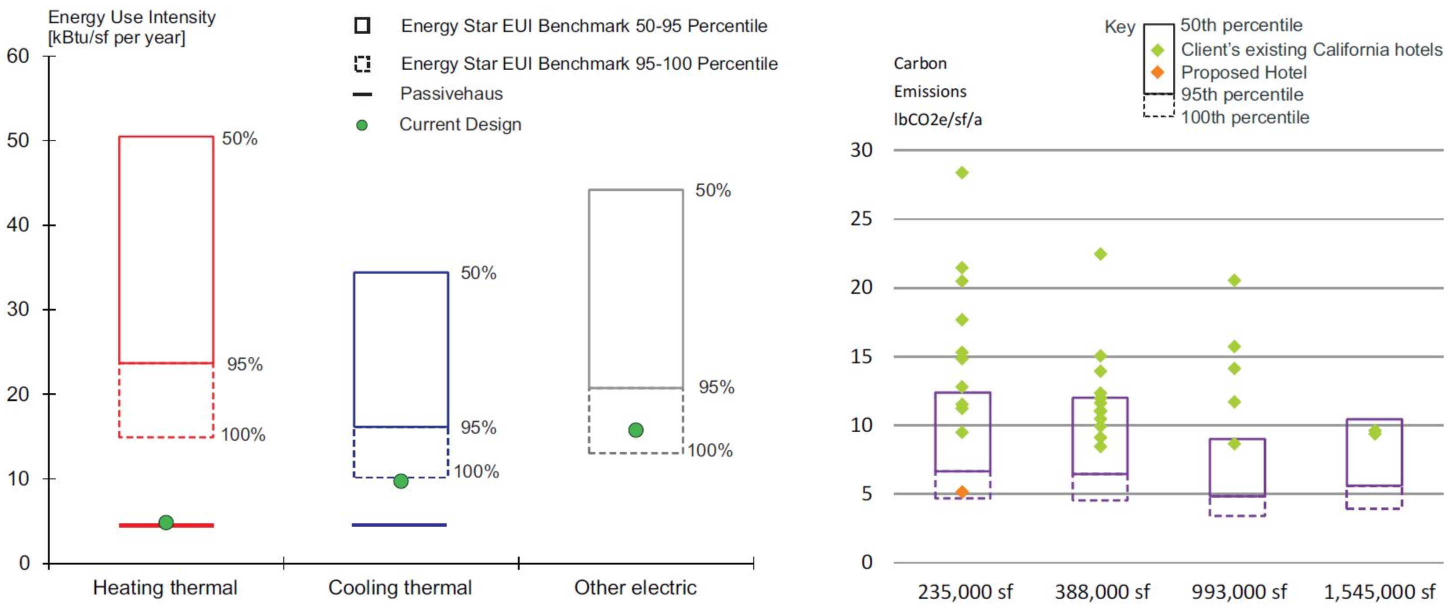


*Figure 3 Energy and carbon benchmarking.*

**Design Influence**

Continuous feedback between architects and consultants (with communication materials as simple as hand-drawn sketches to as complex as whole building drawings and energy/daylighting simulation results in Figure 2) is a sign of a truly integrated design process. Most of this communication is geared towards critical decision making. This process can be explained in three key steps: Understand the situation, Evaluate choices and Explain details.

*Understand the Situation* is about knowing the constraints or boundary conditions for a problem before seeking a solution. For example, the first step in the climate engineering process is to know the local climate for the project. Only after that is understood, can the concept development process begin. Figure 4 shows how this information is taken a step further by comparing climate data for the project location with that of the architect's location. This kind of information has been much appreciated by the architects as they have a 'feeling' for their local climate and find it easier to understand and visualize the climate for the project location due to the graphical comparison.

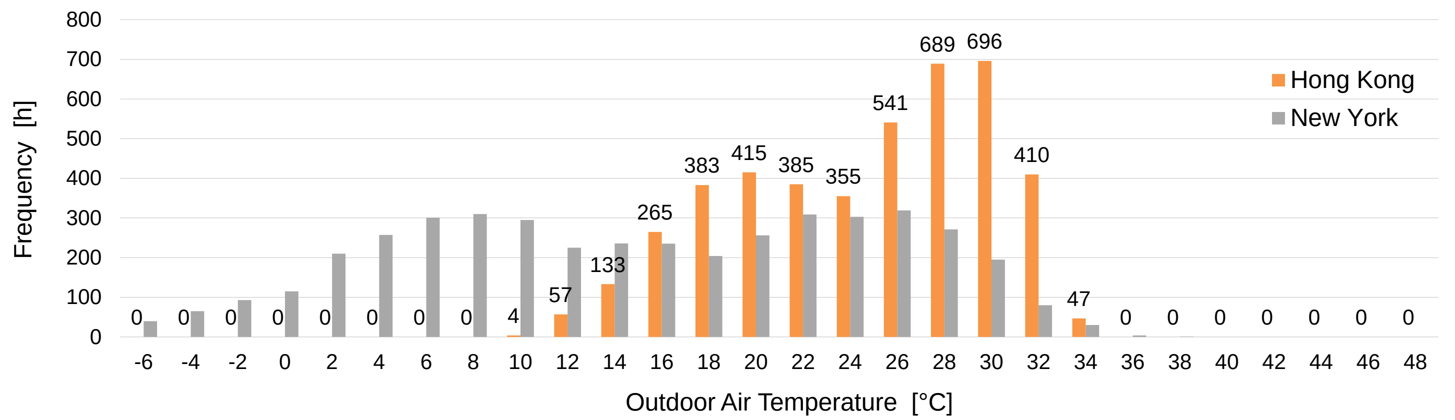


*Figure 4 Temperature histogram of the architect's location and the project location.*

Another example in Figure 5 demonstrates incident solar radiation data for a project with a continuous curving footprint resulting in various (highly glazed) facade orientations. For the purpose of simplification, all the orientations were approximated into a maximum of twelve. For easier data visualization, a wind-rose format was adopted. A shading projection factor was recommended for all simplified orientations in the same format. A mental comparison of 'solar-rose' with a 'plan view' helps better understand the shading requirements for respective orientations. The final design result was a continuous shading overhang varying in depth as per the orientation derived from this study.

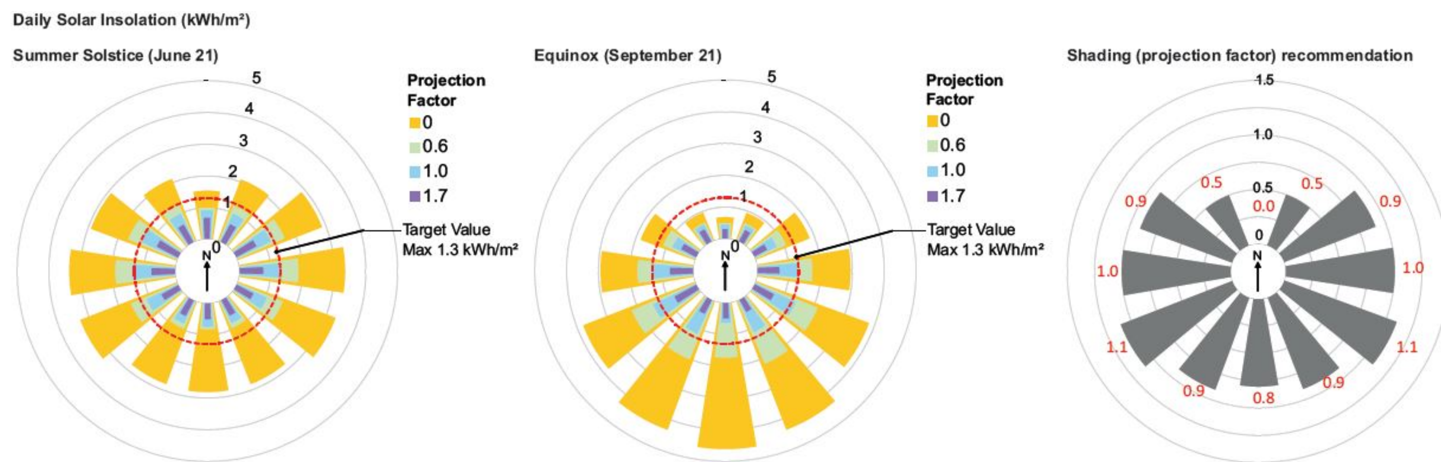


*Figure 5 'Solar rose' – Solar radiation data mapped into a wind-rose format and shading projection factor recommendations.*

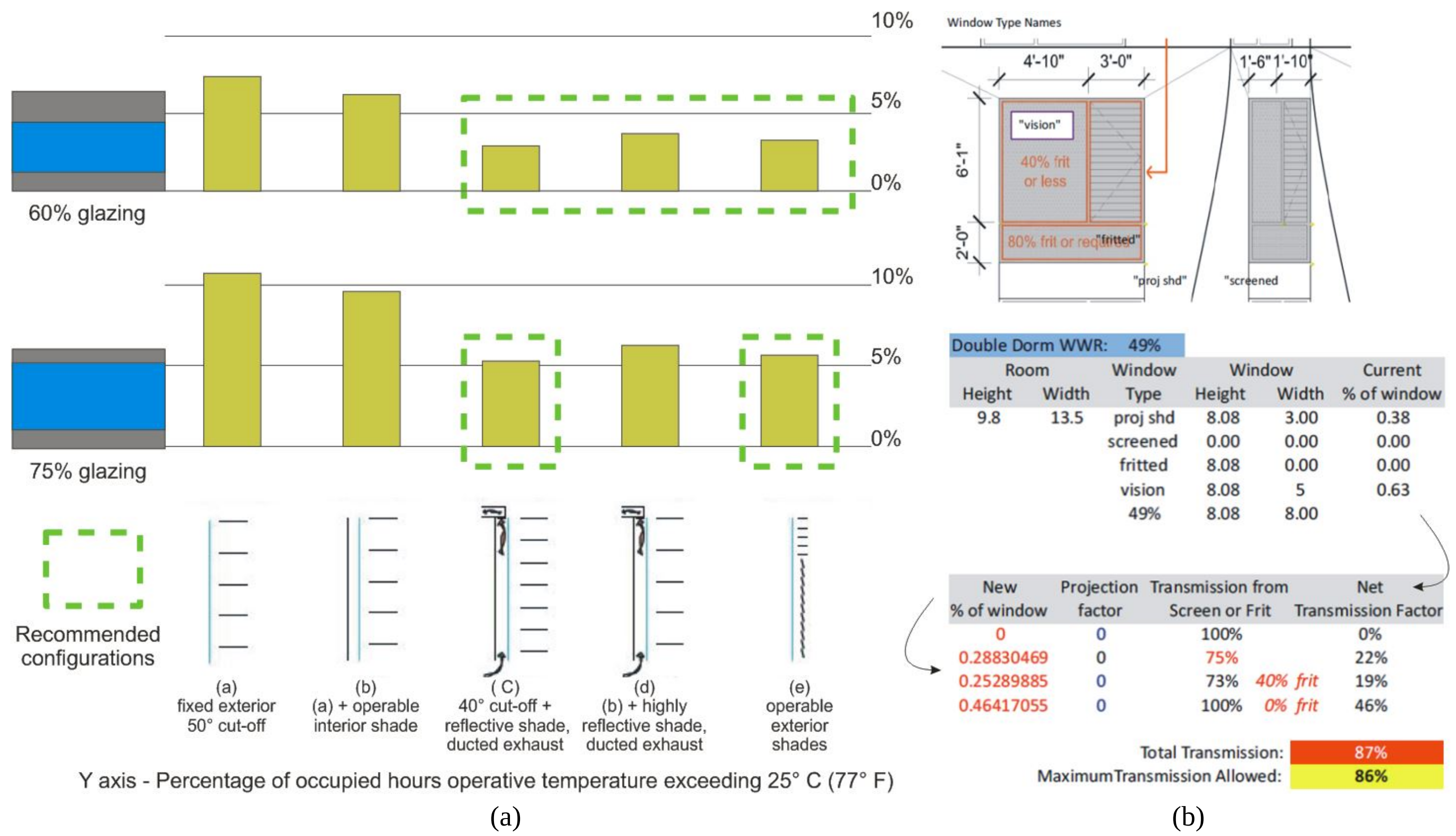


*Figure 6 (a) Comparative comfort study for a 'commons space' façade. (b) Shading transmission calculation tool.*

*Evaluate choices.* In most cases, there is no single 'correct' design solution for a problem but a range of solutions and the task before design teams is to select the desired solution from an available range, based on the given constraints. In the complex process that is building design, there are multiple interdependencies and an ideal decision making process should include consideration and representation of as many critical variables as possible. It is necessary then to present the data in a format which makes a consistent comparison. The critical aspect in this is to make the data visually comprehensible while keeping it scientifically accurate. The goal is to pave the way for exchange of ideas and decision-making based on thorough analysis. The final solution may depend on variables such as aesthetics, user preference, cost and more.

Figure 6(a) Demonstrates results for a comfort study related to a façade configuration for a commons space. Some of the decisions to be made are amount of glazing on the south façade, exterior shading and façade composition. By performing a comparative study with multiple variables, the decision making process is made easier and open.

Another valuable method of effective communication, especially with architects, is to offer a level of flexibility by creating simple and user friendly analysis tools instead of providing end results only. When empowered with an ability to test performance impact of design permutations and combinations in real time, it has helped develop intuition amongst architects. Figure 6(b) shows snapshots of a spreadsheet-based calculation tool which let the architects test different shading transmittances for glazing area on a dormitory room façade. The ability to get results in real-time offered the architects a high level of flexibility within a required framework. The back-end included a combination of results from TRNSYS[2] (Energy simulation software) and spreadsheet calculations. Another significant advantage turned out to be efficient use of time.

*(a)* *(b)* *(c)*

*Figure 7 (a) Final shading design as a result of information in Figure5 (b) South façade of a built project as a result of information in Figure 6(a) (c) Rendering of a dormitory room window design as a result of information in Figure6(b)*

Figure 7 shows the built projects or projects under construction – for which the design decisions were directly influenced by the studies demonstrated through the graphical representations in Figure5 and Figure6.

*Explain Details.* During or after the process of decision making, there is often a requirement to validate design concepts; if they work under a variety of boundary conditions and that there are no weak links. It is especially true in case of concepts or products which are unfamiliar to the design team or decision makers. Often a concept might be rejected not because it doesn't work but because the design team or the decision makers do not have a clear understanding of the concept or their concerns haven't been addressed. It is necessary then as a consultant to improve the understanding and instill a level of confidence about the concept with the help of detailed analysis and effective communication. Figure 8 demonstrates part of a detailed study elaborating the effect of various mechanical systems on operative temperature.

**Physical Sensation**

Physical sensation of energy refers to the experience of physical phenomena such as radiation (solar, radiant heating/cooling) or convection (ventilation) in a habitable space; allowing the building users to appreciate changes in the physical conditions through passive design strategies and by making the invisible, visible. An effective way to improve comfort conditions in the buildings is to provide individual control over the environment and encourage user participation in operation of the building. Providing visual cues to operate windows or to turn the lights off are some of the effective ways (Figure 9).

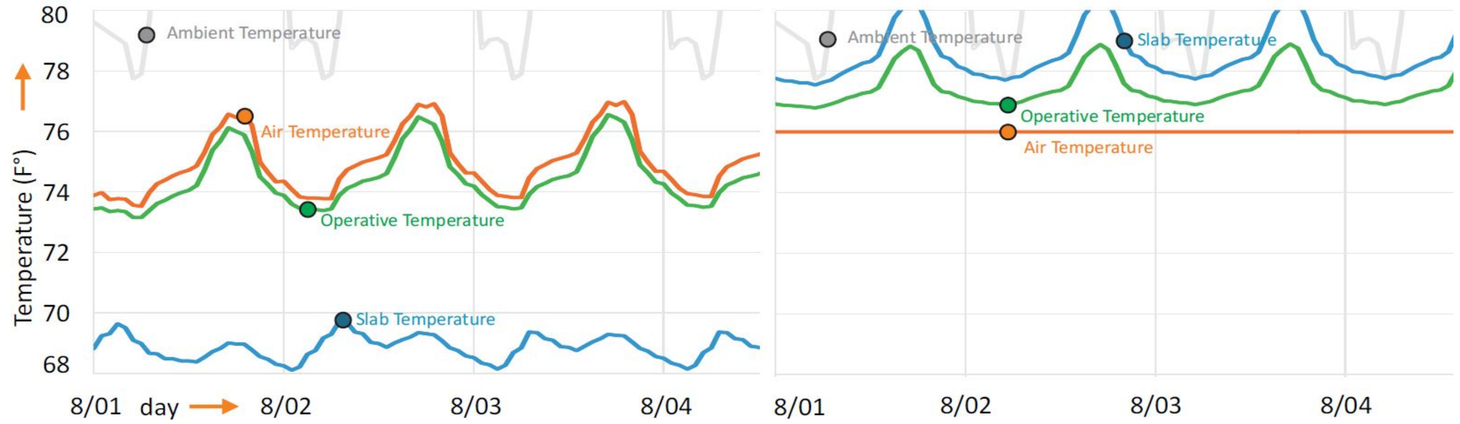


*Figure 8 Comparative comfort study between (a) Radiant system and (b) All air system with 58°F supply temperature.*


(a) (b) (c) (d)

*Figure 9 (a) Winter garden with operable shading. (b) Man-made cloud installation (c) & (d) Operable window indicators.*

**CONCLUSIONS**

Effective graphical communication results in informed decision-making. From our experience on multiple projects at a global scale, the most valuable benefit of precise graphical representation has been the effective use of design team meetings. It means more time for meaningful collaboration and concept development, rather than analysis explanation. This process encourages understanding of range of options and relative influence of different factors, beyond a single fixed recommendation. Enhanced graphical representation backed by precision of engineering knowledge has resulted in an evolved dynamics of architect-consultant relationship - architects are more inclined to keep the consultant's engagement in a design-focused role rather than an analysis focused role - resulting in superior performance oriented and genuinely integrated architectural design.

**REFERENCES**

1. PassivHaus is an internationally recognized, performance-based energy standard in construction. (http://passiv.de/en/index.php)
2. TRNSYS is a complete and extensible simulation environment for the transient simulation of thermal systems including multi-zone buildings. (http://sel.me.wisc.edu/trnsys/features/features.html)
3. Figure 7(a) courtesy of Behnisch Architekten and ZAR
4. Figure 7(c) courtesy of Studio Gang and University of Chicago