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REFINING ENERGY MODEL DATA TO DEVELOP A NARRATIVE: GUIDELINES FOR EFFECTIVE VISUAL COMMUNICATION

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ABSTRACT

Building simulations contain incredibly large amounts of information. Actionable data is often overwhelmed by the sheer quantity and cryptic nature of energy model inputs and outputs. The true value of modeling analysis often depends on effectively communicating the relevant information to decision makers in a timely fashion. Often, modelers have compelling data to share and a rough storyboard for decision makers, but let extraneous data or ineffective communication confuse the issues. This paper shows how concepts from the field of informational graphics including effective data visualization can successfully be adapted to building performance modeling to ensure the stories that modelers want to tell shine through. If done successfully, the value of building energy modeling is enhanced throughout the design and operations process.

INTRODUCTION

Practitioners often spend a large amount of their time developing visual representations of analytical data. The scope and scale of informational graphics have increased with the emergence of capabilities in computational tools as well as the integration of early design modeling. The results of these simulations provide an abundance of data that can be used to create graphs, charts, or figures that highlight key information from the results outputs. Because of the wide range of available information, many practitioners struggle with filtering the data and developing useful visual aids that answer the necessary design questions presented. The data is often presented to architects that are better trained to design and communicate visually or building owners that are more receptive to simple, to the point, graphics. Effective visual information often displays data in a manner that is clear and requires little to no explanation behind it. As data analysts and energy modelers, it is important to understand how to bridge the gap between raw data outputs and useful visual representations of this data.

The need for effective visual communication is often overshadowed by focused effort toward computations and simulations. To create better visualizations, techniques, and processes of designers must be employed. Agrawaka et al. (2011) researched the idea of developing a set of guidelines that improve viewers' comprehension of visually encoded information. Concepts of design are inherently more artistic and creative rather than formulaic, but the ultimate goal is to develop visual forms that facilitate the processing of data. Rather than creating a detailed checklist of how to develop productive visual aids, this paper aims to organize a set of guidelines that represent the qualities of effective visual communication in building simulation.

This guideline is broken down into four parts. The first part is developing the narrative. Understanding the output results and the type of story the outputs will tell is the first step in understanding the type of graphical aids that should be used. The second part is finding the right families of visual materials that clearly highlights the essential function of the data set. An example of this is using pie charts vs stacked bar charts – pie charts are not so effective in comparing different magnitudes of energy, but excellent in displaying proportions. These types of graphics are often used when representing data sets distributed by categories, but depending on how the data is being presented, one might function better than the other. The third part is processing the visual data to make it more articulate. Excel tools can create perfectly functional visual aids but is still limited in what it can provide. Other design tools may need to be employed to articulate more complex data results. The final part is integrating the visual data to provide a clear representation of the narrative. Annotations and commentary can help drive readers to the exact points being made. This four-part guideline, illustrated in the table below, will present a conceptual breakdown of developing effective visual communication.

Table 1 Data Visualization Guideline

DESIGN GUIDELINE	DESCRIPTION
Narrative	Develop an initial understanding of the type of story or idea the visual data will tell.
Function	Provide a sense of visual understanding of the data.
Articulation	Enhance and articulate the visual data with graphical processes and intuitive design choices.
Visual Analysis	Tie together multiple sources of visual data to enrich the concepts being presented.

NARRATIVE

The first step in visual communication is understanding what concepts or stories are trying to be communicated. Specific to energy modeling, it is critical to understand what questions are addressed by the analysis. No practitioner should ever complete an energy model without a clear purpose in mind. The table below provides examples of common questions by selected design phase.

Table 2 Design Phase Examples

DESIGN PHASE	EXAMPLE DESIGN CONSIDERATIONS
Concept / Schematic Design	• Define the building massing and orientation options for energy optimization. • Find and target end-uses that drive energy based on building function and climate location. • Conduct façade analysis including glazing percentages, window shades, etc.
Design Development	• Analyze the energy impacts of the building envelope. • Analyze the effect of glazing percentages and visual transmittance on daylighting. • Analyze HVAC system selections and heat recovery options.
Compliance / Construction Administration	• Conduct energy cost performance using 90.1 methodologies for LEED point estimates. • Conduct local energy code compliance. • Evaluate value engineering options
Measurement & Verification	• Calibrate the energy model and identify major discrepancies between predicted and actual energy use.

Ideally, the modeler will clarify the intent of the model with the design team and owner early in the analysis process. Doing so sets expectations regarding the specific model phase and primes the audience for the type of information and answers they can expect to see. Generally, the earlier in the design phase, the less modeling effort is needed to impact the overall design of the building. Conversely, later in the design phase, many decisions are already set and detailed model inputs are more available, increasing the effort in energy modeling with little impact to the design. Figure 1 below illustrates this concept, taken from Glazer et. al. (2016) when presenting ASHRAE Standard 209.

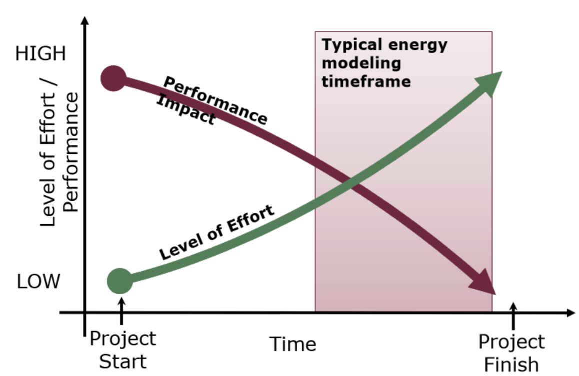

Figure 1 Modeling Effort vs Design Impact

While the modeling effort is lower in the early stages of design, developing visual narratives requires more work and thought. Conversely, most data visualization processes are standardized later in design. For example, LEED documentation and compliance forms often have a template for the type of energy model inputs and outputs are needed. Early design modeling outputs are a little more open-ended and dependent on the type of design considerations the energy model is trying to

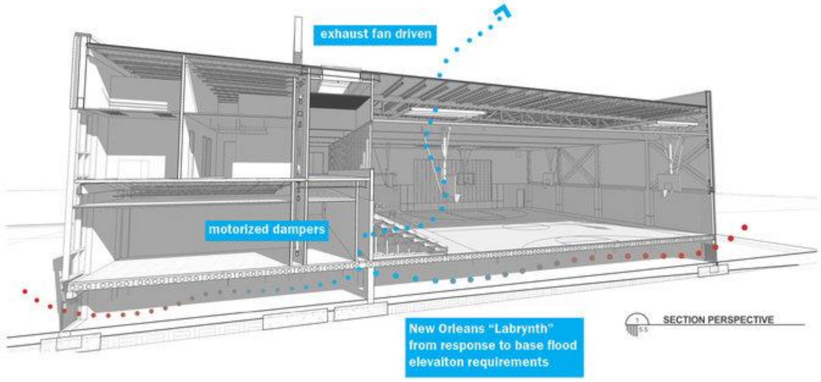

Figure 2 Natural Ventilation Airflow Case Study

inform. Project StaSIO is a platform created by Dunn et. al. and the IBPSA Architectural Simulations Subcommittee which uses ASHRAE Standard 209 as a framework to standardize early design energy model inputs and outputs. The website relies on a community-based approach where users can submit graphical data that can represent a number of simulation topics (thermal comfort, daylight autonomy, load reductions, etc.). Figure 2 shows a case study created by Dunn et. al. (2017) to illustrate the airflow network of a natural ventilation study without using CFD. By leveraging modeling tools (in this case Open Studio), design concepts can be illustrated to a client. The natural ventilation strategy is made clear with directional dots indicating air movement and colors indicating temperatures. This growing database of graphical examples can only help practitioners develop new and better ways to show clients and design teams why a result is occurring or why one design option may be preferred over another.

While it is often the case that practitioners understand the narrative of the data before any simulation results are available, there are times where the simulation results can be unexpected and even drive the concepts or stories the modeler chooses to highlight. Exploring model data and looking for unexpected results can also prove valuable in highlighting design opportunities (or identifying modeling errors).

Once the broad-based modeling results are confirmed, it is important to hone in on the data necessary to answer the critical questions identified in the narration phase. Often modelers can overshare on all the generic modeling inputs and results described above and lose focus on the needed specifics and questions the study prompted. By providing generic, uninteresting data in the visual graphics, the key highlights and narratives can be lost or obscured. It is important to navigate simulation results and provide a basis for the narrative the visual data is trying to present.

FUNCTION

Once the critical questions to be addressed becomes clear, the focus should shift to what type of visualization most clearly answers the questions. Energy modelers must provide "function" within the provided visual material. The functional properties of graphical data provide users with a sense of ease and familiarity with the presented visual data. One of the most commonly used examples of visual function is an energy by end use pie chart. The pie chart shows percentages of energy use by representing the size of the energy use relative to the entire "pie". The largest end-use consumption is represented by the largest piece of the pie. Often, a building type can be inferred from the end use data. For example, Figure 3 below illustrates a pie chart showing the distribution of energy by end use by percentage. From this visual aid alone one can ascertain that the building is located in a heating dominated climate, due to the heating energy being the largest piece of the pie. Also, the building is likely not a residential building because of the low Domestic Hot Water energy use.

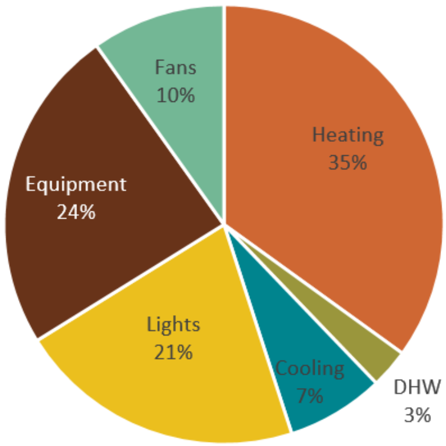

Figure 3 End-Use Pie Chart

Simple concepts such as end-use pie charts are powerful forms of data visualization. Rather than displaying numbers in a spreadsheet, the pie chart represents the metrics in a visually digestible manner. Adding annotations to the chart can further highlight the key take-aways. Another form of visual representation for end uses is a stacked bar chart. Although the bar chart is equally effective, it is better to use a bar chart when doing a comparative analysis of absolute numbers. Figure 4 shows an end-use bar chart of a compliance model, indicating the absolute energy use in the baseline vs proposed models

It is important to consider the type of graphical representation for the data. Providing the right functions to the visual data will better illustrate the concepts and narrative of the results. Another example of functional visual data is train or subway maps seen in most major cities. Henry Charles Beck was an English electrical designer best known for creating the London

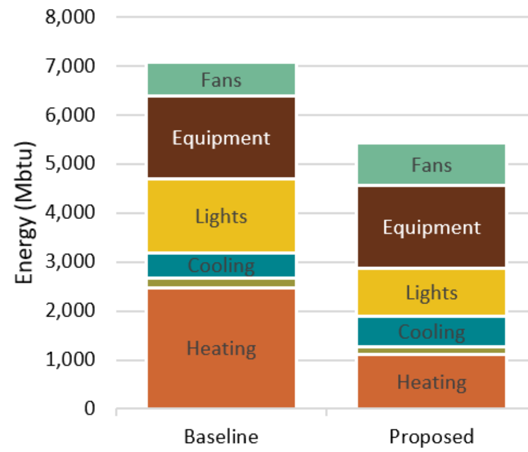

Figure 4 Stacked Column Chart

Underground map in 1931 (Figure 5). This map simplifies the rail map while providing a sense of directionality. The map, however, is not spatially or geographically accurate, with the use of straight lines and evenly spaced subway stations. Despite the inaccuracies, the maps function is not to give the observer a sense of distance or even a sense of exact location, but rather a sense of direction which the map communicates successfully. Beck is even quoted as saying “If you’re going underground, why do you need to bother about geography? It‘s not so important. Connections are the thing.” (Hadlaw, 2003)

An analogy to building simulation is providing diagrams or sketches that help illustrate how equipment is modeled. While far from being constructable drawings, these conceptual visual aids help less technical design team members or clients see connections between equipment that may be transferring or absorbing heat or energy.

Figure 5 London Underground Map

Effective data visualization in a sense is a form of simplifying large data sets. One case study involves a cooling load study done to understand peak zone cooling loads and the associated available terminal types. A primary factor driving the cooling loads in the space was the orientation of the perimeter zones. The project is located in the Pacific Northwest where large solar gains are experienced on south, west, and east facing zones. Another driving factor was the space type of the zone, where the occupancy in office space types is less dense than classroom space types. The modeler could have chosen to simply create a table showing the zone loads as in Table 3.

Table 3 Zone Cooling Loads

ZONE NAME	ORIENTATION	COOLING LOAD [BTU/H/SF]
P/L1_Academic_01	West	36.3
I/L1_Academic_04	Interior	12.6
I/L1_Academic_07	Interior	12.2
P/L1_Academic_10	North	20.0
P/L1_Academic_11	South	24.4
P/L1_Academic28	West	14.1
P/L3_Office_17	West	18.1
P/L3_Office_18	North	10.2
I/L3_Office_19	Interior	9.4
I/L3_Office_20	Interior	9.3
P/L3_Office_21	South	16.5
P/L3_Office_22	Atrium	14.7
P/L1_Lobby_24	West	5.4
P/L1_Lobby_25	South	35.9
I/L1_Lobby_26	Interior	3.3
P/L1_Lobby_27	East	37.3

To better visualize the cooling loads, a zone map was created. The zone map shows the peak cooling loads of each zone using color coding (Figure 6). Red indicates larger cooling loads, while yellow represents moderate cooling loads, and green represents low cooling loads. The blue zones facing north represent zones with potential for overcooling. The first zone map shows a floor with academic loads while the second map shows a floor with office spaces. This zone map functions as a visual representation of a tabled data set showing the cooling loads for each space, their orientation, and the space type. This information is much more easily absorbed in the map format than in the table format. Again, focusing on function and what visualization makes it easiest for a viewer to absorb information is crucial.

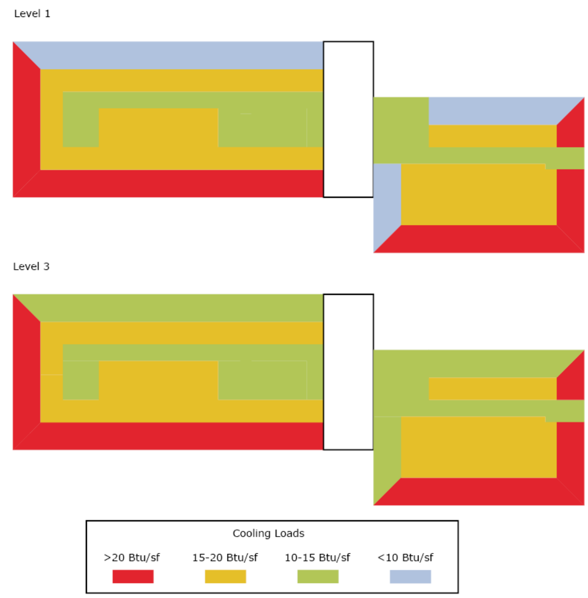

Figure 6 Cooling Load Zone Map

ARTICULATION

Enhancing visual information with aesthetic, post-production is key to making the visual data more interesting. This is a process more often overlooked as it can be time-consuming and considered unimportant to many engineers and analysts. Often, tables and graphs made in Excel are sufficient for providing visual data. Other times, with more complex data sets and multiple variables being addressed, other forms of visual data is needed.

As recognized by Srivastav et. al. (2009), simulation visualization struggles with the complexity of the data set they are trying to represent. Simple 2D graphs made in Excel will sometimes be insufficient in effectively communicating the results. Data tools as Tableau and graphic tools such as InDesign or Illustrator provide options in codifying complex data into presentable visual aids. This is where levels of creativity and design processes are critical in making the material presentable.

"Colors play a central role in data visualization, where they are used to label, measure and enliven data." (Lin, 2013). Studies have shown that certain colors engage a visual interpreter in different ways. In the study conducted by Lin et. al. (2013), it was found that semantically resonant colors improve graph reading performance. A good resource for selecting colors is Adobe's color palette (Figure 7).

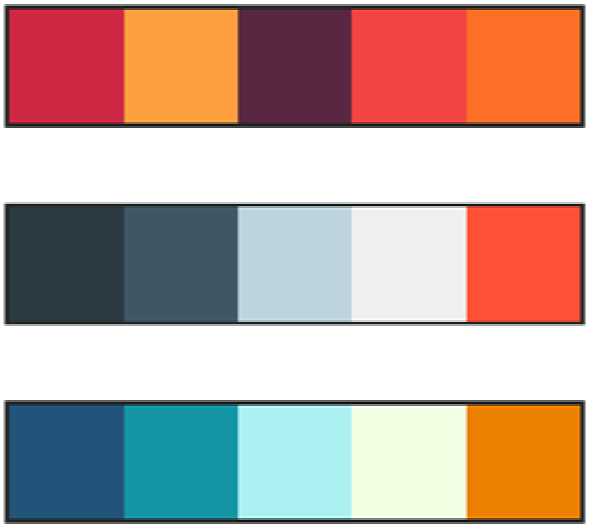

Figure 7 Color Palette

VISUAL ANALYSIS

More and more whole building simulation tools are providing results viewers with useful and diverse output charts. IES-VE, OpenStudio, and other widely used simulation software have developed and improved their built-in results viewer (Figure 8). It is however important not to rely solely on the simulation tool and leave the results limited to the software's capability. The guidelines above present a design-centric approach for practitioners in building simulation to develop simulation visualization.

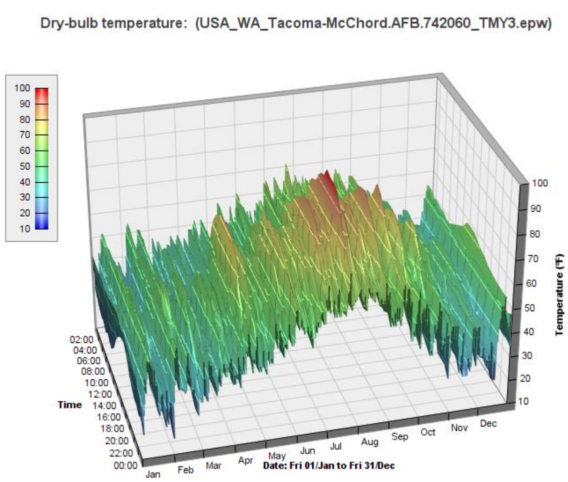

Figure 8 3D Graphs in IES-VE

In visual analysis, there are often opportunities where combining multiple sources of data into a single graphical element can enrich the narrative being displayed. Figure 9 shows the energy profile of a baseline model with the energy profile of a proposed model super-imposed on top of it. Combining the data profile for the two sets of data shows the difference in seasonal energy between the two models. The darker blue profile represents the baseline model, where the envelope is not as thermally resistant and the energy is more impacted by the seasonal heating loads in the winter. The lighter blue energy profile represents the proposed model, showing that the super insulated envelope is more resilient to outdoor conditions by having a "flatter" profile.

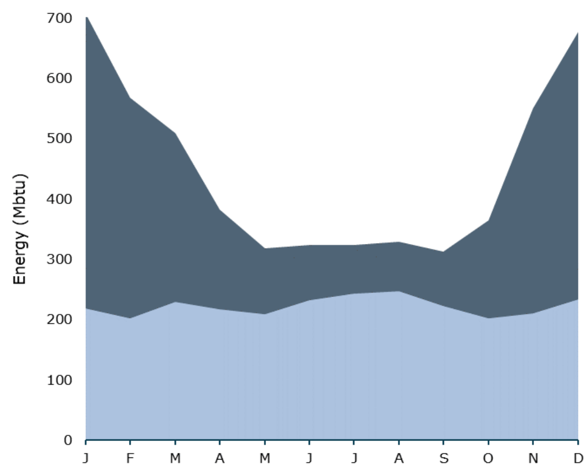

Figure 9 Annual Energy Profile

Integrating multiple data sets into a single visual form can often effectively communicate the intent of the narrative. In a comparative analysis, it is often beneficial to see the data sets together to get a better idea of the magnitude of differences that are trying to be displayed.

CONCLUSION

Development in data visualization in the simulation community is continually evolving as the capabilities of our tools provides results that need new visual comprehension. As trained engineers and analysts, practitioners in the building simulation community often think systematically. Visual communication is a blend of systematic thinking and creative design thought processes. The importance of visual communication cannot be stressed enough as it is often the key to providing key stakeholders and decision makers with the information they require.

Although there is no definitive formula, or standard in generating visual outputs, there is a guideline in which effective visual data and ineffective visual data can be distinguished. The key points are: does the visual material clearly represent the concept or narrative of the data with inference rather than a verbal or textual explanation? Does the function of the visual material present the data in the most effective and efficient manner? And finally, is the visual material articulate and captivating? If these points are addressed by the visual presentation of the data set, then the interpreter should be able to clearly gather and understand the reasoning of the visual material.

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