

## **ARCHITECTURE & ENERGY IN PRACTICE: IMPLEMENTING AN INFORMATION SHARING WORKFLOW**

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### ABSTRACT

This study aims to understand the interactions between architects and engineers on a sample project using a developed workflow map. The iconography of the workflow map shows the level of confidence in the exchanged information, and the specific details of each information exchange. This map is developed to support the work of architects and engineers in the BIM-energy modeling process. By creating an implementation template for the workflow map, this study shows how it can expose pitfalls and technicalities that often derail current practices. It can also help owners make decisions and project managers better understand workflow improvement opportunities.

### INTRODUCTION

Today's increased focus on energy efficiency, stricter codes, and sustainability has driven the demand for the building industry to perform comprehensive energy analysis on projects, either as part of an energy audit or included in the design process (American Institute of Architects, 2012). California leads the way in this regard. The California Public Utilities Commission's Zero Net Energy (ZNE) Action Plan states that by 2030 all new commercial buildings will need to be zero net energy and 50% of all existing buildings will have to be converted to be zero net energy (ZNE Stakeholders, 2010). The only way these targets can be achieved is if energy analysis tools are utilized better than they are today.

Parallel to the growing demand for, and use of, sophisticated tools to enhance energy efficiency, the building industry is turning to Building Information Modeling (BIM) for enhanced integration between disciplines in the production of projects. Once standard computer-aided drafting tools are being replaced by BIM solutions, which incorporate three dimensional modeling with smart features to ease coordination and design flexibility. Industry-wide adaptation of BIM surged from 28% in 2007 to 71% in 2012 (McGraw-Hill Construction, 2012).

While it would seem obvious that the integration of BIM and energy modeling technologies should be the natural next step in analyzing and reducing energy use, increasing air quality, and achieving ZNE goals, the reality is that communication between architects

and engineers, experts in their respective modeling protocols, is not effective and their expectations are often not properly aligned. "There appears to be a disconnect in the profession between what some parties think is happening and what is actually happening." (Becerik-Gerber et al., 2010)

### MISALIGNMENT OF EXPECTATIONS

As architects and buildings engineers collaborate in the building design process, they exchange information on a regular basis. They work separately toward a common goal and have meetings to synchronize their development. Most of this workflow is not documented and is based on the practice and experience of decades. Even though in recent years many methods and tools of the design have changed on both sides, these improvements are not changing the process – they target the same old process with its fundamental shortcomings, and do not advance the state of the art. As they leave the meeting table, architects and engineers have different expectation about what the other side is going to deliver to the next meeting or how much effort the identified next exercise will take. "They are not resolving the underlying problems in the use of building energy performance simulation and analysis, and can ultimately contribute relatively little to the design of more energy efficient buildings." (Bazjanac, 2008)

As an example, the efficiency of the Heating, Ventilation, and Air Conditioning (HVAC) systems is often discussed at coordination meetings in the early phases of schematic design. To meet the energy goals of the project, an early decision about the selection of the HVAC system is important, yet the information available for the engineers to make a recommendation is not specific enough. This could lead to a situation later on where the team has to choose a different HVAC system; however, the architects will have made many subsequent decisions that do not leave much flexibility to accommodate such a change at that point. In this example the expectation of the specificity of the information is misaligned.

In the advanced design development phases another example can be seen. As the façade design is becoming more specific, engineers are usually asked to model and validate certain fenestration changes.

The effort to run the calculations of a seemingly simple validation are often underestimated by the architects either resulting in missed deadlines or a related scenario, where additional changes to the fenestration make the original calculations irrelevant.

It seems that while technology issues remain challenging, the more fundamental, underlying issue is that communication between architects and engineers is frequently causing misalignment in expectations. When architects and engineers work with data, they often do not consider the related margin of error when discussing estimated values. These values are often taken explicitly to make design decisions without realizing that this information can change throughout the course of a project, keeping the team from reaching their desired goals.

### THE WORKFLOW MAP

To combat misalignments in expectations, workflow maps can be immensely valuable to help design teams more comfortably adopt better processes. They can serve as roadmaps and references for how the process can and should work. Specifically, the detailed planning of the information exchange can be an effective way to enhance the use of energy modeling.

#### **Types of exchanged information**

For this study, twelve information categories that architects and engineers typically exchange through the design process were identified. Figure 1 lists the twelve information categories with color-coded flow lines, their respective icons, and examples of the detailed information referred to by the category.

#### **Confidence level**

For a given exchange of information, a confidence level parameter can be used to indicate the specificity of the data. This establishes the exchanged data as a percentage of available information at any point during the design process. This percentage can change with every information category from a low number up to 100%. Depending on the information category, the value can be high early. In other cases, it can increase gradually through the design phases. As an example, climate data can be quite specific early on in the project, which translates to a high confidence level. In the case of the fenestration information category, the exchanged data often gradually gains a higher confidence level as the design progresses. Some categories will never reach 100% confidence level since even after occupation the data can be only estimated. This is most often true for the occupancy category. The simple indication of the confidence level can provide a shared understanding of the specificity of the exchanged information for both architects and engineers. With the help of this indicator, they can plan their tasks with more clarity. (Grinberg et al., 2013)

#### **The language of exchange**

The workflow map for this study, as illustrated in Figure 2, identifies the ways in which architects and engineers communicate and collaborate. This type of workflow map can be applied to any project and customized to reflect the specifics of any project. The iconography of the workflow map shows the level of confidence in the exchanged information and the specific details of each information exchange. (Grinberg et al., 2012)

The example pre-schematic workflow map of Figure 2 consists of four key areas: the timeline and swim lanes, the points of information exchange, the information flow, and the holistic energy analysis circle.

The timeline can cover the design process through all phases starting from pre-schematic design and ending at post occupancy. As all projects are slightly different, time is represented as a fraction of each phase, 100% being the end of the phase. The swim lanes indicate areas of responsibility. The architects are responsible for providing some categories of information, the engineers are responsible for others, and some are defined at joint meetings. The swim lanes identify where the information category comes from.

As meetings and informal information exchanges are planned, the information category discussed at each exchange gets plotted on the timeline. The information categories are identified with their unique icon on the workflow map.

The information flow is connecting the same information categories in the form of color-coded lines. All of these lines feed into the holistic energy analysis circles of each phase representing a continuing development of information.

The energy modeling circles represent the major energy modeling exercises of each phase. The circles are symbols of the iterative nature of the energy modeling calculations. Although all information categories on the workflow map serve as input to the major energy modeling exercises, if information categories appear in the energy modeling circle, it means that those categories are redefined through the energy modeling exercise itself.

With these definitions, the workflow map can describe the continuous development of information and highlight the responsibilities and timing.

### PROCEDURE FOR IMPLEMENTATION

#### **Information gap**

In creating the workflow map, it became clear that there is an information gap that results from the way inputs are gathered for the energy model. After every final exchange of an information category in a design phase, the engineers start to work in the background on the energy model, using the exchanged value as the input to the model. Even with today's technology,

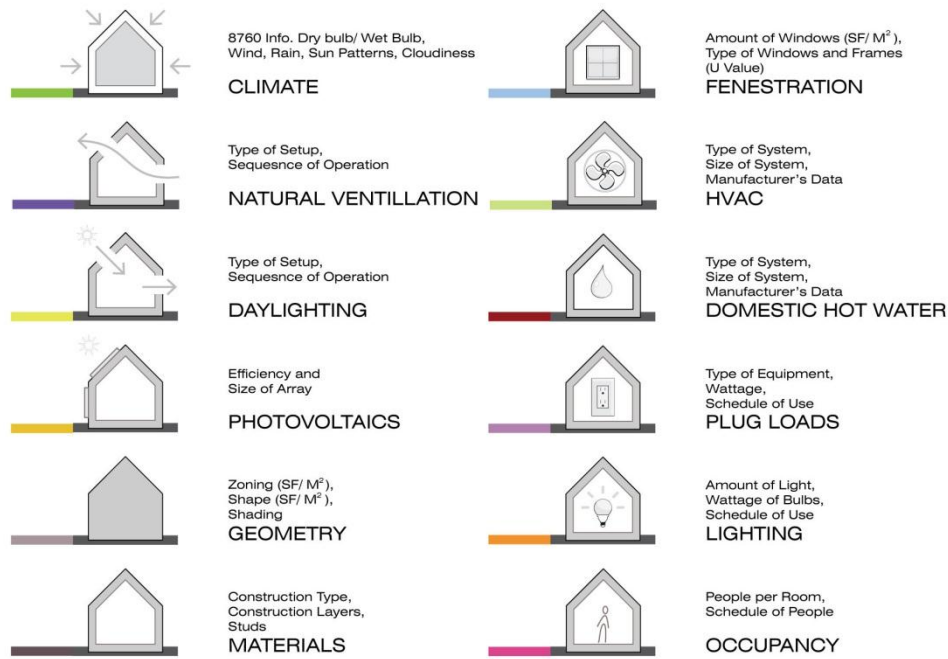


Figure 1 The twelve information categories identified as elements of the language of data exchange.

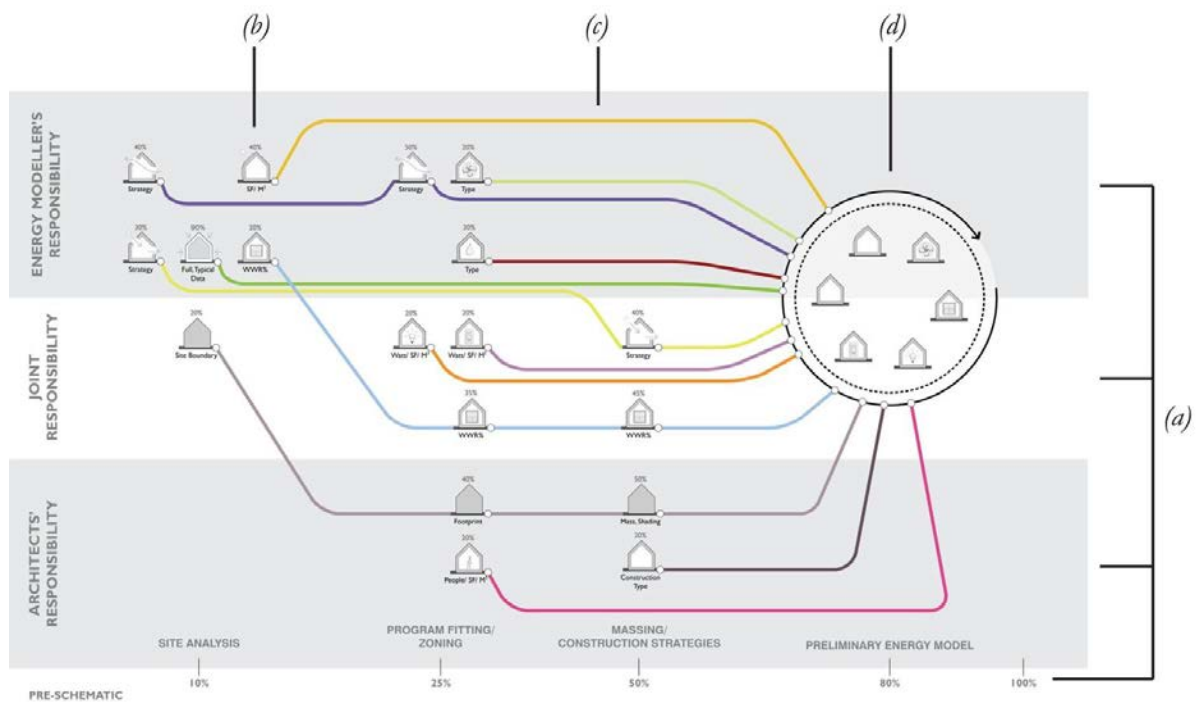


Figure 2 Key areas of the workflow map: (a) Timeline and swim lanes, (b) Point of information exchange, (c) Information flow, and (d) Energy modeling circle.

“Modelers spend a large amount of time creating the building definition for the energy analysis software.” (Im et al., 2012) Concurrently the design work continues and by the time the results of the energy model are available, the original input can have a different value. Figure 3 shows the information gap occurring during the pre-schematic design phase with

the materials information category as an example. In this case, the construction type information gets factored into the phase-end energy model from the middle of the pre-schematic phase. This clear way of visualization can be useful for project managers when planning for the appropriate utilization of energy modeling.

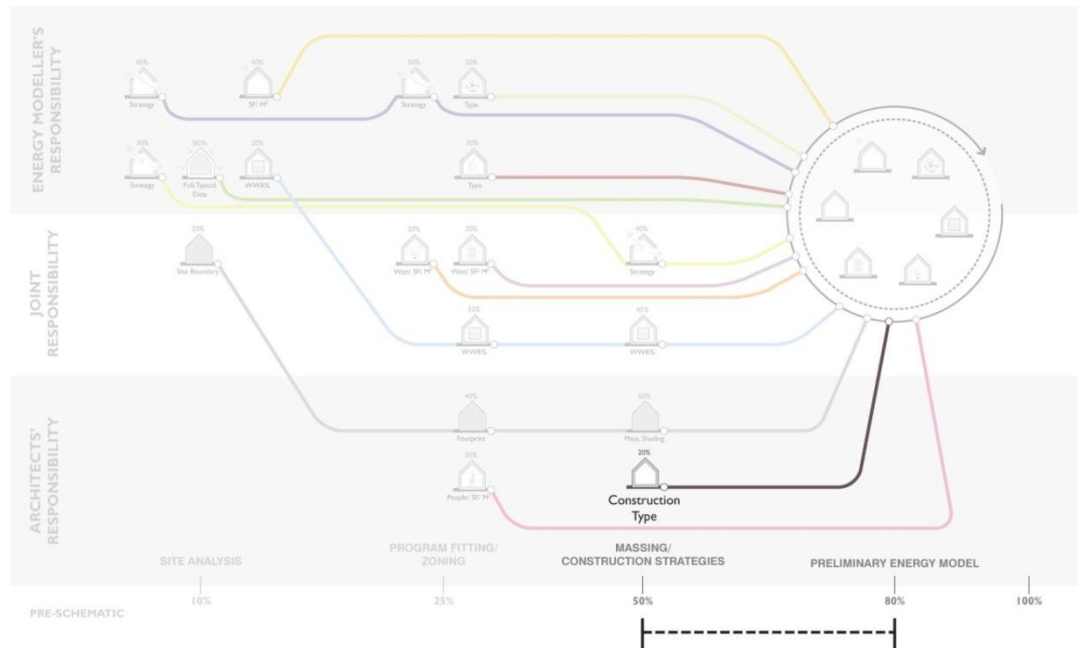


Figure 3 Information gap.

### Implementation template

In order to implement the workflow map on an actual project, it must be untangled for practical use and customization. This can be done by adopting an updated version of the Figure 2 map. This update can be seen in Figure 4, which uses a pre-schematic project phase as an example. While the main characteristics are retained from Figure 2, the Figure 4 variant has a straight path for each one of the twelve information types. This more clearly demonstrates the information gap by pointing to where inputs come from while also showing that the design process continuously progresses.

Because the different information types are more clearly separated, the repeated icons from Figure 2 can be replaced by simple station markers to identify points of exchange. Responsibilities for providing the information are then assigned to the appropriate party at each of these station markers. The energy modeling circle from Figure 2 is also replaced by a time frame that engages all of the information types as inputs, showing which ones are redefined through the process and which ones simply advance concurrently to it.

As shown in Figure 5, this updated workflow map can be reinterpreted in a spreadsheet format, making it an easily customizable implementation template. Since this format now more closely mimics other project planning diagrams, the template is more adaptable, allowing design teams to modify it as necessary for their particular project. When this detailed planning of the information exchange process can be done by the team members themselves, it will help them understand requirements, dependencies, and risks more

thoroughly, thus greatly reducing the misalignment in expectations.

## EXPERIMENT AND DISCUSSION

### A sample commercial retrofit project

To test the practicality of the implementation template, a sample project is used as an experiment platform. The specific mechanical retrofit project is a 6,000 square foot commercial building with offices, open cubicles, conference rooms, and locker rooms that serve the client's staff. The building utilizes low energy, nonconventional HVAC systems to heat and cool the building, and Photovoltaics (PV) for electrical power generation.

The client is adding a supplemental chiller to address the cooling capacity deficits of the current system. Before developing a retrofit design, the client would like the design consultant to update their existing energy model to reflect the current building configurations. Using the model, the client would like the consultant to determine the appropriate size of window awnings to adapt. The client would also like the consultant to analyze if the existing daylighting strategy could be improved, if building plug loads could be reduced, and how many PV arrays need be added to produce a net zero solution. These measures serve to lower the cooling loads, thus reducing the size of the additional chiller, and bring the building closer to a goal of becoming a ZNE facility.

Using this information from the client and the implementation template, the consultant is able to put together a workflow map for the schematic design phase of the project as shown in Figure 6. From the kickoff meeting, it can be seen that a certain amount

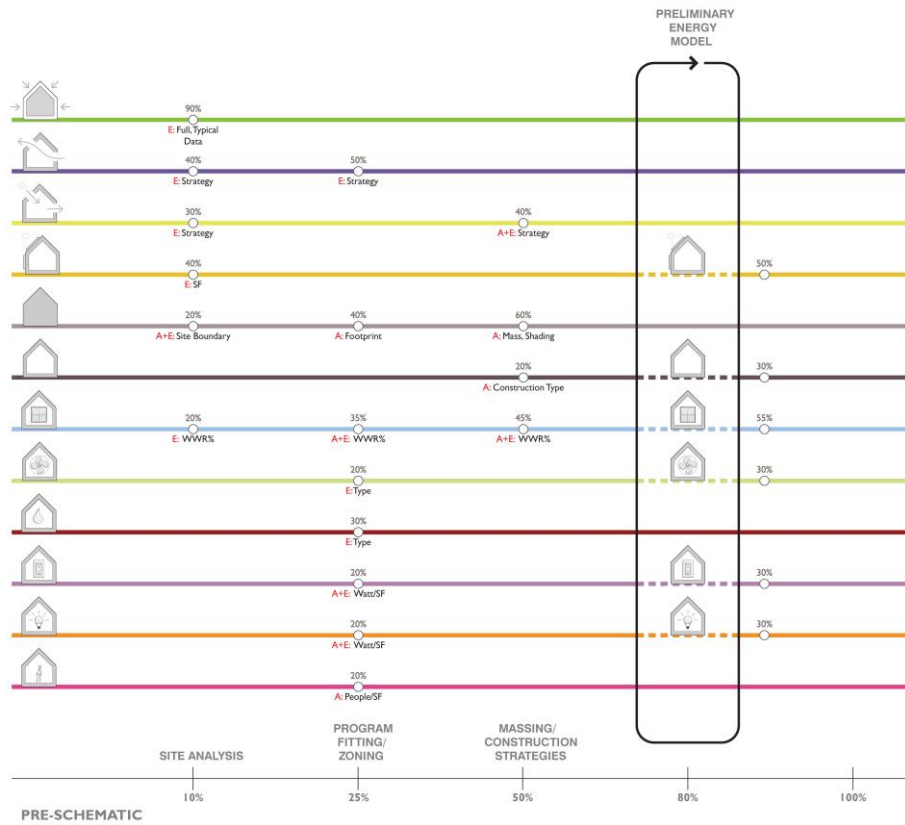


Figure 4 The updated workflow map.

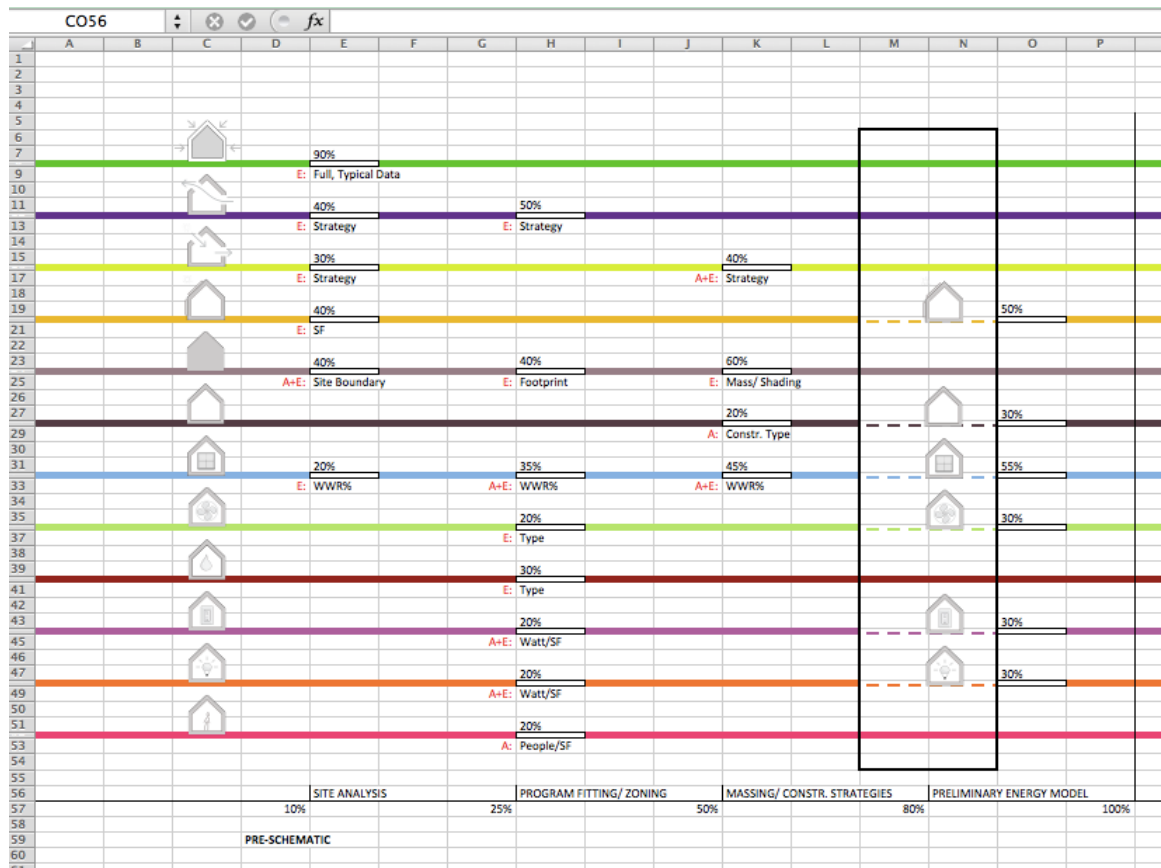


Figure 5 Spreadsheet screenshot.

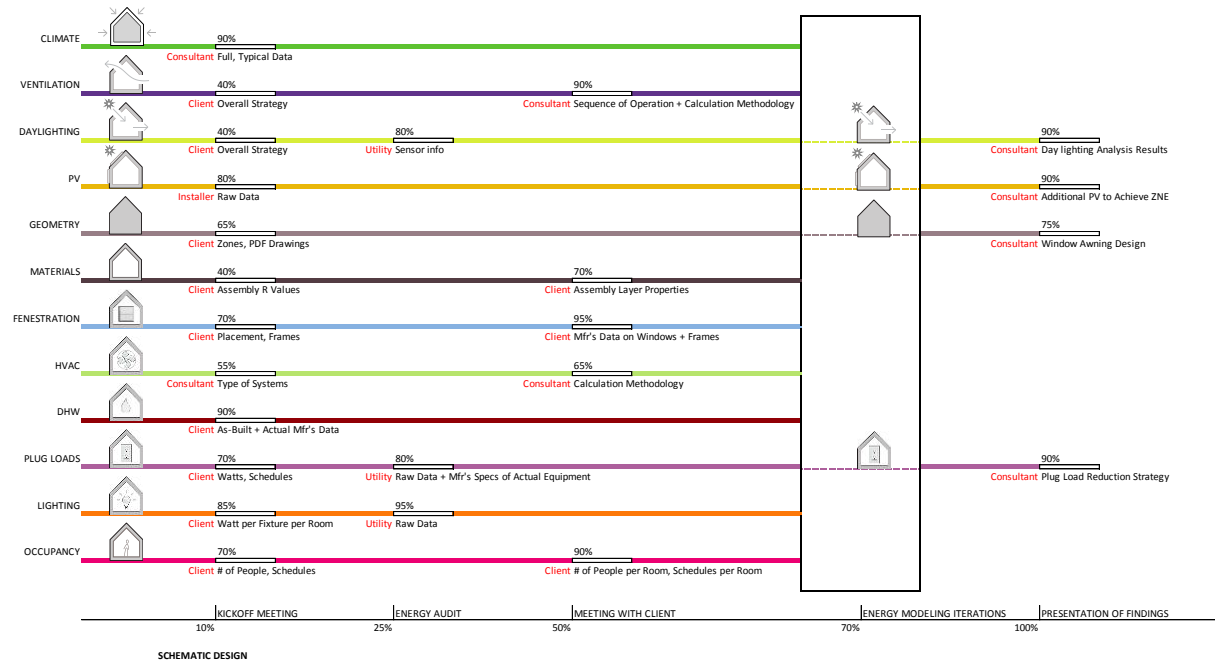


Figure 6 A workflow map of a sample commercial retrofit project's schematic design phase.

of inputs are known from the start, with the client supplying the architectural information. Other inputs can be refined by the utility through an energy audit and by a follow-up meeting with the client to gather additional information.

The simple process of creating the workflow diagram allows the consultant to see what pieces of the energy modeling puzzle are necessary to gather and where the most accurate information can be found, such as engaging the PV installer to provide the existing raw data of electrical power generation. Once complete, the workflow allows the client to not only understand the process, but to see the value in the various steps of creating an energy model.

**Calculating input value**

To further make use of the data gathered by the workflow map, the consultant can determine the degree to which different information types can affect the energy modeling results. For the sample commercial retrofit project, the consultant can rank each information type from most important to least important as shown in Table 1. In determining total energy use for this project, PV is the most significant consideration, even over climate or geometry, because it is the only source of energy production. Changing the amount of PV would have the most dramatic impact on the site's overall energy use. On the other hand, ventilation, materials, and Domestic Hot Water (DHW) are the least important because they contribute relatively little to the energy use breakdown of the building. Changing the values associated with these three information types would have the least amount of impact to the site's energy use.

Table 1 Rank of information type importance for the commercial retrofit project

Rank	Type
1st	PV
2nd	CLIMATE
	GEOMETRY
	PLUG LOADS
3rd	DAYLIGHTING
	HVAC
	LIGHTING
	OCCUPANCY
4th	FENESTRATION
5th	VENTILATION
	MATERIALS
	DHW

When all the information types become inputs to the energy modeling iteration process, the ranks can be used to calculate a weighted average for all of their confidence levels. The confidence levels of more important information types would be weighed heavier than the confidence level of less important information types. The resulting weighted average could be viewed as an indicator of the energy model's reliability to make sound energy use predictions. Using the project as an example, the confidence level of the PV would be dominant for determining the certainty of the energy model's results, while the confidence level of the DHW would be relatively unimportant.

This method of understanding the certainty of results allows for the calculation of the different involvement scenarios. The need for an energy audit

or a follow up meeting with the client can be analyzed. Table 2 shows the result certainty for different combinations of involvement.

*Table 2  
Weighted average of confidence levels for different layers of involvement*

Type	KICKOFF MEETING	KICKOFF MEETING + ENERGY AUDIT	KICKOFF MEETING + MEETING WITH CLIENT	KICKOFF MEETING + ENERGY AUDIT + MEETING WITH CLIENT
CLIMATE	90%	90%	90%	90%
VENTILATION	40%	40%	90%	90%
DAYLIGHTING	40%	80%	40%	80%
PV	80%	80%	80%	80%
GEOMETRY	65%	65%	65%	65%
MATERIALS	40%	40%	70%	70%
FENESTRATION	70%	70%	95%	95%
HVAC	55%	55%	65%	65%
DHW	90%	90%	90%	90%
PLUG LOADS	70%	80%	70%	80%
LIGHTING	85%	95%	85%	95%
OCCUPANCY	70%	70%	90%	90%
<b>Result</b>	<b>73%</b>	<b>77%</b>	<b>76%</b>	<b>81%</b>

If only the kickoff meeting takes place and the energy model is run off of those inputs, the result certainty will be 73%. If an energy audit is performed, the daylighting, plug loads, and lighting input categories will be updated with more accurate information, increasing their confidence levels. This will cause the result certainty to go up to 77%. If no energy audit takes place, but instead additional information will be gathered by a meeting with the client, the result certainty will be 76%. If all three, the kickoff meeting, the energy audit, and the meeting with the client, occur as depicted in Figure 6, then the resulting certainty will be 81%.

Because this result certainty directly translates to risk, a price association can be interpreted for the need of any one project step. Performing an energy audit for the commercial retrofit project, for example, can add 4% of certainty to the energy model's predictions, meaning that it mitigates risk by that much as well. By understanding the relationship of tasks to their impact on the results, project managers can use this to clearly lay out requirements and outcomes. Furthermore, calculating and presenting this analysis to owners can also help them directly understand the value for each involvement situation as it relates to the completed building project.

## CONCLUSION

Creating an implementation template has allowed a developed workflow map to be used on a project in practice. The design team was able to generate a workflow for their specific commercial retrofit project by using a spreadsheet version of the map. The workflow map proved useful for helping the team understand the required energy modeling inputs

and evaluate the need for additional tasks to clarify some of the information.

Because this method of project planning is high level, it can be used not just by architects and engineers, as originally intended, but by multiple disciplines or parties involved, depending on the building and project type. The sample commercial retrofit project, for example, is a coordination process between a consultant, the client, the PV installer, and the local utility.

Implementing the workflow map helps communicate the process of exchanging information and alleviates the misalignment in expectations. Furthermore, by understanding the connection between responsibilities and their influence on the results, the various members of the project team can quantify the risk and price for each task. This allows for better decision making and acknowledges the value of a good and efficient design process.

## ACKNOWLEDGEMENT

The writers would like to acknowledge and thank the following important groups: the management team of the Stantec Research and Development Fund lead by Dr. Rosamund Hyde for their continuing financial support of our work, The Stantec Northern California Marketing Team lead by Nicole Collins for their promotional support, David Scheer and Adam Menter at Autodesk for their valuable collaboration and networking, Asbjorn Levring and Daniel Nielsen at the Danish Technology Institute for their generous collaboration, the International Building Performance Simulation Association San Francisco Chapter and our colleagues and peers for their feedback and support.

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