Review of BPM Protocols and BEM Reporting Output

Final Report

Delivered to: IBPSA-USA Building Data Exchange Project Execution Committee
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Introduction

The outputs of building energy modeling (BEM) software are not provided in a standardized format. Utilities, Code Authorities, and Rating Systems use building performance modeling (BPM) protocols to demonstrate design compliance and to predict building performance with BEM software. Standardizing the BEM outputs for BPM protocols would streamline the submission documentation and review process, as well as simplify workflow automation. It would also enable more effective crowd sourcing of analysis techniques and data visualization via efforts like IBPSA-USA's Project STASIO. Additionally, output standardization would reduce the time required to format submission documentation, allowing project teams more time for design-assist modeling to improve building performance.

IBPSA-USA, with funding from the DOE, created a research project to review BPM protocols and common BEM software outputs with the goal of summarizing patterns and commonalities in current practice. This report compiles the results of this IBPSA-USA research project, "BPM Protocol and BEM Reporting Output". The project was broken out into six tasks defined as:

1. Task 1: Establish a list of BPM Protocols to review.
2. Task 2: Document reporting outputs for each BPM protocol identified in Task 1.
3. Task 3: Identify four common BEM software and document the default results.
4. Task 4: Review Project STASIO graphics to identify common outputs useful for design analysis.
5. Task 5: Create a report that compiles results from Task 2 through 4 and include the following:
    a) Common outputs and levels of aggregation
    b) Notable outliers
    c) Reporting trends
    d) High-level recommendation for standardization
    e) Suggest next steps
6. Task 6: Submit final report to IBPSA-USA that is to be included in a larger submission to U.S. Department of Energy.

To limit the scope, the project focused only in BEM outputs and did not consider BEM inputs or BPM input validation. The research and documentation was conducted between March 2023 and January 2024.

Background

Shortly after establishing the research project, IBPSA-USA's Data Models working group was tapped to begin establishing a list of BPM protocols and BEM software for review. The Data Models working group consists of 4 to 10 volunteer software developers and energy modeling practitioners and is open to all IBPSA-USA members and outside stakeholders. This group was established in July 2020, and has created a Data Modeling Consensus Document, and supported the creation of a Time Series Data Model. For this research project, the group met on a bi-weekly basis to develop a preliminary list of BPM protocols and BEM software. The group then created an RFP to hire a consultant to refine, review, and report on the preliminary lists. In August, Betz Consult was selected. While working on each task, Betz Consult regularly met with the working group to review progress and obtain feedback.

The working group would like to use this report in considering the future development of a BPM output reporting schema. This report may also be used by rating authorities in the development of future BPM protols.

Task 1: Identify BPM Protocols for Review

A preliminary list of BPM protocols was included in the project request for proposal (RFP) document shown in Figure 1.1.

Protocol Name	Type
ASHRAE Standard 90.1 Performance Based Compliance Form	Code Compliance
Energy Design Assistance Program Tracker (EDAPT)	Utility Incentive
LEED V4.1 Minimum Energy Performance Calculator (MEPC)	Certification/Rating System
Expand Project StaSIO list	Performance Design
Oregon SEED	Code Compliance
New York City ECC	Code Compliance
NYSERDA Performance Path	Certification/Rating System
Vancouver	Code Compliance
City of Boulder	Code Compliance
RESNET HERS Registry Schema	Certification/Rating System
ASHRAE 229 RMD Schema	
DOE Asset Score	Certification/Rating System
179D	Certification/Rating System
Companion tool - Utility Programs	Utility Incentive
GridOptimal Building Pilot ACP Calculator	Certification/Rating System
California Title 24	Code Compliance
ASHRAE 90.1-2019 Official Compliance forms	Code Compliance
Standard 209-2018 Output	Performance Design
AIA 2030 DDx (confirm name)	Performance Design

Figure 1.1: Task 1 Preliminary List of BPM Protocols

This list was a starting point for the research team's discussion as the protocols were evaluated in Task 2. Initially the intent was to complete Task 1 prior to starting Task 2, however the team decided that pursuing Task 1 in parallel with Task 2 was more prudent in case the schedule allowed for the incorporation of more protocols.

The selected protocols are intended to be a representative sample ranging from large internationally recognized protocols like ASHRAE 90.1 and LEED, state protocols like California Title 24 and New York State Energy Code, municipal protocols like Vancouver and City of Boulder, utility protocols, and unique protocols like ASHRAE 209, ASHRAE 228, and 179D tax forms. The team's goal was comprehensive in its collection and review of types of protocols, however new protocols are being developed all the time. The review of protocols ended on October 12th, 2023. Protocols developed near or after this date were not included in this research.

Protocol Filtering

As the project progressed, several BPM protocols were dismissed from the Task 1 list as they did not include additional reporting requirements beyond what was already addressed. The following is a summary of the dismissed protocols and the rationale for removal.

- **New York City Energy Code:** References ASHRAE 90.1-2016, which is covered by the ASHRAE 90.1 protocol.
  - The program does reference Building Performance Factor in the compliance forms, but that is a post processed calculation within ASHRAE 90.1-2016.
  - The form allows for use of Appendix G or ECB methods.

- **Oregon SEED Program:** The SEED program is intended for state owned buildings to assure the building is designed to energy and environmental standards.
  - Energy model outputs are documented in appendix H of the Energy Analysis Report.
  - The outputs collected include energy (split between electricity and natural gas) and energy cost.
  - The energy end-use categories are contained within the lists found in LEED MEPC and ASHRAE 90.1 forms.
  - The form also includes spaces to document individual energy efficiency measures, however the type of information documented is consistent with other output categories.
- **City of Vancouver Energy Modeling Guidelines:** The modeling guidelines are a supplement to the National Energy Code of Canada for Buildings, Part 8. The protocol makes recommendations for building inputs and performance factor calculations.
  - The City of Vancouver also publishes energy checklists that reference ASHRAE 90.1-2016, which would in turn be covered under the ASHRAE 90.1 protocol.
- **Grid Optimal:** Uses hourly electricity outputs from a whole building energy model, and applies grid factors to calculate grid optimization metrics along with other helpful outputs.
  - The requirements in Grid Optimal are similar to the ones found in California Title 24, and was thus dismissed from the list.
- **179D:** This protocol is for determining tax incentives and leverages various versions of ASHRAE 90.1 depending on the year of tax filing. ASHRAE 90.1 requirements are already covered.
  - There are post processing requirements using the outputs from BEM tools to itemize individual energy efficiency measures using typical energy end-use outputs.
  - BEM software used to determine tax incentives must comply with IRS requirements which are listed here: Requirements and Submission Process for Qualified Software (energy.gov)
- **AIA 2030 DDx:** The AIA 2030 Design Data Exchange collects energy usage intensity (EUI) values that can be obtained from the AIA 2030 Zero Tool or other benchmark platform. A predicted EUI is also collected as part of the project's energy modeling.
  - EUI data is collected in most protocols so AIA 2030 is already covered within previously selected protocols.

Figure 1.2 is the final list of BPM protocols included in Task 1

1.	LEED v4 MEPC
2.	ASHRAE 90.1-2016/2019 Compliance Forms
3.	Boulder Colorado 2020 Commercial Energy Modeling Report
4.	New York State Energy Code
5.	ANSI/RESNET/ICC Standard 201 (and RESNET MINHERS)
6.	ASHRAE Standard 209
7.	ASHRAE Standard 229P
8.	California Title 24

Figure 1.2: Task 1 Final List of BPM Protocols

Beyond Standard Reporting

Three identified protocols require the energy model input and output files be submitted to the reviewers. These include: ASHRAE 90.1, RESNET, and the New York Energy Code. However, most jurisdictions that adopt ASHRAE 90.1 do not request the energy model input and output files. The New York Energy Code only requires model files to be submitted if the eQUEST modeling software is used for the project.

This approach allows reviewers access to a lot more outputs than what is listed in any reviewed protocol. Additional outputs made available in most simulation output files include: equipment part load hours and thermal load components (facade, ventilation, etc.) to name a few that would further assist in verifying the quality of the energy model.

Post Processed Compliance Values

There are numerous post processed values required by the listed BPMs such as energy cost, energy usage intensity, carbon emissions, performance indexes, and building performance factors to name a few. These values are often used for determining compliance and for benchmarking. However, these values were not included in the matrix as the post processed values using the reported energy values in the matrix in addition to several inputs such as square footage and system types. The input values are outside the scope of this research project.

Exceptional Calculations

Exceptional calculations are not specifically called out in the matrix however nearly all the protocols do require documentation of exceptional calculations with energy and power outputs when applicable. However, as exceptional calculations typically occur outside of the primary modeling software it was not called out explicitly in the Task 2 matrix. The types of outputs include impacts to energy and power by end-use, but no new end-uses are defined as the nature of exceptional calculations is that they are to be flexible to meet users needs in adjusting energy and power values.

Task 2: Document BPM Protocol Outputs

This section documents the results and the process the project team used to identify which outputs to document in the Task 2 report. The team started by reviewing ASHRAE 90.1 and LEED MEPC as the two most common BPM protocols used in the United States. These protocols were used to establish an initial framework for documenting outputs to aide discussion with the Data Models Working Group within the IBPSA-USA Building Data Exchange group. The team then added individual protocols documenting additional requirements as they arose. If a protocols did not add a new reporting category it was dismissed as documented above.

Task 2 Results

Figure 2.1 below is the final Task 2 matrix developed that contains all the relevant energy end-use categories and quality assurance categories from all eight protocols selected in Task 1. The green highlighted categories were selected by the research team to be considered the highest priority based on frequency of adoption and the current regulatory environment.

The following are key metrics from the 48 recorded categories contained in the eight protocols.

- eight protocols include:
  - Interior lighting
  - Service water heating
  - Space cooling
  - Space heating
- seven protocols include:
  - Miscellaneous equipment
  - Fans - Indoor ventilation
  - Heat rejection
- six protocols include:
  - Refrigeration
  - Pumps
  - Unmet heating hours
  - Unmet cooling hours

The highest number of end-use and quality assurance categories adopted by any protocol is ASHRAE 90.1 at 26 categories. These metrics shows the level of fragmentation that exists in BPM protocols and the challenges faced by users of the protocols and for BEM software developers.

The full matrix is included in Appendix A of this report.

Task 2: Structure for IBPSA BPM Protocol Comparison		
	Revision: Final version issued 2 November 2023	
		Green highlighted top priority end-uses
Item #	**Category**	**Reporting Requirement**
1	**Energy End-Use**	Interior Lighting
2		Interior Lighting - Process
3		Exterior Lighting
4		Lighting in Apartments
5		Receptacle Equipment
6		Office Equipment
7		Misc Equipment
8		Misc Equipment (Nat Gas)
9		Elevators and Escalators
10		Refrigeration Equipment
11		Refrigeration Equipment - Unregulated
12		IT Equipment
13		Service Water Heating
14		Service Water Heating - Electricity
15		Cooking
16		Industrial Process
17		Mechanical Ventilation
18		Fans - Indoor Ventilation
19		Fans - Kitchen Ventilation
20		Fans - Parking Garage
21		Pumps
22		Space Cooling
23		Cooling (Nat Gas)
24		Dehumidification
25		Heat Rejection
26		Heat Pump Supplementary
27		Space Heating
28		Space Heating (Electricity)
29		Humidification
30		Heat Recovery
31		Auxiliary (Nat Gas)
32		Other - Nat Gas
33		Other - Electricity
34		Other - Nat Gas
35		Other - Electricity
36		Motors
37		Renewable Energy
38		Battery
39		Exported Energy
40		Fossil On-site Generation
41		Building Transformers
42	**Quality Assurance**	Unmet Heating Hours
43		Unmet Cooling Hours
44		Error Messages
45		Warning Messages
46		System Load
47		Peak Electric Load
48		Peak Energy Month

Figure 2.1: Summary of Energy End-Use and Quality Assurance Categories.

Task 2 Discussion

Several trends and insights were observed by the research team that have been documented in this section. It is hoped that developers of BPM protocols will implement these observations into future versions of the protocols and reporting tools.

Fuel Flexibility

Several protocols define fuel sources in the energy end-use category whereas others leave the fuel type flexible. An example of a protocol defining fuels includes heating and heating (electric) or cooling and cooling (natural gas). Five out of 41 energy end-use categories could be eliminated as separate end-use categories with a fuel flexibility approach.

In order to simplify reporting, the research team recommends that separate fuel specific end-use categories be eliminated and the fuel source be defined independent of the end-use category within the reporting tool. If multiple fuel sources are used, such as a mixture of electric and natural gas heating, then a second flexible reporting category should be available within the reporting tool.

Most protocols define fuel types, which most commonly includes electricity and natural gas. A full list of fuel types referenced in BPM protocols include:

- Electricity
- Natural Gas
- Fuel oil
- Propane
- Purchased steam
- Purchased chilled water
- Purchased hot water
- Renewable energy
- Solar energy

Furthermore, some protocols leave blank/flexible spaces for user defined fuel types in case the list is missing an applicable fuel or in some cases multiple types of renewable energy may be applied.

The research team observed that cooking is one end-use that is not broken out by fuel type in any protocol. Electrical and natural gas cooking equipment is very commonly found in the same kitchen, and large commercial kitchens on campuses often use steam in addition to natural gas and electricity. **The team recommends that protocols that break out cooking as an energy end-use adopt a fuel flexibility approach.**

Lighting

Lighting is a critical energy end-use and is identified by all eight protocols included in Task 2. Most of the protocols do require certain types of lighting to be broken out such as process lighting, exterior lighting, and lighting in apartments.

Lighting in apartments was specifically called out by two protocols: Boulder Colorado 2020 Commercial Energy Modeling Report and New York State Energy code. Both of these protocols refer to ASHRAE 90.1 that does regulate residential lighting, but doesn't specifically require lighting in apartments to be reported separately. Both the New York State and Boulder Energy codes allow dwelling lighting to be exempted from lighting compliance, which in turn may drive the rationale for

breaking it out separately so the energy totals are correct, but it is easier for reviewers to exclude the energy for compliance purposes.

Transformers

Electrical transformers have been present in buildings since electricity was first provided to adjust the voltage to the needs of the systems and devices using electricity. Higher voltage levels are used to distribute electricity at the neighborhood scale and larger to minimize the size of the transmission lines, however lower voltage levels are used inside buildings to enhance safety. Most protocols have not historically required transformers and their energy use to be included in energy models, but this is slowly changing.

Transformer energy use occurs in two ways: 1) the conversion loss that occurs when changing voltage, and 2) the energy required to keep transformers within an appropriate temperature range if they're present inside a building and served by HVAC. None of the protocols that required documentation of transformer energy defined precisely what that means in terms of which values should be included in the end-use.

The regulation of transformers is currently too simplistic to be accurately captured in energy models as the regulations define single point efficiencies at either 35% of peak load or 50% of peak load depending on the capacity of the transformer. Transformer performance curves are not flat and therefore the efficiency will change as the electrical load changes. An approach similar to IEER for cooling performance would be required to cover the full load range.

Transformer energy is also worth capturing accurately as an energy end-use as the buildings industry moves towards decarbonization goals. More accurate calculation of the building's total electricity use will assist in accurately estimating the building's demand on the electrical grid. The transformer efficiency may have a noticeable impact on overall energy use as all electricity used in a building will pass through at least one transformer prior to use. Many protocols and owners are asking modelers to estimate carbon emissions related to the building's operations. If transformer energy consumption is excluded, these models may be missing 2-5% of the total electricity, skewing the carbon emissions calculations.

Fan Energy

Fan energy is one of the most common energy outputs in BPM protocols, and is typically focused on indoor ventilation. Ventilation, defined as the mechanical or natural movement of air, is found in most buildings as a means of distributing heating, cooling, and conditioned outside air. Fan energy almost always uses electricity as a fuel source.

BPM protocols don't treat fan energy in the same way. Most protocols reference the methods documented in ASHRAE 90.1, which regulates fan power allowances. ASHRAE 90.1 even defines a method to break out fan power from packaged HVAC systems to specifically regulate the fan energy.

Conversely, RESNET takes the opposite approach merging fan energy into the heating and cooling energy end-uses. Fan energy used to distribute the heating and cooling is aggregated into the energy end-use that it is supporting. Also, RESNET specifically requires ceiling fan energy to be combined with miscellaneous electrical loads.

Many, but not all protocols break out kitchen ventilation and parking garage ventilation from indoor ventilation. These are again regulated separately by energy codes so the protocols break them out.

Heat Pump Supplementary Energy

ASHRAE 90.1 defines heat pump supplementary energy as a secondary heating energy end-use by means of electrical resistance, steam, hot water, or gas. When heat pumps operate in cold temperatures, they may require use of a separate energy source to achieve the desired setpoint.

The use of this energy end-use category in BPM protocols should be clarified and locked down for users due to the move towards electrified heating systems in colder climates where supplemental energy use is increasing. This end-use is of particular importance in terms of peak electrical load for decarbonization and electrification studies informed by energy models.

This end-use category has often been misused by modelers for reporting the energy associated with separate heating and cooling systems such as a heat recovery chiller or the energy associated with the heat pumps in a hybrid ground source system. Protocols should add a category for secondary heating and cooling systems to avoid this misuse of terminology that can lead to misinterpretation of results. Alternatively, the secondary heating and cooling energy could be aggregated into the primary heating and cooling end-uses, but it is then difficult to determine the relative impact of each system.

Finally, some BEM software include auxiliary energy uses such as crankcase and base pan heaters among others and aggregate it into a related category. Some protocols indicate that this energy should be eliminated since it's not regulated, however this energy use is often required for systems to function. BPM protocols should clarify that these end-use should be included and where they should be reported. BEM software developers should clearly define for users where these inputs are located and how to ensure they are reported properly if applicable.

Regulated and Unregulated Process Loads

The concept of regulated and unregulated process loads is a relatively recent addition to energy codes and standards. For many years process loads were defined as a collection of unregulated energy consuming devices and systems that did count to the overall energy use of the building being modeled, but didn't have regulations defining an energy usage allowance. As energy performance goals become more stringent several process loads have become regulated requiring a separation of energy end-uses that used to be aggregated.

Only ASHRAE 90.1 and LEED specifically categorize regulated and unregulated process loads at this time. It is likely the other protocols that reference ASHRAE 90.1 are on a slower update cycle and have not made this change yet. It will however become more common over time.

End-Use Aggregation and Disaggregation

The research team recommends a flexible approach to aggregation and disaggregation of energy end-use categories. A high level of disaggregation can become cumbersome to energy modelers as shown by the 48 documented reporting end-use categories in the task 2 results section.

BEM software developers will need to offer a high level of customization enabling users to adjust to which ever protocol they're modeling for the energy end-uses are found in their building. For example, an office building may have a small IT closet that could likely be categorized as a miscellaneous load whereas a similar sized office building may have a data center inside that should be broken out as a separate IT energy end-use. The same could be said for elevators in a low-rise versus a high-rise building, refrigeration systems, and other systems.

The research team recommends that thresholds be set for when an energy end-use should be broken out into it's own end-use category. If more than 10% of an energy end-use category can be attributed to a single end-use device(s) or system(s), then it shall be broken out into it's own end-use category. For example, if a building has significant elevator use that exceeds 10% of the building's total energy, then this category should be broken out from miscellaneous energy use.

Quality Assurance

Some protocols require documentation of quality assurance metrics such as unmet heating and cooling load hours to assist reviewers in determining if the energy model is of good quality at least at a high level. Some, protocols directly require energy model quality assurance metrics to be provided in their forms or tools.

It should be noted that there are also aggregated inputs used for quality assurance such as square footage and window-to-wall ratio. This research project is focused solely on model calculated outputs rather than energy model inputs.

Reporting Time Step

The term time step for this project needs to be clearly defined as it differs from the traditional use in BEM. In BEM, the term time step is used to define the smallest increment of time in which calculations are performed such as 1-hour, 15-minutes, etc.

The protocols do not require this resolution for reporting where values are typically aggregated into annual values. Unmet hours for example are a summation of hours for a year, and so the reporting time step is an annual value as monthly unmet hours are not reported in any protocol. A few end-use categories do require peak values that may be averaged over a sub-hourly time step such as peak power.

All the BEM software discussed in Task 3 below use hourly or sub-hourly time steps for calculations and so more granular data is available.

Task 3: BEM Default Outputs

Task 3 consists of testing the default outputs of widely used modeling engines within BEM software and comparing them against the categories defined in Task 2. Per the RFP, the following four engines were considered:

1. EnergyPlus
2. DOE-2
3. Apache
4. TRACE

To review the default outputs from the above engines, the following BEM software were considered:

1. EnergyPlus v23.2
2. eQUEST 3.65
3. IES-VE
4. Trane TRACE 700

In summary, all the tested software provided standard output reporting that covers all ten high priority output categories (highlighted in green in Figure 2.1) as well as most of the other identified Task 2 categories.

Tables summarizing the Task 3 tests include the following five data points: aggregation, energy unit, power unit, time step, and reference. The aggregation data point is relevant to reporting categories that aren't separately displayed in the standard reports, but are calculated within the modeling engine. For example, lighting in apartments is aggregated into lighting for EnergyPlus.

This study focused on default output reports rather than digging into every possible capability and workaround that exists as this would have increased the scope. It was decided that it was a reasonable expectation for users to be able to access and document default reports. Conversely, it was not expected that a typical user knows about every workaround for their particular software.

The energy unit and power units are defined when they are fixed by the software. Many software report the same end use with different units in different reports, but aren't necessarily unit flexible. For example, eQUEST reports energy by end-use in both the BEPS and BEPU reports. The BEPS report only uses MMBtu per year as the reporting value whereas the BEPU uses kWh for electricity, therms for natural gas, and MMBtu of other fuel types.

All software offer a mixture of annual, monthly, and hourly time steps for reporting, however the standard reports tends to focus on annual aggregated values. This was expected as most protocols require values to be reported for a full year. Task 3 is focused on the requirements set by Task 2 so mostly annual time steps are identified along with the corresponding report reference. This column should not be read as a limitation of the software, rather it lists that the software meets the requirement of the reporting category.

Finally, the reporting reference identifies the name of a report where the output category can be found. As noted in the units description, values are often reported in more than one place. The references are not an exhaustive list of where each category is reported, but rather a confirmation that the value is available in the identified default report. When two references are shown it is to identify that the energy and power values are reported in separate reports for that end-use, in the order of the energy value in the first report and the power value in the second report.

EnergyPlus 23.2

EnergyPlus version 23.2 is the current version available for download at the time of this research. This software was downloaded and the reports were generated from a sample model file. All standard reports are contained within the .html file except the errors and warnings report that is listed in the .err file that are generated by the software after each model run. There are several reports within the .html file that are referenced in Figure 3.1 below.

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories							
	Revision: Final draft for Task 3 meeting, 30 Nov 2023						
		Green highlighted top priority end-uses					
Task 2: Reporting Matrix					EnergyPlus v23.2		
Item #	Category	Reporting Requirement	Aggregation	Default Energy Unit	Default Power Unit	Time Step	Reference
1	Energy End-Use	Interior Lighting		GJ	W	Annual	*: End Uses, **: End Uses
2		Interior Lighting - Process	Interior Lighting				
3		Exterior Lighting		GJ	W	Annual	*: End Uses, **: End Uses
4		Lighting in Apartments	Interior Lighting				
5		Receptacle Equipment	Misc Equipment				
6		Office Equipment	Misc Equipment				
7		Misc Equipment		GJ	W	Annual	*: End Uses, **: End Uses
8		Misc Equipment (Nat Gas)	Misc Equipment	GJ	W	Annual	*: End Uses, **: End Uses
9		Elevators and Escalators	Misc Equipment				
10		Refrigeration Equipment		GJ	W	Annual	*: End Uses, **: End Uses
11		Refrigeration Equipment - Unregulated	Refrigeration Equipment				
12		IT Equipment	Misc Equipment				
13		Service Water Heating	Heating	GJ	W		
14		Service Water Heating - Electricity	Heating				
15		Cooking	Misc Equipment				
16		Industrial Process	Misc Equipment				
17		Mechanical Ventilation	Fans				
18		Fans - Indoor Ventilation		GJ	W	Annual	*: End Uses, **: End Uses
19		Fans - Kitchen Ventilation	Fans				
20		Fans - Parking Garage	Fans				
21		Pumps		GJ	W	Annual	*: End Uses, **: End Uses
22		Space Cooling		GJ	W	Annual	*: End Uses, **: End Uses
23		Cooling (Nat Gas)	Cooling				
24		Dehumidification					
25		Heat Rejection		GJ	W	Annual	*: End Uses, **: End Uses
26		Heat Pump Supplementary	Heating				
27		Space Heating		GJ	W	Annual	*: End Uses, **: End Uses
28		Space Heating (Electricity)	Heating				
29		Humidification		GJ	W	Annual	*: End Uses, **: End Uses
30		Heat Recovery		GJ	W	Annual	*: End Uses, **: End Uses
31		Auxiliary (Nat Gas)	Misc Equipment				
32		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types
33		Other - Electricity					Software is flexible to add loads and flexible on fuel types
34		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types
35		Other - Electricity					Software is flexible to add loads and flexible on fuel types
36		Motors	Misc Equipment				
37		Renewable Energy		GJ	W	Annual	*: End Uses, **: End Uses
38		Battery					
39		Exported Energy		GJ		Annual	*: Electric Loads Satisified
40		Fossil On-site Generation		GJ	W	Annual	*:Electric Loads Satisfied, **: End Uses
41		Building Transformers					
42	Quality Assurance	Unmet Heating Hours				Hours	*: Comfort and Setpoint Not Met Summary
43		Unmet Cooling Hours				Hours	*: Comfort and Setpoint Not Met Summary
44		Error Messages					This data is located in a separate .err file.
45		Warning Messages					This data is located in a separate .err file.
46		System Load					
47		Peak Electric Load					
48		Peak Energy Month					
							*Annual Building Utility Performance Summary
							**Demand End Use Components Summary

Figure 3.1: EnergyPlus Default Outputs Results

The following additional notes elaborate on certain line items to assist readers with nuances particular to EnergyPlus.

- Miscellaneous equipment is labeled as "Interior Equipment" and EnergyPlus also breaks out "Exterior Equipment" into a separate line it.
- Refrigeration equipment is not broken out by "Regulated" or "Unregulated".
- Service hot water reporting is only broken out under certain circumstances. If a stand-alone heating system is used, then the energy will be reported as "Water Systems" and can contain non-potable water treatment and pumping. If served by a shared heating system with space heating, it will be aggregated under "Heating".
- Renewable energy generation systems are labeled as "Generators".
- Fossil fuel energy generation systems are labeled as "Generators".
- The .err file is separate from the standard .html output report file that may not be shared with the reviewer and may also not be noticed by novice users of EnergyPlus.
- The Peak Electric Load and Peak Energy Month is not in the default reports, and must be activated by the user.

eQUEST 3.65

eQUEST 3.65 is the current version available for download at the time of this research. This software was downloaded and the reports were generated from a sample model file. All standard reports are contained within the .SIM file that is generated by the software after each model run. There are several reports within the .SIM file that are referenced in Figure 3.2 below.

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories							
	Revision: Final draft for Task 3 meeting. 30 Nov 2023						
		Green highlighted top priority end-uses					
Task 2: Reporting Matrix				eQUEST 3.65			
Item #	Category	Reporting Requirement	Aggregation	Default Energy Unit	Default Power Unit	Time Step	Reference
1	Energy End-Use	Interior Lighting		kWh	kW	Annual	BEPU, PS-F
2		Interior Lighting - Process	Interior Lighting				
3		Exterior Lighting		kWh	kW	Annual	BEPU, PS-F
4		Lighting in Apartments	Interior Lighting				
5		Receptacle Equipment	Misc Equipment				
6		Office Equipment	Misc Equipment				
7		Misc Equipment		kWh	kW	Annual	BEPU, PS-F
8		Misc Equipment (Nat Gas)	Misc Equipment				
9		Elevators and Escalators	Misc Equipment				
10		Refrigeration Equipment	Refrigeration Equipment - Unregulated				
11		Refrigeration Equipment - Unregulated		kWh	kW	Annual	BEPU, PS-F
12		IT Equipment	Misc Equipment				
13		Service Water Heating		Therm	Therm/hr	Annual	BEPU, PS-F
14		Service Water Heating - Electricity	Service Water Heating				
15		Cooking	Misc Equipment				
16		Industrial Process	Misc Equipment				
17		Mechanical Ventilation	Fans - Interior Ventilation				
18		Fans - Indoor Ventilation		kWh	kW	Annual	BEPU, PS-F
19		Fans - Kitchen Ventilation	Fans - Interior Ventilation				
20		Fans - Parking Garage	Fans - Interior Ventilation				
21		Pumps		kWh	kW	Annual	BEPU, PS-F
22		Space Cooling		kWh	kW	Annual	BEPU, PS-F
23		Cooling (Nat Gas)	Space Cooling				
24		Dehumidification					
25		Heat Rejection		kWh	kW	Annual	BEPU, PS-F
26		Heat Pump Supplementary		kWh	kW	Annual	BEPU, PS-F
27		Space Heating		Therm	Therm/hr	Annual	BEPU, PS-F
28		Space Heating (Electricity)	Space Heating				
29		Humidification	Space Heating				
30		Heat Recovery		MMBtu	kBtu/hr	Annual	ERV
31		Auxiliary (Nat Gas)	Misc Equipment				
32		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types
33		Other - Electricity					Software is flexible to add loads and flexible on fuel types
34		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types
35		Other - Electricity					Software is flexible to add loads and flexible on fuel types
36		Motors	Misc Equipment				
37		Renewable Energy		Therm	Therm/hr	Annual	PS-C
38		Battery					
39		Exported Energy					PS-C
40		Fossil On-site Generation					PS-C
41		Building Transformers					
42	Quality Assurance	Unmet Heating Hours		hr		Annual	BEPU
43		Unmet Cooling Hours		hr		Annual	BEPU
44		Error Messages				Annual	ATTN
45		Warning Messages				Annual	ATTN
46		System Load		kWh	kW	Annual	PS-E
47		Peak Electric Load		kWh	kW	Annual	PS-E
48		Peak Energy Month		kWh	kW	Annual	PS-E

Figure 3.2 eQUEST Default Outputs Results

The following additional notes elaborate on certain line items to assist readers with nuances particular to eQUEST.

- Task lights are broken out as a default output.
- The exterior lighting end-use can be used for other process loads in eQUEST if the user is not careful with their inputs.
- If natural gas is applied to a process load, then it'll be automatically reported under Misc Equip with the appropriate fuel source.
- A separate, manually created, meter would be required to separately report regulated and unregulated refrigeration energy. If the appropriate equipment is assigned to the correct meters then regulated and unregulated refrigeration can be reported as separate line items in the standard reports.
- The service hot water will automatically report the correct fuel source (electricity, natural gas, etc) as specified by the user.
- If a natural gas fired chiller is selected, then it'll be automatically reported under Space Cooling with the appropriate fuel source.
- If electric heating or any electric auxiliary energy (eg. blower for boiler makeup air, etc.), then it'll be reported under Space Heating with the appropriate fuel source.
- If humidification is added, the energy is reported by fuel into the heating end-use category
- Energy impacts of heat recovery are aggregated into appropriate end-use categories rather than being reported separately.
- The renewable generation systems in eQUEST are limited to photovoltaic arrays

- An additional meter is required to separately report renewable energy, but the reports are generated automatically if properly configured by the user.
- An additional meter is required to separately report on-site generated fossil energy, but the reports are generated automatically if properly configured by the user.
- Transformers can be modeled in eQUEST, but are not separately reported. Each end-use is impacted per the applicable electricity use.
- User will need to manually identify the specific month with the highest electrical load from the PS-E report.

IES-VE

IES-VE staff provided a compilation of reports generated by IES-VE in response to a request for information that included a description of this project and the Task 2 reporting categories. The provided reports were then compared to the Task 2 reporting categories and alignments noted. A full compilation of the reports are included in Appendix D.

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories

Revision: Final draft for Task 3 meeting. 30 Nov 2023

Green highlighted top priority end-uses

Task 2: Reporting Matrix							IES-VE	
Item #	Category	Reporting Requirement	Availability	Aggregation	Default Energy Unit	Default Power Unit	Time Step	Reference
1	Energy End-Use	Interior Lighting	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
2		Interior Lighting - Process	x		MWh		Annual	California Title 24 Report: Energy Use Summary,
3		Exterior Lighting						
4		Lighting in Apartments		Interior Lighting				
5		Receptacle Equipment	x		MWh		Annual	California Title 24 Report: Energy Use Summary,
6		Office Equipment	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
7		Misc Equipment	x		kBtu/yr	kBtu/h	Annual	
8		Misc Equipment (Nat Gas)						
9		Elevators and Escalators	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
10		Refrigeration Equipment	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
11		Refrigeration Equipment - Unregulated		Other - Electricity				
12		IT Equipment		Misc Equipment				
13		Service Water Heating	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
14		Service Water Heating - Electricity	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
15		Cooking	x		kBtu/ft2-yr		Annual	California Utility Incentives Report for Savings By Design
16		Industrial Process		Misc Equipment				
17		Mechanical Ventilation		Fans				
18		Fans - Indoor Ventilation	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
19		Fans - Kitchen Ventilation		Fans				
20		Fans - Parking Garage		Fans				
21		Pumps	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
22		Space Cooling	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
23		Cooling (Nat Gas)	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
24		Dehumidification						
25		Heat Rejection	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
26		Heat Pump Supplementary						
27		Space Heating	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
28		Space Heating (Electricity)	x		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type
29		Humidification						
30		Heat Recovery						
31		Auxiliary (Nat Gas)						
32		Other - Nat Gas	x		kBtu/yr		Annual	Energy and Cost Summary by Fuel Type
33		Other - Electricity	x		kBtu/yr		Annual	Energy and Cost Summary by Fuel Type
34		Other - Nat Gas						
35		Other - Electricity						
36		Motors	x		MWh			California Title 24 Report: Energy Use Summary,
37		Renewable Energy	x		MWh			California Title 24 Report: Energy Use Summary,
38		Battery	x		MWh			California Title 24 Report: Energy Use Summary,
39		Exported Energy						
40		Fossil On-site Generation						
41		Building Transformers						
42	Quality Assurance	Unmet Heating Hours	x				Hours	Advisory Messages
43		Unmet Cooling Hours	x				Hours	Advisory Messages
44		Error Messages	x				Quantity	Advisory Messages
45		Warning Messages	x				Quantity	Advisory Messages
46		System Load	x			Btu/h	Annual	HVAC Reports
47		Peak Electric Load	x			kW	Annual	Energy Model Output Report
48		Peak Energy Month	x		MMBtu		Month	Automated ASHRAE 90.1 Spreadsheet Reports for Energy, Cost & PCI

Figure 3.3: IES-VE Default Outputs Results

The following additional notes elaborate on certain line items to assist readers with nuances particular to IES-VE.

- The “Miscellaneous Equipment” category is labeled as "Other Regulated Loads" or "Other Unregulated Loads" as appropriate.
- A separate unregulated refrigeration category is not available. The unregulated refrigeration energy is aggregated into "Other Unregulated Loads".
- “Other-Nat Gas” and “Other - Electricity” categories are available for both regulated and unregulated energy.
- The “System Load” category covers the primary thermals (chiller, boiler, etc.) and air-side HVAC systems (furnace, DX, etc.).

Trane TRACE 700

Trane staff provided a compilation of reports generated by Trane TRACE 700 in response to a request for information that included a description of this project and the Task 2 reporting categories. The provided reports were then compared to the Task 2 reporting categories and alignments noted.

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories							
	Revision: Final draft for Task 3 meeting. 30 Nov 2023						
		Green highlighted top priority end-uses					
Task 2: Reporting Matrix						Trane TRACE 700	
Item #	Category	Reporting Requirement	Aggregation	Default Energy Unit	Default Power Unit	Time Step	Reference
1	Energy End-Use	Interior Lighting		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary
2		Interior Lighting - Process	Interior Lighting				
3		Exterior Lighting		kWh	kW	Annual	Equipment Energy Consumption
4		Lighting in Apartments	Interior Lighting				
5		Receptacle Equipment		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary
6		Office Equipment	Receptacles				
7		Misc Equipment	Receptacles				
8		Misc Equipment (Nat Gas)	Receptacles				
9		Elevators and Escalators	Receptacles				
10		Refrigeration Equipment	Receptacles				
11		Refrigeration Equipment - Unregulated	Receptacles				
12		IT Equipment	Receptacles				
13		Service Water Heating		Therms	Therms/hr	Annual	Equipment Energy Consumption
14		Service Water Heating - Electricity		kWh	kW	Annual	Equipment Energy Consumption
15		Cooking	Receptacles				
16		Industrial Process	Receptacles				
17		Mechanical Ventilation	Supply Fans				
18		Fans - Indoor Ventilation		MMBtu	kBtu/hr		Energy Cost Budget/PRM Summary
19		Fans - Kitchen Ventilation	Supply Fans				
20		Fans - Parking Garage	Supply Fans				
21		Pumps		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary
22		Space Cooling		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary
23		Cooling (Nat Gas)	Cooling				
24		Dehumidification					
25		Heat Rejection		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary
26		Heat Pump Supplementary		kWh	kW	Annual	Equipment Energy Consumption
27		Space Heating		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary
28		Space Heating (Electricity)		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary
29		Humidification	Heating				
30		Heat Recovery		kWh	kW	Annual	Equipment Energy Consumption
31		Auxiliary (Nat Gas)	Receptacles				
32		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types
33		Other - Electricity					Software is flexible to add loads and flexible on fuel types
34		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types
35		Other - Electricity					Software is flexible to add loads and flexible on fuel types
36		Motors	Receptacles				
37		Renewable Energy		kWh	kW	Annual	Equipment Energy Consumption
38		Battery					
39		Exported Energy		kWh	kW	Annual	Equipment Energy Consumption
40		Fossil On-site Generation		Therms	Therms/hr	Annual	Equipment Energy Consumption
41		Building Transformers		kWh	kW	Annual	Equipment Energy Consumption
42	Quality Assurance	Unmet Heating Hours					Energy Cost Budget/PRM Summary
43		Unmet Cooling Hours					Energy Cost Budget/PRM Summary
44		Error Messages					Scan for Errors
45		Warning Messages					Scan for Errors
46		System Load		kW		Annual	Electrical Peak Checksums, Equipment Energy Consumption
47		Peak Electric Load		kW		Annual	Electrical Peak Checksums
48		Peak Energy Month		kWh		Annual	Monthly Energy Consumption

Figure 3.4: Trane TRACE 700 Default Outputs Results

The following additional notes elaborate on certain line items to assist readers with nuances particular to Trane TRACE 700.

- Modeler must create “Exterior Lighting” as a base utility for it to be reported automatically.
- If energy meter is set to natural gas, it will be separately reported as natural gas for “Miscellaneous Equipment”.
- “IT Equipment” can be modeled separately if data center check box is marked by the user.
- Modeler must create “Service Water Heating” as a base utility for it to be reported automatically. The selected fuel type will be reported automatically.
- “Fans - Indoor Ventilation” is labeled as "Fans-Conditioned" indicating that fans used in unconditioned areas are not included in the reporting if applicable to the project.
- If a natural gas fired chiller is selected, then it'll be automatically reported under Space Cooling with the appropriate fuel source.
- “Space Heating - Electricity” would include draft fans and other controls for boilers if applicable and would be automatically reported.
- Modeler must create “Renewable Energy” as a base utility for it to be reported automatically.
- Net metering report is only available if the energy produced by base utility is larger than consumption, a negative consumption will be shown.
- “Fossil On-Site Generation” is labeled as "Cogeneration".
- Modeler must create “Transformers” as a base utility for it to be reported automatically.

- Error and warning messages are generated in a separate text file that may not be shared with the reviewer and may also not be noticed by novice users of TRACE 700.
- User mus manually determine specific “Peak Energy Month”.

Task 3 Discussion

The BEM software directly covered all critical reporting categories and most of the other reporting categories. It’s worth noting that EnergyPlus was the only software to not fully report all the identified critical categories per Task 2, specifically service hot water under all configurations. Users must provide special accommodations to separately report SHW which is regulated in all eight BPM protocols from Task 2.

Specific selections, inputs, and/or workarounds all the BEM software are able to effectively address nearly each category, but this much of this is dependent upon the users experience. This puts pressure on users to ensure that models are properly configured. It also puts pressure on reviewers to understand the nuances of how each software reports energy for compliance when compliance documentation is missing.

Modelers and reviewers of energy models can reference this report to verify that certain outputs can or cannot be generated. Software developers should provide websites written for users and for reviewers on where specific outputs can be found.

All output files are linked here in the IBPSA-USA working group project folder:
https://drive.google.com/drive/u/0/folders/1tlQiIiHrbRRMyWnapfxb93lj6BWaBEUF

Task 4: Project STASIO Outputs

Task 4 references Project STASIO, which is a building performance modeling graphics competition that has been hosted by IBPSA since 2017. The competition focuses on graphics that use simulation and BEM to inform building design. The objective of task 4 is to identify graphics and their associated outputs as well as any correlation between Tasks 2 and 3. The intention of this task is to identify BEM outputs that are particularly helpful for building, but may not be part of BPM protocol requirements.

The graphics selected from the STASIO library in address two key criteria: occupant comfort and decarbonization. These criteria were identified as critical to building design and emerging compliance discussions. Samples of the graphics are included in the report with a full list shown in Appendix C.

Each graphic was reviewed using the following criteria:

- Does the graphic support a Task 2 protocol?
- Are there outputs from an energy modeling engine tested in Task 3?
- Are there inputs typically found in BEM software?
- Is the data post processed?
- What is the time step of the data?
- Are multiple energy model runs required?

Selected Graphics

This section shows three graphics selected to highlight how STASIO graphics may be incorporated into BPM protocols and typical BEM analysis. Additional graphics and data are shown in Appendix C.

The first graphic, shown in Figure 4.1, represents equivalent CO2 (CO2e) emissions annually for a code minimum (Baseline) and Proposed model from the present until 2050.

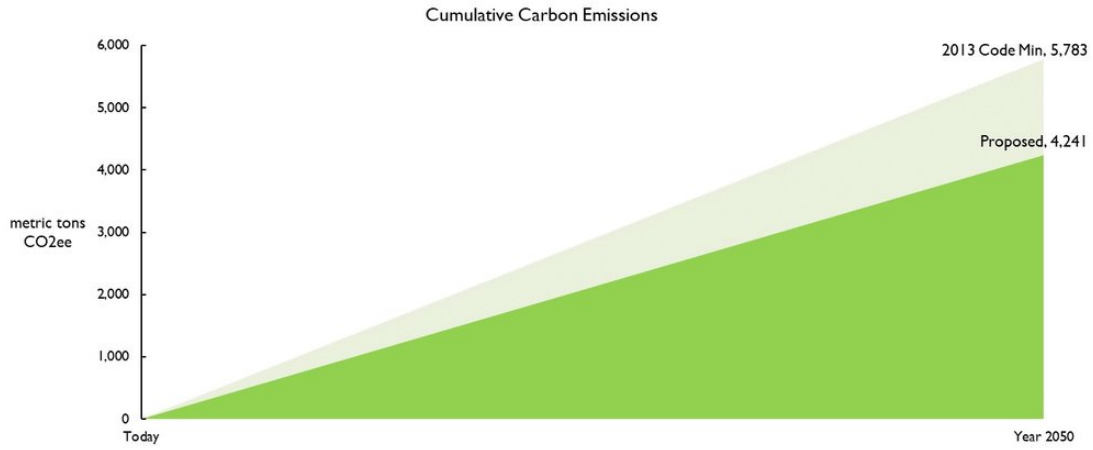

Figure 4.1: Building Carbon Emissions Over Time (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-l4j2e-k44rx/)

- Does the graphic support a Task 2 protocol?
  - Some protocols do ask for CO2e values for a single year, however this is considered a post processed output per Task 2.

- Are there outputs from an energy modeling engine tested in Task 3?
  - Yes, the annual energy results per utility from the model engine will inform the post-processed CO2e calculations.
- Are there inputs typically found in BEM software?
  - No model inputs are shown in the graphic.
- Is the data post processed?
  - Yes, the data does need to be post-processed in some Task 3 energy modeling engines, whereas others do include this output.
- What is the time step of the data?
  - The time step is annual
- Are multiple energy model runs required?
  - A Baseline and Proposed model are required for this graphic.

This graphic could be standardized for compliance with relative ease. A key point is that each jurisdiction would need to define CO2e emissions rates for applicable fuel types, electrical transmission losses, and source energy efficiency. There would also need to be allowances for green power purchases. Finally, the grid is not static and does improve over time so the chart should not be linear. Each jurisdiction adopting this graphic would need to provide a CO2e emission rate for each year in line with expectations for the selected utility grid.

The second graphic shown in Figure 4.2 is a load duration curve for plant equipment. This graphic is flexible enough for any primary thermals (heating and cooling equipment), but in this case a boiler, a storage tank, and a combined heat and power (CHP) system are shown.

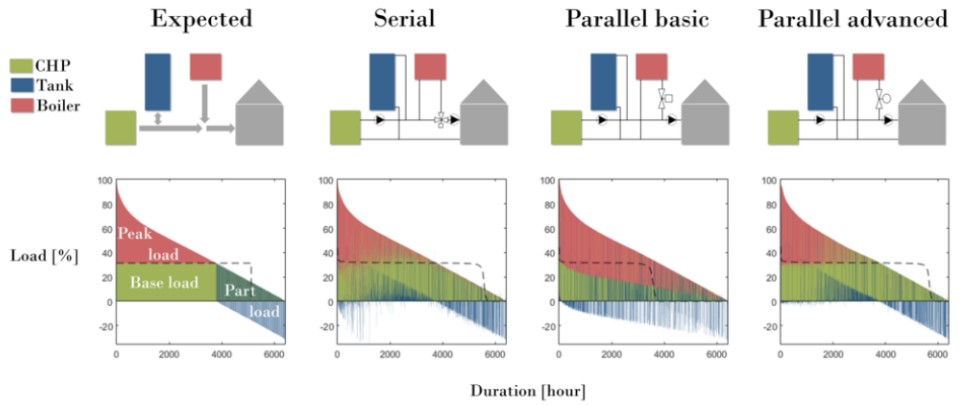

Figure 4.2: Load Duration Curves for Different Plant Configurations (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-enm8z/)

- Does the graphic support a Task 2 protocol?
  - No, this graphic supports design only. However, it does assist project teams with managing peak loads that are a required output for some protocols.
- Are there outputs from an energy modeling engine tested in Task 3?
  - The Load % output would be the hourly heating energy calculated by the energy model engine, and each piece of equipment's contribution towards meeting the load.
- Are there inputs typically found in BEM software?
  - No inputs are used in this graphic.
- Is the data post processed?
  - The data is post processed from hourly results of the energy model to generate the graphic with the applicable colors. This could be achieved in most spreadsheet tools.
- What is the time step of the data?
  - Hourly load data
- Are multiple energy model runs required?
  - A single load duration curve is based on a single model run. The graphic shows four load duration curves, but this is not required.

Load duration curves assist project teams in defining how frequently certain pieces of equipment will be operating. These curves are commonly developed for CHP systems, but will take on additional value as the industry moves towards electrification. Replacing carbon based fuel sources with electrical heat sources such as air-source heat pumps can require significant capital investment. Identifying that some of the equipment will have very few run hours will inform project teams how to best manage peak electrical loads. Batteries, storage, and other peak shaving solutions could then be highlighted. Also, the value of other peak shaving solutions such as envelope upgrades could be more accurately estimated. Standardizing this graphic would be helpful for protocols that regulate or manage peak utility loads.

The third graphic shown in Figure 4.3 focuses on occupant comfort for individual spaces before and after renovation.

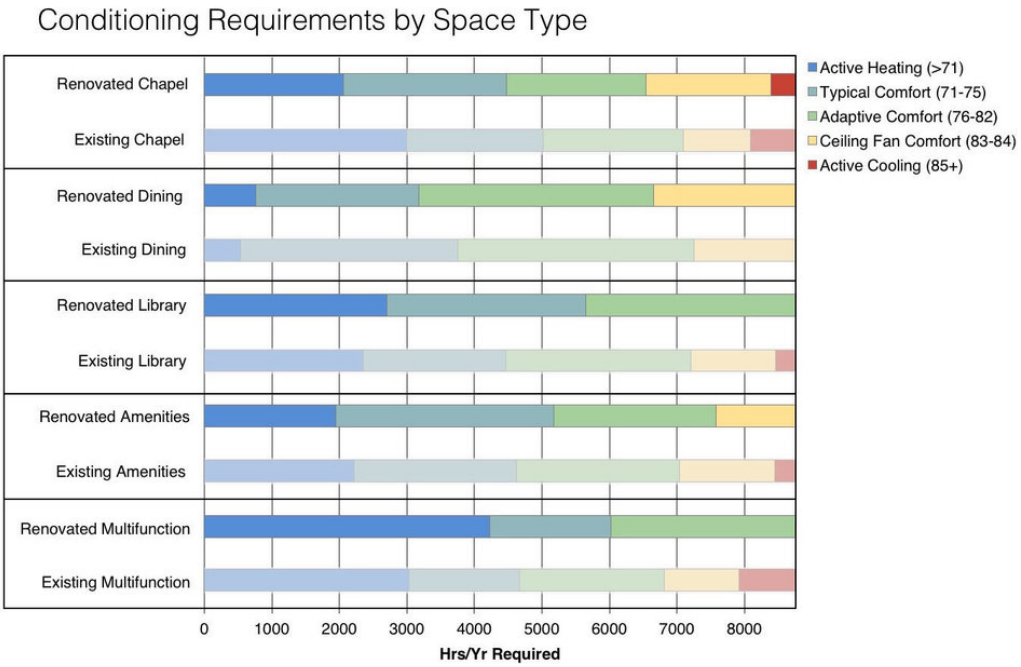

Figure 4.3: Occupant Comfort For Individual Spaces (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-enm8z-z2lp6/)

- Does the graphic support a Task 2 protocol?
  - Most protocols do require documentation of unmet load hours, however the data shown is more granular both in terms of level of comfort and on individual spaces rather than whole buildings.
- Are there outputs from an energy modeling engine tested in Task 3?
  - Hourly zone level temperature and humidity outputs are available from all the energy model engine outputs.
- Are there inputs typically found in BEM software?
  - The only model input would be documenting the zone name so that data can be tagged accurately.
- Is the data post processed?
  - The hourly zone temperature and humidity values need to be post-processed into the applicable temperature bins.
- What is the time step of the data?
  - The time step is hourly data.
- Are multiple energy model runs required?
  - Two runs are required, in this case a before and after renovation. This could be modified to a Baseline and Proposed comparison.

Standardizing a graphic like this would be valuable for typical spaces in jurisdictions that also enforce a comfort standard like ASHRAE 55. For example, LEED has a thermal comfort credit, but is not explicitly part of the LEED BPM protocol.

Task 4 Discussion

A key difference between STASIO and the Task 2 protocols is that the audiences are different. STASIO graphics are developed for the project team to inform design. The Task 2 protocols are typically focused on the final stages of energy modeling for compliance and rating system scoring with the exception of ASHRAE Standard 209 that requires certain tasks be completed in different design phases. Energy modeling is most valuable to the project when used in the early stages of design and has limited value when only used at the end for compliance and rating system scoring.

All of the graphics do require a level of post-processing that may be difficult to automate within a BEM software in order for them to be meaningful and robust. Protocol developers that want to include standardized graphics would likely need to create tools that can take the pertinent model engine outputs to generate the desired graphics so as not to limit the software that can be used to comply with the protocol. Some of the graphics shown in Appendix C are highly specialized and project specific and may be impossible to standardize such as the ones showing floor plans.

None of the graphics required outputs that the energy modeling engines can't provide, however several graphics do require hourly outputs. Many of the graphics require multiple model runs to generate the relevant data. Some of the graphics could be modified to a Baseline versus a Proposed model run graphic style for compliance.

The two decarbonization graphics shown in this section are probably reasonable candidates for standardization using Baseline and Proposed models with some modification for protocols addressing decarbonization and peak load management.

Conclusions

This research project reviewed fourteen building performance modeling protocols of which eight were selected for detailed documentation to create a comprehensive matrix of reporting categories. The six protocols that were not included had reporting requirements that were the same as previously selected protocols. All the BPM protocols had significant reporting category overlap and a series of critical outputs that are regulated by energy codes were present in seven out of eight protocols. ANSI/RESNET was fairly unique among the protocols as it is focused on residential buildings rather than commercial buildings. There were 48 reporting categories identified, but no protocol required more than 26 categories. Frequently the names of the categories were somewhat different from one protocol to the next and/or broke out fuel types by end-use category (ie. electric heat vs. natural gas heat).

Four common building energy modeling engines and related software were tested against the reporting categories to highlight key similarities and differences. Finally, project STASIO was reviewed to determine if additional reporting categories should be created beyond the ones required by the BPM protocols and to verify whether the modeling engines could generate the required outputs. The intention of this task is to identify BEM outputs that are particularly helpful for building design, but may not be part of the BPM protocol requirements.

The BEM software directly covered all critical reporting categories and most of the other reporting categories. With manual workarounds the BEM software are able to effectively address nearly each category, but relies on the user's experience.

Project STASIO was referenced to determine if additional standard reporting categories can be identified and if BEM software can provide the outputs rather than highly customized post-processed values. There were several graphics that could be modified and adopted as standard outputs for protocols that have an emphasis on decarbonization and/or thermal comfort.

Recommendations

In order to streamline the compliance process, BPM protocols should be more specific with their terminology. Furthermore, types of energy should be flexible in the compliance forms rather than always having separate line items for the same end-use with multiple fuels. Fuel flexibility is going to continue to be a focus area as the building industry electrifies and decarbonizes. Identifying ways to streamline documentation such as determining thresholds for end-uses to be reported separately or aggregated would be beneficial for users.

IBPSA should lead the development of a consensus document on terminology with BEM software developers so that reviewers receiving standard reports are not left wondering if the values are reported in the right categories. The BPM protocol developers should reference this document as well.

Project STASIO provided limited value to this project in terms of reporting categories beyond the protocols as the focus of STASIO has largely been on informing design rather than compliance. However, the STASIO committee may want to include a future competition that focuses on compliance graphics that compare the project's Baseline and Proposed results. Many of the graphics shown in Task 4 and Appendix C could be adapted to meet this goal. These graphics could then be

adopted by BPM protocols for compliance if energy model reviewers find them useful. An additional note is that the judges for these graphics should be drawn from entities that do not generate models, but review them such as code officials, owners, and rating system reviewers.

The IBPSA-USA Data Models Working Group will present the project results to the larger committee and discuss next steps. The committee plans to move towards the development of an output reporting schema.

Appendices

A. Task 2 BPM Matrix
B. Task 3 BEM Matrix
C. Project STASIO Graphics
D. IES-VE Letter Feedback

Appendix A: Task 2 Matrix

Task 2: Structure for IBPSA BPM Protocol Comparison

Revision: Final version issued 2 November 2023

		Green highlighted top priority end-uses	Task 1: BPM Protocols LEED v4 MEPC			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	kWh	kW	Year	
2		Interior Lighting - Process	kWh	kW	Year	u
3		Exterior Lighting	kWh	kW	Year	
4		Lighting in Apartments				
5		Receptacle Equipment	kWh	kW	Year	u
6		Office Equipment				
7		Misc Equipment				
8		Misc Equipment (Nat Gas)	Therm	MMBtu/hr	Year	
9		Elevators and Escalators	kWh	kW	Year	u
10		Refrigeration Equipment	kWh	kW	Year	u
11		Refrigeration Equipment - Unregulated				
12		IT Equipment	kWh	kW	Year	u
13		Service Water Heating	Therm	MMBtu/hr	Year	
14		Service Water Heating - Electricity				
15		Cooking	kWh	kW	Year	u
16		Industrial Process	kWh	kW	Year	u
17		Mechanical Ventilation				
18		Fans - Indoor Ventilation	kWh	kW	Year	
19		Fans - Kitchen Ventilation	kWh	kW	Year	u
20		Fans - Parking Garage	kWh	kW	Year	u
21		Pumps	kWh	kW	Year	
22		Space Cooling	kWh	kW	Year	
23		Cooling (Nat Gas)	Therm	MMBtu/hr	Year	
24		Dehumidification				
25		Heat Rejection	kWh	kW	Year	
26		Heat Pump Supplementary	kWh	kW	Year	
27		Space Heating	Therm	MMBtu/hr	Year	
28		Space Heating (Electricity)	kWh	kW	Year	
29		Humidification				
30		Heat Recovery				
31		Auxiliary (Nat Gas)	Therm	MMBtu/hr	Year	
32		Other - Nat Gas				
33		Other - Electricity				
34		Other - Nat Gas				
35		Other - Electricity				
36		Motors				
37		Renewable Energy	Undefined	Undefined	Year	
38		Battery				
39		Exported Energy				
40		Fossil On-site Generation				
41		Building Transformers				
42	**Quality Assurance**	Unmet Heating Hours	Hr		Year	
43		Unmet Cooling Hours	Hr		Year	
44		Error Messages				
45		Warning Messages				
46		System Load				
47		Peak Electric Load				
48		Peak Energy Month				

Task 2: Structure for IBPSA BPM Protocol Comparison

Revision: Final version issued 2 November 2023

		Green highlighted top priority end-uses	Task 1: BPM Protocols ASHRAE 90.1-2016/19 Compliance Forms			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	kWh	kW	Year	
2		Interior Lighting - Process	kWh	kW	Year	u
3		Exterior Lighting	kWh	kW	Year	
4		Lighting in Apartments				
5		Receptacle Equipment				
6		Office Equipment				
7		Misc Equipment	kWh	kW	Year	
8		Misc Equipment (Nat Gas)	Therm	kBtu/hr	Year	u
9		Elevators and Escalators	kWh	kW	Year	
10		Refrigeration Equipment	kWh	kW	Year	
11		Refrigeration Equipment - Unregulated	kWh	kW	Year	u
12		IT Equipment				
13		Service Water Heating	Therm	kBtu/hr	Year	
14		Service Water Heating - Electricity	kWh	kW	Year	
15		Cooking				
16		Industrial Process	kWh	kW	Year	u
17		Mechanical Ventilation				
18		Fans - Indoor Ventilation	kWh	kW	Year	
19		Fans - Kitchen Ventilation				
20		Fans - Parking Garage	kWh	kW	Year	
21		Pumps	kWh	kW	Year	
22		Space Cooling	kWh	kW	Year	
23		Cooling (Nat Gas)	Therm	kBtu/hr	Year	
24		Dehumidification				
25		Heat Rejection	kWh	kW	Year	
26		Heat Pump Supplementary	kWh	kW	Year	
27		Space Heating	Therm	kBtu/hr	Year	
28		Space Heating (Electricity)	kWh	kW	Year	
29		Humidification				
30		Heat Recovery				
31		Auxiliary (Nat Gas)				
32		Other - Nat Gas	Therm	kBtu/hr	Year	
33		Other - Electricity	kWh	kW	Year	
34		Other - Nat Gas	Therm	kBtu/hr	Year	u
35		Other - Electricity	kWh	kW	Year	u
36		Motors				
37		Renewable Energy				
38		Battery				
39		Exported Energy				
40		Fossil On-site Generation				
41		Building Transformers				
42	**Quality Assurance**	Unmet Heating Hours	Hr		Year	
43		Unmet Cooling Hours	Hr		Year	
44		Error Messages				
45		Warning Messages				
46		System Load				
47		Peak Electric Load				
48		Peak Energy Month				

Task 2: Structure for IBPSA BPM Protocol Comparison

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		Green highlighted top priority end-uses	Task 1: BPM Protocols Boulder Colorado 2020 Commercial Energy Modeling Report			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	Undefined	Undefined	Year	
2		Interior Lighting - Process	Undefined	Undefined	Year	
3		Exterior Lighting	Undefined	Undefined	Year	
4		Lighting in Apartments	Undefined	Undefined	Year	
5		Receptacle Equipment				
6		Office Equipment				
7		Misc Equipment	Undefined	Undefined	Year	
8		Misc Equipment (Nat Gas)	Undefined	Undefined	Year	
9		Elevators and Escalators	Undefined	Undefined	Year	
10		Refrigeration Equipment	Undefined	Undefined	Year	
11		Refrigeration Equipment - Unregulated	Undefined	Undefined	Year	
12		IT Equipment	Undefined	Undefined	Year	
13		Service Water Heating	Undefined	Undefined	Year	
14		Service Water Heating - Electricity	Undefined	Undefined	Year	
15		Cooking	Undefined	Undefined	Year	
16		Industrial Process				
17		Mechanical Ventilation				
18		Fans - Indoor Ventilation	Undefined	Undefined	Year	
19		Fans - Kitchen Ventilation	Undefined	Undefined	Year	
20		Fans - Parking Garage	Undefined	Undefined	Year	
21		Pumps	Undefined	Undefined	Year	
22		Space Cooling	Undefined	Undefined	Year	
23		Cooling (Nat Gas)	Undefined	Undefined	Year	
24		Dehumidification				
25		Heat Rejection	Undefined	Undefined	Year	
26		Heat Pump Supplementary	Undefined	Undefined	Year	
27		Space Heating	Undefined	Undefined	Year	
28		Space Heating (Electricity)	Undefined	Undefined	Year	
29		Humidification				
30		Heat Recovery				
31		Auxiliary (Nat Gas)				
32		Other - Nat Gas				
33		Other - Electricity				
34		Other - Nat Gas				
35		Other - Electricity				
36		Motors				
37		Renewable Energy	Undefined	Undefined	Year	
38		Battery				
39		Exported Energy				
40		Fossil On-site Generation				
41		Building Transformers	Undefined	Undefined	Year	
42	**Quality Assurance**	Unmet Heating Hours				
43		Unmet Cooling Hours				
44		Error Messages				
45		Warning Messages				
46		System Load				
47		Peak Electric Load				
48		Peak Energy Month				

Task 2: Structure for IBPSA BPM Protocol Comparison

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		Green highlighted top priority end-uses	Task 1: BPM Protocols New York State Energy Code			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	kWh	kW	Year	
2		Interior Lighting - Process	kWh	kW	Year	
3		Exterior Lighting	kWh	kW	Year	
4		Lighting in Apartments	kWh	kW	Year	
5		Receptacle Equipment				
6		Office Equipment				
7		Misc Equipment	kWh	kW	Year	
8		Misc Equipment (Nat Gas)				
9		Elevators and Escalators				
10		Refrigeration Equipment	kWh	kW	Year	
11		Refrigeration Equipment - Unregulated				
12		IT Equipment				
13		Service Water Heating	Therm	MMBtu/hr	Year	
14		Service Water Heating - Electricity	kWh	kW	Year	
15		Cooking				
16		Industrial Process				
17		Mechanical Ventilation				
18		Fans - Indoor Ventilation	kWh	kW	Year	
19		Fans - Kitchen Ventilation				
20		Fans - Parking Garage				
21		Pumps	kWh	kW	Year	
22		Space Cooling	kWh	kW	Year	
23		Cooling (Nat Gas)	Therm	MMBtu/hr	Year	
24		Dehumidification				
25		Heat Rejection	kWh	kW	Year	
26		Heat Pump Supplementary	kWh	kW	Year	
27		Space Heating	Therm	MMBtu/hr	Year	
28		Space Heating (Electricity)	kWh	kW	Year	
29		Humidification				
30		Heat Recovery				
31		Auxiliary (Nat Gas)				
32		Other - Nat Gas				
33		Other - Electricity				
34		Other - Nat Gas				
35		Other - Electricity				
36		Motors				
37		Renewable Energy				
38		Battery				
39		Exported Energy				
40		Fossil On-site Generation				
41		Building Transformers				
42	**Quality Assurance**	Unmet Heating Hours	Hrs		Year	
43		Unmet Cooling Hours	Hrs		Year	
44		Error Messages	Number			
45		Warning Messages				
46		System Load				
47		Peak Electric Load				
48		Peak Energy Month				

Task 2: Structure for IBPSA BPM Protocol Comparison

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		Green highlighted top priority end-uses	Task 1: BPM Protocols ANSI/RESNET/ICC Standard 301 (and RESNET MINHERS)			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	kWh	Undefined	Year	
2		Interior Lighting - Process				
3		Exterior Lighting				
4		Lighting in Apartments				
5		Receptacle Equipment				
6		Office Equipment				
7		Misc Equipment	kWh	Undefined	Year	
8		Misc Equipment (Nat Gas)				
9		Elevators and Escalators				
10		Refrigeration Equipment	kWh	Undefined	Year	
11		Refrigeration Equipment - Unregulated				
12		IT Equipment				
13		Service Water Heating	kWh	Undefined	Year	
14		Service Water Heating - Electricity				
15		Cooking	kWh	Undefined	Year	
16		Industrial Process				
17		Mechanical Ventilation	kWh	Undefined	Year	
18		Fans - Indoor Ventilation				
19		Fans - Kitchen Ventilation				
20		Fans - Parking Garage				
21		Pumps				
22		Space Cooling	kWh	Undefined	Year	
23		Cooling (Nat Gas)				
24		Dehumidification	kWh	Undefined	Year	
25		Heat Rejection				
26		Heat Pump Supplementary				
27		Space Heating	kWh	Undefined	Year	
28		Space Heating (Electricity)				
29		Humidification				
30		Heat Recovery				
31		Auxiliary (Nat Gas)				
32		Other - Nat Gas				
33		Other - Electricity				
34		Other - Nat Gas				
35		Other - Electricity				
36		Motors				
37		Renewable Energy	kWh	Undefined	Year	
38		Battery	kWh	Undefined	Year	
39		Exported Energy				
40		Fossil On-site Generation	kWh	Undefined	Year	
41		Building Transformers				
42	**Quality Assurance**	Unmet Heating Hours	Hr		Year	
43		Unmet Cooling Hours	Hr		Year	
44		Error Messages				
45		Warning Messages				
46		System Load	kBtu	Undefined	Year	
47		Peak Electric Load				
48		Peak Energy Month				

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		Green highlighted top priority end-uses	Task 1: BPM Protocols ASHRAE Standard 209			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	Undefined	Undefined	Year	
2		Interior Lighting - Process				
3		Exterior Lighting				
4		Lighting in Apartments				
5		Receptacle Equipment				
6		Office Equipment				
7		Misc Equipment	Undefined	Undefined	Year	
8		Misc Equipment (Nat Gas)				
9		Elevators and Escalators				
10		Refrigeration Equipment				
11		Refrigeration Equipment - Unregulated				
12		IT Equipment				
13		Service Water Heating	Undefined	Undefined	Year	
14		Service Water Heating - Electricity				
15		Cooking				
16		Industrial Process				
17		Mechanical Ventilation				
18		Fans - Indoor Ventilation	Undefined	Undefined	Year	
19		Fans - Kitchen Ventilation				
20		Fans - Parking Garage				
21		Pumps				
22		Space Cooling	Undefined	Undefined	Year	
23		Cooling (Nat Gas)				
24		Dehumidification				
25		Heat Rejection	Undefined	Undefined	Year	
26		Heat Pump Supplementary				
27		Space Heating	Undefined	Undefined	Year	
28		Space Heating (Electricity)				
29		Humidification				
30		Heat Recovery				
31		Auxiliary (Nat Gas)				
32		Other - Nat Gas				
33		Other - Electricity				
34		Other - Nat Gas				
35		Other - Electricity				
36		Motors				
37		Renewable Energy				
38		Battery				
39		Exported Energy				
40		Fossil On-site Generation				
41		Building Transformers				
42	**Quality Assurance**	Unmet Heating Hours	Hr		Year	
43		Unmet Cooling Hours	Hr		Year	
44		Error Messages				
45		Warning Messages				
46		System Load				
47		Peak Electric Load	Undefined	Undefined	Month	
48		Peak Energy Month	Undefined	Undefined	Month	

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		Green highlighted top priority end-uses	Task 1: BPM Protocols ASHRAE Standard 229			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	Undefined	Undefined	Year	
2		Interior Lighting - Process				
3		Exterior Lighting	Undefined	Undefined	Year	
4		Lighting in Apartments				
5		Receptacle Equipment				
6		Office Equipment	Undefined	Undefined	Year	
7		Misc Equipment	Undefined	Undefined	Year	
8		Misc Equipment (Nat Gas)				
9		Elevators and Escalators	Undefined	Undefined	Year	
10		Refrigeration Equipment	Undefined	Undefined	Year	
11		Refrigeration Equipment - Unregulated				
12		IT Equipment	Undefined	Undefined	Year	
13		Service Water Heating	Undefined	Undefined	Year	
14		Service Water Heating - Electricity				
15		Cooking	Undefined	Undefined	Year	
16		Industrial Process	Undefined	Undefined	Year	
17		Mechanical Ventilation				
18		Fans - Indoor Ventilation	Undefined	Undefined	Year	
19		Fans - Kitchen Ventilation				
20		Fans - Parking Garage	Undefined	Undefined	Year	
21		Pumps	Undefined	Undefined	Year	
22		Space Cooling	Undefined	Undefined	Year	
23		Cooling (Nat Gas)				
24		Dehumidification				
25		Heat Rejection	Undefined	Undefined	Year	
26		Heat Pump Supplementary				
27		Space Heating	Undefined	Undefined	Year	
28		Space Heating (Electricity)				
29		Humidification	Undefined	Undefined	Year	
30		Heat Recovery	Undefined	Undefined	Year	
31		Auxiliary (Nat Gas)				
32		Other - Nat Gas	Undefined	Undefined	Year	
33		Other - Electricity	Undefined	Undefined	Year	
34		Other - Nat Gas	Undefined	Undefined	Year	
35		Other - Electricity	Undefined	Undefined	Year	
36		Motors	Undefined	Undefined	Year	
37		Renewable Energy				
38		Battery				
39		Exported Energy				
40		Fossil On-site Generation				
41		Building Transformers	Undefined	Undefined	Year	
42	**Quality Assurance**	Unmet Heating Hours				
43		Unmet Cooling Hours				
44		Error Messages				
45		Warning Messages				
46		System Load				
47		Peak Electric Load				
48		Peak Energy Month				

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		Green highlighted top priority end-uses	Task 1: BPM Protocols Title 24 - Non-Residential			
Item #	**Category**	**Reporting Requirement**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Unregulated**
1	**Energy End-Use**	Interior Lighting	MWh		Year	
2		Interior Lighting - Process	MWh		Year	
3		Exterior Lighting				
4		Lighting in Apartments				
5		Receptacle Equipment	MWh		Year	
6		Office Equipment				
7		Misc Equipment	MWh		Year	
8		Misc Equipment (Nat Gas)				
9		Elevators and Escalators				
10		Refrigeration Equipment				
11		Refrigeration Equipment - Unregulated				
12		IT Equipment				
13		Service Water Heating	MWh		Year	
14		Service Water Heating - Electricity				
15		Cooking				
16		Industrial Process				
17		Mechanical Ventilation				
18		Fans - Indoor Ventilation	MWh		Year	
19		Fans - Kitchen Ventilation				
20		Fans - Parking Garage				
21		Pumps	MWh		Year	
22		Space Cooling	MWh		Year	
23		Cooling (Nat Gas)				
24		Dehumidification				
25		Heat Rejection	MWh		Year	
26		Heat Pump Supplementary				
27		Space Heating	MWh		Year	
28		Space Heating (Electricity)				
29		Humidification				
30		Heat Recovery				
31		Auxiliary (Nat Gas)				
32		Other - Nat Gas				
33		Other - Electricity				
34		Other - Nat Gas				
35		Other - Electricity				
36		Motors	MWh		Year	
37		Renewable Energy	MWh	kW	Year	
38		Battery	MWh		Year	
39		Exported Energy	kWh		Year	
40		Fossil On-site Generation				
41		Building Transformers				
42	**Quality Assurance**	Unmet Heating Hours	Hr		Year	
43		Unmet Cooling Hours	Hr		Year	
44		Error Messages				
45		Warning Messages				
46		System Load				
47		Peak Electric Load				
48		Peak Energy Month				

Appendix B: Task 3 Matrix

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories

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Green highlighted top priority end-uses

Task 2: Reporting Matrix			Task 3: Energy Modeling Software Default Outputs eQUEST 3.65					
Item #	**Category**	**Reporting Requirement**	**Aggregation**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Reference**	**Notes**
1	**Energy End-Use**	Interior Lighting		kWh	kW	Annual	BEPU, PS-F	Task lights available as a default output
2		Interior Lighting - Process	Interior Lighting					
3		Exterior Lighting		kWh	kW	Annual	BEPU, PS-F	Other process loads may be applied to this end-use
4		Lighting in Apartments	Interior Lighting					
5		Receptacle Equipment	Misc Equipment					
6		Office Equipment	Misc Equipment					
7		Misc Equipment		kWh	kW	Annual	BEPU, PS-F	
8		Misc Equipment (Nat Gas)	Misc Equipment					If natural gas is applied to a process load, then it'll be automatically reported under Misc Equip with the appropriate fuel source.
9		Elevators and Escalators	Misc Equipment					
10		Refrigeration Equipment	Refrigeration Equipment - Unregulated					A separate meter would be required to separately report regulated refrigeration energy
11		Refrigeration Equipment - Unregulated		kWh	kW	Annual	BEPU, PS-F	
12		IT Equipment	Misc Equipment					
13		Service Water Heating		Therm	Therm/hr	Annual	BEPU, PS-F	
14		Service Water Heating - Electricity	Service Water Heating					If elecrticity is applied to SWH, then it'll be automatically reported under Domest Hot Wtr with the appropriate fuel source.
15		Cooking	Misc Equipment					
16		Industrial Process	Misc Equipment					
17		Mechanical Ventilation	Fans - Interior Ventilation					
18		Fans - Indoor Ventilation		kWh	kW	Annual	BEPU, PS-F	
19		Fans - Kitchen Ventilation	Fans - Interior Ventilation					
20		Fans - Parking Garage	Fans - Interior Ventilation					
21		Pumps		kWh	kW	Annual	BEPU, PS-F	
22		Space Cooling		kWh	kW	Annual	BEPU, PS-F	
23		Cooling (Nat Gas)	Space Cooling					If a natural gas fired chiller is selected, then it'll be automatically reported under Space Cooling with the appropriate fuel source.
24		Dehumidification						
25		Heat Rejection		kWh	kW	Annual	BEPU, PS-F	
26		Heat Pump Supplementary		kWh	kW	Annual	BEPU, PS-F	
27		Space Heating		Therm	Therm/hr	Annual	BEPU, PS-F	
28		Space Heating (Electricity)	Space Heating					If electric heating or any electric auxiliary energy (eg. blower for boiler makeup air, etc.), then it'll be reported under Space Heating with the appropriate fuel source.
29		Humidification	Space Heating					if humidification is added, the energy is reported by fuel into the heating end-use category
30		Heat Recovery		MMBtu	kBtu/hr	Annual	ERV	Energy impacts of heat recovery are also aggregated into appropriate end-use categories
31		Auxiliary (Nat Gas)	Misc Equipment					
32		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types	
33		Other - Electricity					Software is flexible to add loads and flexible on fuel types	
34		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types	
35		Other - Electricity					Software is flexible to add loads and flexible on fuel types	
36		Motors	Misc Equipment					
37		Renewable Energy		Therm	Therm/hr	Annual	PS-C	Limited to photovoltaic arrays
38		Battery						
39		Exported Energy					PS-C	A separate meter is required to separately report renewable energy
40		Fossil On-site Generation					PS-C	A separate meter would be required to separately report on-site generated fossil energy
41		Building Transformers						Can be modeled, but are not separately reported. Each end-use is impacted per the applicable electricity use
42	**Quality Assurance**	Unmet Heating Hours		hr		Annual	BEPU	
43		Unmet Cooling Hours		hr		Annual	BEPU	
44		Error Messages				Annual	ATTN	
45		Warning Messages				Annual	ATTN	
46		System Load		kWh	kW	Annual	PS-E	
47		Peak Electric Load		kWh	kW	Annual	PS-E	
48		Peak Energy Month		kWh	kW	Annual	PS-E	User will need to manually identify the specific month with the highest electrical load from the report

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories

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Green highlighted top priority end-uses

Task 2: Reporting Matrix			Task 3: Energy Modeling Software Default Outputs IES-VE					
Item #	**Category**	**Reporting Requirement**	**Aggregation**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Reference**	**Notes**
1	**Energy End-Use**	Interior Lighting		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
2		Interior Lighting - Process		MWh		Annual	California Title 24 Report: Energy Use Summary,	
3		Exterior Lighting						
4		Lighting in Apartments	Interior Lighting					
5		Receptacle Equipment		MWh		Annual	California Title 24 Report: Energy Use Summary,	
6		Office Equipment		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
7		Misc Equipment		kBtu/yr	kBtu/h	Annual		Labeled as "Other Regulated Loads" or "Other Unregulated Loads"
8		Misc Equipment (Nat Gas)						
9		Elevators and Escalators		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
10		Refrigeration Equipment		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
11		Refrigeration Equipment - Unregulated	Other - Electricity					Separate section for unregulated energy, but Ref not called out
12		IT Equipment	Misc Equipment					
13		Service Water Heating		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
14		Service Water Heating - Electricity		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
15		Cooking		kBtu/ft2-yr		Annual	California Utility Incentives Report for Savings By Design	
16		Industrial Process	Misc Equipment					
17		Mechanical Ventilation	Fans					
18		Fans - Indoor Ventilation		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
19		Fans - Kitchen Ventilation	Fans					
20		Fans - Parking Garage	Fans					
21		Pumps		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
22		Space Cooling		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
23		Cooling (Nat Gas)		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
24		Dehumidification						
25		Heat Rejection		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
26		Heat Pump Supplementary						
27		Space Heating		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
28		Space Heating (Electricity)		kBtu/yr	kBtu/h	Annual	Energy and Cost Summary by Fuel Type	
29		Humidification						
30		Heat Recovery						
31		Auxiliary (Nat Gas)						
32		Other - Nat Gas		kBtu/yr		Annual	Energy and Cost Summary by Fuel Type	Available for both regulated and unregulated energy
33		Other - Electricity		kBtu/yr		Annual	Energy and Cost Summary by Fuel Type	Available for both regulated and unregulated energy
34		Other - Nat Gas						
35		Other - Electricity						
36		Motors		MWh			California Title 24 Report: Energy Use Summary,	
37		Renewable Energy		MWh			California Title 24 Report: Energy Use Summary,	
38		Battery		MWh			California Title 24 Report: Energy Use Summary,	
39		Exported Energy						
40		Fossil On-site Generation						
41		Building Transformers						
42	**Quality Assurance**	Unmet Heating Hours				Hours	Advisory Messages	
43		Unmet Cooling Hours				Hours	Advisory Messages	
44		Error Messages				Quantity	Advisory Messages	
45		Warning Messages				Quantity	Advisory Messages	
46		System Load			Btu/h	Annual	HVAC Reports	Reports for primary thermals and air-side HVAC available
47		Peak Electric Load			kW	Annual	Energy Model Output Report	
48		Peak Energy Month		MMBtu		Month	Automated ASHRAE 90.1 Spreadsheet Reports for Energy, Cost & PCI	User will need to manually identify the specific month with the highest electrical load from the report

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories

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Green highlighted top priority end-uses

Task 2: Reporting Matrix			Task 3: Energy Modeling Software Default Outputs Trane TRACE 700					
Item #	**Category**	**Reporting Requirement**	**Aggregation**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Reference**	**Notes**
1	**Energy End-Use**	Interior Lighting		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary	
2		Interior Lighting - Process	Interior Lighting					
3		Exterior Lighting		kWh	kW	Annual	Equipment Energy Consumption	Modeler must create this as a base utility
4		Lighting in Apartments	Interior Lighting					
5		Receptacle Equipment		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary	
6		Office Equipment	Receptacles					
7		Misc Equipment	Receptacles					
8		Misc Equipment (Nat Gas)	Receptacles					If energy meter is set to nat gas, it will be separately reported as nat gas
9		Elevators and Escalators	Receptacles					
10		Refrigeration Equipment	Receptacles					
11		Refrigeration Equipment - Unregulated	Receptacles					
12		IT Equipment	Receptacles					Can be modeled separately if data center check box is marked
13		Service Water Heating		Therms	Therms/hr	Annual	Equipment Energy Consumption	Modeler must create this as a base utility
14		Service Water Heating - Electricity		kWh	kW	Annual	Equipment Energy Consumption	Modeler must create this as a base utility
15		Cooking	Receptacles					
16		Industrial Process	Receptacles					
17		Mechanical Ventilation	Supply Fans					
18		Fans - Indoor Ventilation		MMBtu	kBtu/hr		Energy Cost Budget/PRM Summary	Labeled as "Fans-Conditioned"
19		Fans - Kitchen Ventilation	Supply Fans					
20		Fans - Parking Garage	Supply Fans					
21		Pumps		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary	
22		Space Cooling		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary	
23		Cooling (Nat Gas)	Cooling					If a natural gas fired chiller is selected, then it'll be automatically reported under Sp
24		Dehumidification						
25		Heat Rejection		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary	
26		Heat Pump Supplementary		kWh	kW	Annual	Equipment Energy Consumption	
27		Space Heating		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary	
28		Space Heating (Electricity)		MMBtu	kBtu/hr	Annual	Energy Cost Budget/PRM Summary	Would include draft fans and other controls for boilers
29		Humidification	Heating					
30		Heat Recovery		kWh	kW	Annual	Equipment Energy Consumption	
31		Auxiliary (Nat Gas)	Receptacles					
32		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types	
33		Other - Electricity					Software is flexible to add loads and flexible on fuel types	
34		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types	
35		Other - Electricity					Software is flexible to add loads and flexible on fuel types	
36		Motors	Receptacles					
37		Renewable Energy		kWh	kW	Annual	Equipment Energy Consumption	Modeler must create this as a base utility
38		Battery						
39		Exported Energy		kWh	kW	Annual	Equipment Energy Consumption	Net metering is only available. If energy produced by base utility is larger than con
40		Fossil On-site Generation		Therms	Therms/hr	Annual	Equipment Energy Consumption	Labeled as "Cogeneration"
41		Building Transformers		kWh	kW	Annual	Equipment Energy Consumption	Modeler must create this as a base utility
42	**Quality Assurance**	Unmet Heating Hours					Energy Cost Budget/PRM Summary	
43		Unmet Cooling Hours					Energy Cost Budget/PRM Summary	
44		Error Messages					Scan for Errors	This is generated in a separate text file
45		Warning Messages					Scan for Errors	This is generated in a separate text file
46		System Load		kW		Annual	Electrical Peak Checksums, Equipment Energy Consumption	
47		Peak Electric Load		kW		Annual	Electrical Peak Checksums	
48		Peak Energy Month		kWh		Annual	Monthly Energy Consumption	Requires manual calculation to determine specific month

Task 3: BEM Default Outputs vs. Task 2 Reporting Categories
Revision: Final version 30 November 2023

Green highlighted top priority end-uses

Task 2: Reporting Matrix			Task 3: Energy Modeling Software Default Outputs EnergyPlus v23.2					
Item #	**Category**	**Reporting Requirement**	**Aggregation**	**Default Energy Unit**	**Default Power Unit**	**Time Step**	**Reference**	**Notes**
1	**Energy End-Use**	Interior Lighting		GJ	W	Annual	*: End Uses, **: End Uses	
2		Interior Lighting - Process	Interior Lighting					
3		Exterior Lighting		GJ	W	Annual	*: End Uses, **: End Uses	
4		Lighting in Apartments	Interior Lighting					
5		Receptacle Equipment	Misc Equipment					
6		Office Equipment	Misc Equipment					
7		Misc Equipment		GJ	W	Annual	*: End Uses, **: End Uses	Labeled as "Interior Equipment". Also breaks out "Exterior Equipment"
8		Misc Equipment (Nat Gas)	Misc Equipment	GJ	W	Annual	*: End Uses, **: End Uses	
9		Elevators and Escalators	Misc Equipment					
10		Refrigeration Equipment		GJ	W	Annual	*: End Uses, **: End Uses	Not broken out by "Regulated" or "Unregulated"
11		Refrigeration Equipment - Unregulated	Refrigeration Equipment					
12		IT Equipment	Misc Equipment					
13		Service Water Heating	Heating	GJ	W			If a stand-alone heating system is used, then the energy will be reported as "Water Systems" and can contain non-potable water treatment and pumping. If served by a shared heating system with space heating, it will be aggregated under "Heating".
14		Service Water Heating - Electricity	Heating					
15		Cooking	Misc Equipment					
16		Industrial Process	Misc Equipment					
17		Mechanical Ventilation	Fans					
18		Fans - Indoor Ventilation		GJ	W	Annual	*: End Uses, **: End Uses	Labeled as "Fans".
19		Fans - Kitchen Ventilation	Fans					
20		Fans - Parking Garage	Fans					
21		Pumps		GJ	W	Annual	*: End Uses, **: End Uses	
22		Space Cooling		GJ	W	Annual	*: End Uses, **: End Uses	Labeled as "Cooling".
23		Cooling (Nat Gas)	Cooling					
24		Dehumidification						
25		Heat Rejection		GJ	W	Annual	*: End Uses, **: End Uses	
26		Heat Pump Supplementary	Heating					
27		Space Heating		GJ	W	Annual	*: End Uses, **: End Uses	Labeled as "Heating".
28		Space Heating (Electricity)	Heating					
29		Humidification		GJ	W	Annual	*: End Uses, **: End Uses	
30		Heat Recovery		GJ	W	Annual	*: End Uses, **: End Uses	
31		Auxiliary (Nat Gas)	Misc Equipment					
32		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types	
33		Other - Electricity					Software is flexible to add loads and flexible on fuel types	
34		Other - Nat Gas					Software is flexible to add loads and flexible on fuel types	
35		Other - Electricity					Software is flexible to add loads and flexible on fuel types	
36		Motors	Misc Equipment					
37		Renewable Energy		GJ	W	Annual	*: End Uses, **: End Uses	Labeled as "Generators"
38		Battery						
39		Exported Energy		GJ		Annual	*: Electric Loads Satisified	
40		Fossil On-site Generation		GJ	W	Annual	*:Electric Loads Satisfied, **: End Uses	Labeled as "Generators"
41		Building Transformers						
42	**Quality Assurance**	Unmet Heating Hours				Hours	*: Comfort and Setpoint Not Met Summary	
43		Unmet Cooling Hours				Hours	*: Comfort and Setpoint Not Met Summary	
44		Error Messages					This data is located in a separate .err file.	This might not be submitted to the reviewer or be obvious to the user.
45		Warning Messages					This data is located in a separate .err file.	This might not be submitted to the reviewer or be obvious to the user.
46		System Load						
47		Peak Electric Load						This data is not in the default reports. The users must activate the reports
48		Peak Energy Month						This data is not in the default reports. The users must activate the reports

*Annual Building Utility Performance Summary
**Demand End Use Components Summary

Appendix C: Task 4 Project STASIO

Appendix C contains the other selected STASIO graphics and the relevant data per the identified criteria. For reference, each graphic was reviewed using the following criteria:

- Does the graphic support a Task 2 protocol?
- Are there outputs from an energy modeling engine tested in Task 3?
- Are there inputs typically found in BEM software?
- Is the data post processed?
- What is the time step of the data?
- Are multiple energy model runs required?

This graphic contains glazing parameters and energy usage intensity for multiple model runs.

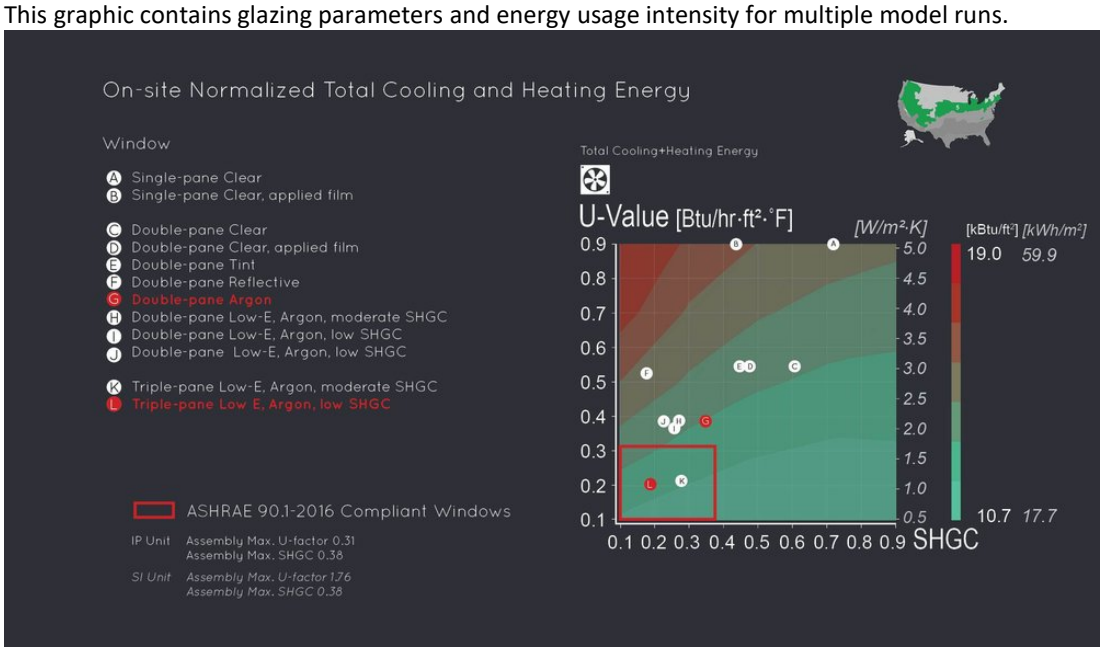


Figure C.1: Glazing Parameters versus Energy Usage Intensity (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2/)

- Does the graphic support a Task 2 protocol?
  - This graphic indirectly supports protocols as it identifies compliant windows, in this case ASHRAE 90.1-2016 within the red box on the lower left.
- Are there outputs from an energy modeling engine tested in Task 3?
  - Yes, the energy output is output in all model engines, and all the modeling tools include the post processing to generate an EUI value.
- Are there inputs typically found in BEM software?
  - Yes, glazing u-value and SHGC are available as inputs in each modeling engine.
- Is the data post processed?
  - The post-processing comes from stitching together various model runs.
- What is the time step of the data?
  - The time step for the energy data is annual.
- Are multiple energy model runs required?
  - The graphic contains 12 model runs, but would not require that for compliance and could show just a Baseline and Proposed model runs.

Given the move towards decarbonization, and the impact building envelopes can have this graphic could be standardized. The output could be CO2e rather than EUI among many other key

performance indicators. Additional envelope values such as opaque construction u-values would also be relevant.

This graphic shows hourly grid emissions, and three hourly model runs for the base building, the base with a PV system, and a the base with the PV system and batteries.

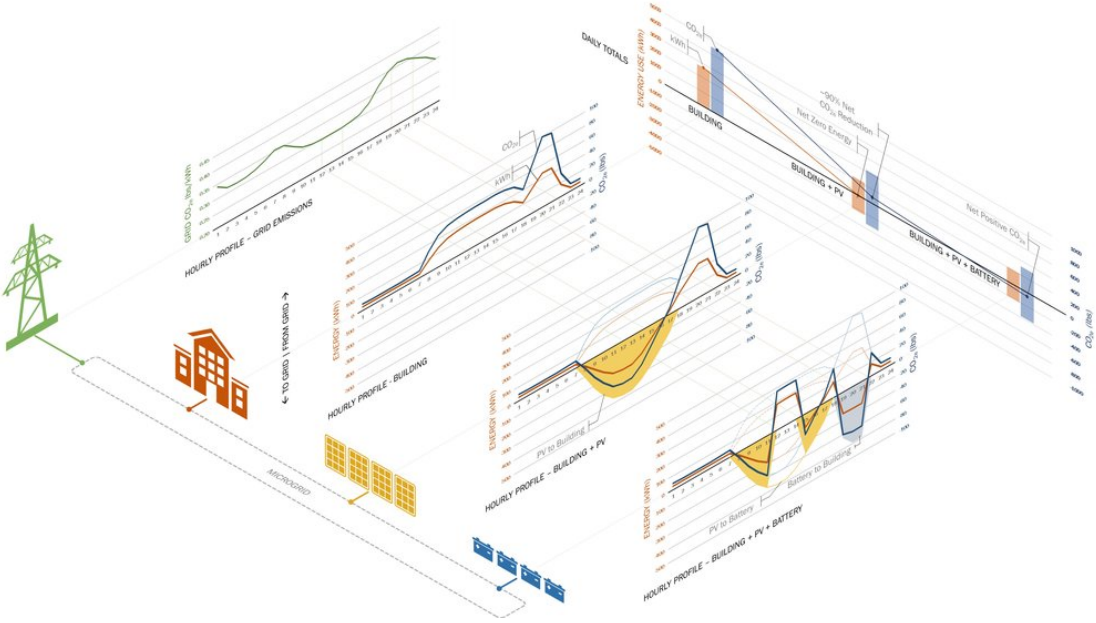


Figure C.2: Hourly Grid Emissions versus Hourly Energy Results (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-l4j2e-86kr3/)

- Does the graphic support a Task 2 protocol?
  - Some protocols are do require outputs related to renewable energy, batteries, and CO2e emissions.
- Are there outputs from an energy modeling engine tested in Task 3?
  - Yes, the hourly electrical demand results could be generated by the energy modeling engine. Not all the engines support renewable energy or are limited in the types of renewable energy. The same is true for batteries so exceptional calculations may be required.
- Are there inputs typically found in BEM software?
  - No
- Is the data post processed?
  - The post-processing comes from stitching together the three model runs, and may also include exceptional calculations if the selected modeling tool doesn't support renewables or batteries.
- What is the time step of the data?
  - The time step is hourly, for a single day.
- Are multiple energy model runs required?
  - The graphic contains 3 model runs, but would not require that for compliance and could show just a Baseline and Proposed model runs with the required renewables and storage included in the runs.

This graphic is valuable as it shows the impact on the utility grid and the creation of the "duck curve" caused by a large amount of renewable energy generated during daytime hours. Another value of this graphic for compliance would for buildings to demonstrate they are not just relying on PV and batteries and may use other features to assist the electric grid's management of renewable energy. Standardizing this graphic would be feasible if the adopting jurisdiction developed infrastructure to support the generation of the graphic. It would be a significant effort for modeling engines to be upgraded to generate this graphic internally. Furthermore, the graphic could be recreated as flat

graphic rather than an isometric that is difficult to recreate. Four time series plots and a bar chart could be arranged in a simpler arrangement.

This graphic was selected as a comfort graphic with the metric daylight autonomy. There were several daylight graphics in the STASIO library.

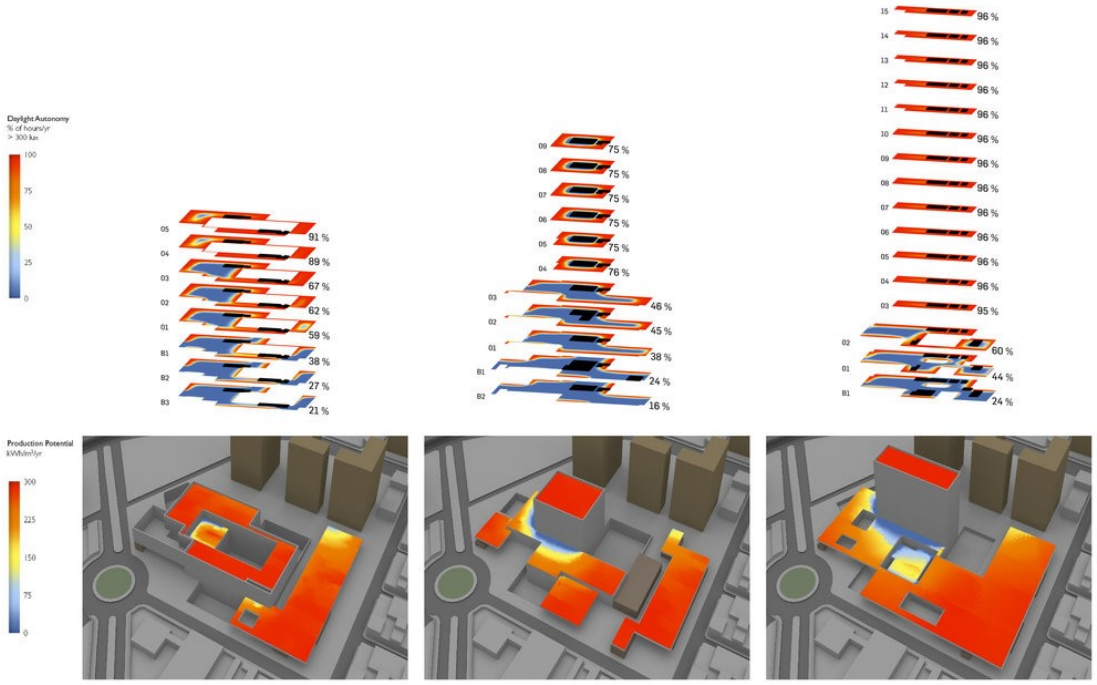


Figure C.3: Daylight Autonomy by Space (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-l4j2e-2pxkr/)

- Does the graphic support a Task 2 protocol?
  - No, none of the protocols have daylight requirements. The LEED protocol has a related credit regarding daylight, however it is separate from the LEED modeling protocol.
- Are there outputs from an energy modeling engine tested in Task 3?
  - No, although the energy modeling software do account for the energy impact of daylight harvesting. Certain versions of IES-VE are coupled with Radiance to develop daylight models.
- Are there inputs typically found in BEM software?
  - Only the space geometry is found in the energy model, however there are numerous surface characteristics such as reflectance required for daylight modeling that are not included in energy models.
- Is the data post processed?
  - Not applicable as model engines are not generating this data.
- What is the time step of the data?
  - Annual time step.
- Are multiple energy model runs required?
  - It's a single model run showing the impacts on multiple floors.

Daylight autonomy is part of comfort, but not calculated as part of energy models or required in BPM protocols. Including daylight autonomy or any other daylight metric as part of a protocol would be a significant effort. It would also be a significant effort to incorporate daylight modeling into energy model engines that don't currently support daylight modeling. Therefore, standardization of daylight graphics is not recommended for any protocol or modeling engine at this time.

This graphic informs project design by comparing the percentage of operable glazed area versus occupant comfort.

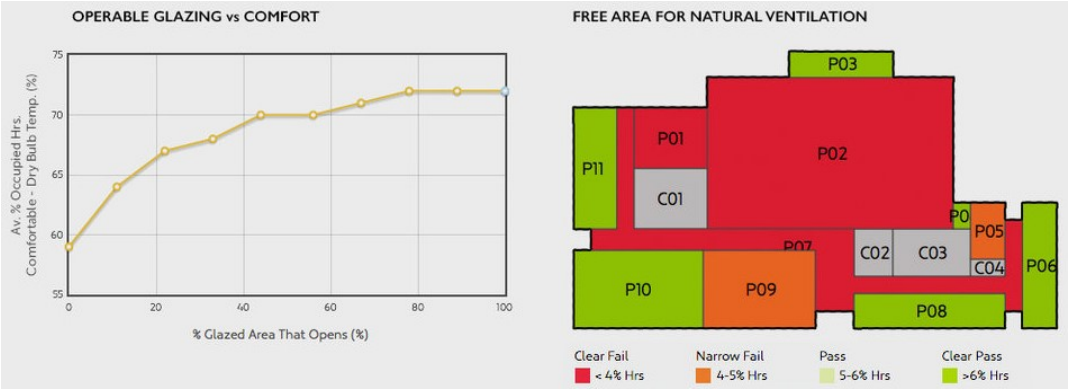


Figure C.4: Occupant Comfort vs. Percentage of Operable Glazed Area (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-l4j2e-6fwhe-9rgst/)

- Does the graphic support a Task 2 protocol?
  - No, none of the protocols have natural ventilation requirements and only indirectly address comfort via unmet load hours.
- Are there outputs from an energy modeling engine tested in Task 3?
  - Yes, some of the energy modeling engines can model natural ventilation systems and can track the correlation of open glazed area versus occupant temperature.
- Are there inputs typically found in BEM software?
  - There are no inputs in this graphic from the energy model, but both the graphic and the model do reference the floor plans.
- Is the data post processed?
  - There is post processing as there are multiple energy model runs required to create the data. Also, developing the floor plan heat map needs to be created manually.
- What is the time step of the data?
  - Annual time step.
- Are multiple energy model runs required?
  - Multiple models are used in this graphic to inform design. A Baseline vs. Proposed approach could be taken for compliance, however no protocol currently requires natural ventilation.

This graphic is useful for model users to identify the efficacy of natural ventilation to inform design, but has no applications in today's modeling protocols. Standardization of this graphic is not recommended until protocols adopt natural ventilation requirements.

This graphic overlays a comfort metric, percentage of hours outside comfort range, onto a floor plan.

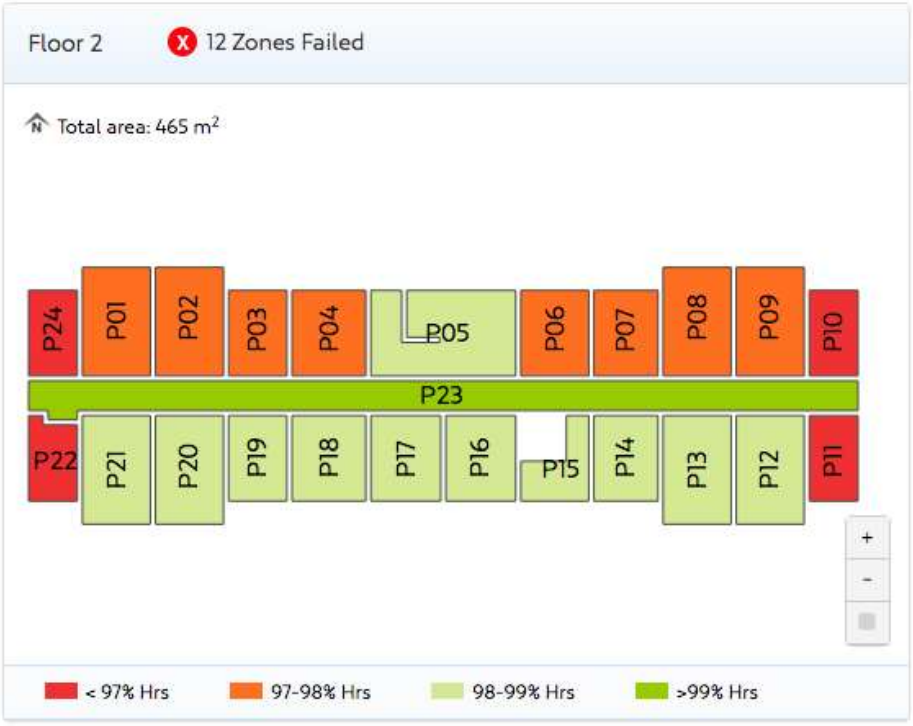


Figure C.5: Percentage of Hours Outside Occupant Comfort Range Per Zone (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-24mhr/)

- Does the graphic support a Task 2 protocol?
  - No, none of the protocols have comfort metrics and only indirectly address comfort via unmet load hours.
- Are there outputs from an energy modeling engine tested in Task 3?
  - Yes, all of the energy models can output values such as temperature and humidity to determine thermal comfort.
- Are there inputs typically found in BEM software?
  - There are no inputs in this graphic from the energy model, but both the graphic and the model do reference the floor plans.
- Is the data post processed?
  - There is post processing to develop the floor plan heat map to be created manually.
- What is the time step of the data?
  - Annual time step.
- Are multiple energy model runs required?
  - No

This graphic is useful for modelers to identify where unmet hours are located and would be useful for any project that needs to also comply with thermal comfort requirements such as ASHRAE 55. Standardization of this graphic is not recommended until protocols adopt thermal comfort requirements beyond unmet load hours.

This graphic contains numerous variables including window to wall ratio, moveable window shade status, occupant comfort using the PMV metric from ASHRAE 55, solar radiation, and ambient temperature.

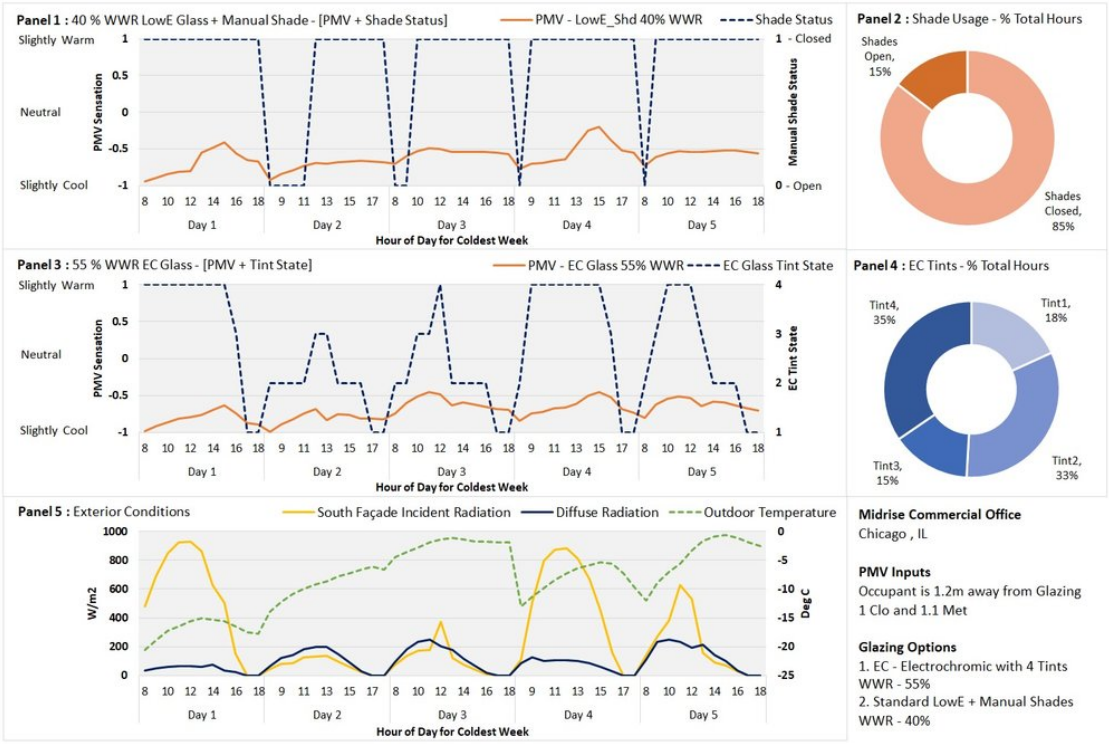


Figure C.6: Hourly Solar Shading Graphic, Envelope Parameters and Thermal Comfort Impacts (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-enm8z-bgzew/)

- Does the graphic support a Task 2 protocol?
  - No, none of the protocols have comfort metrics and only indirectly address comfort via unmet load hours.
- Are there outputs from an energy modeling engine tested in Task 3?
  - Yes, all of the energy models can output values such as temperature and humidity to determine thermal comfort. The percentage of hours where the shades or drawn or the dynamic glazing is tinted can be output from the energy model schedules manually.
- Are there inputs typically found in BEM software?
  - There are several inputs in this graphic that are also used in energy models. The weather file will provide radiation and ambient temperature conditions. The window-to-wall ratio is an input as are the shading properties. Dynamic glazing is used in this graphic as well that can be modeled in modeling engines with the correct inputs and schedules.
- Is the data post processed?
  - There is post processing to this custom graphic to overlay all the defined inputs and outputs.
- What is the time step of the data?
  - Hourly time step for five days
- Are multiple energy model runs required?
  - Yes, two runs are required for two different glazing and shading solutions. The two model runs could Baseline vs. Proposed if desired.

This graphic would be difficult to standardize as thermal comfort and the impact of shading is not regulated by any protocol. The two model runs be used in protocols however, standardizing the graphic is not recommended at this time.

This graphic shows multiple model runs with parametric comparisons of energy savings measures and the associated carbon impacts.

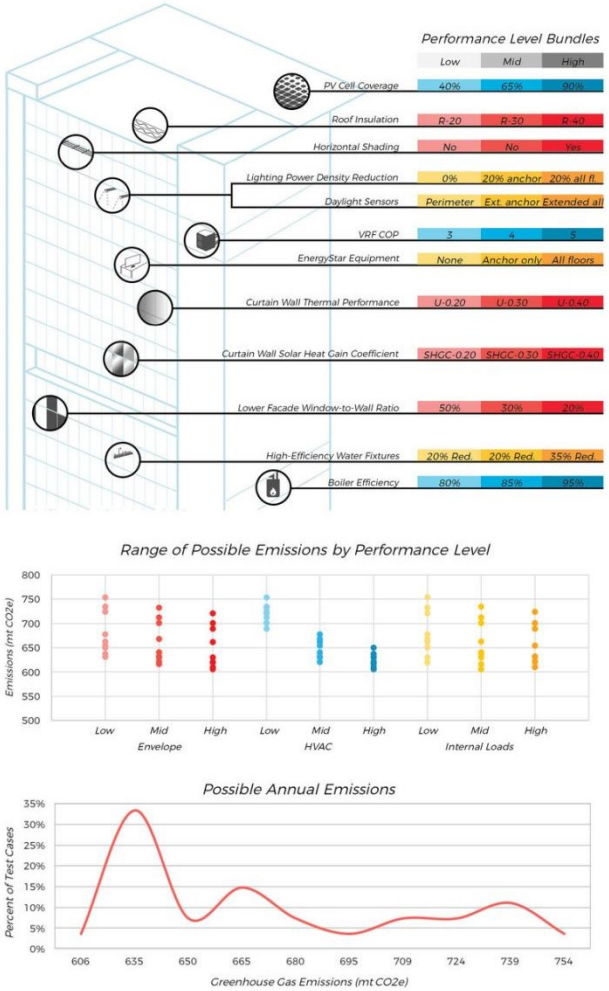
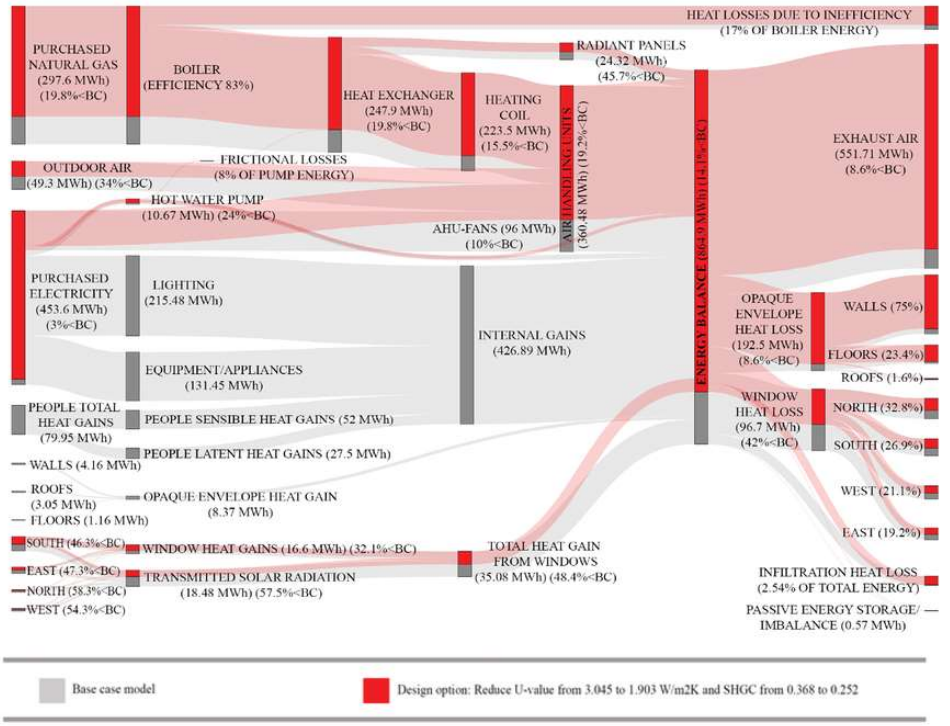


Figure C.6: Carbon Savings Measures and Associated Greenhouse Gas Emissions. (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-enm8z-4m6f6/)

- Does the graphic support a Task 2 protocol?
  - No, the multitude of model runs required to generate the carbon emissions estimates goes well beyond anything required by a protocol defined in Task 2.
- Are there outputs from an energy modeling engine tested in Task 3?
  - Yes, all of the energy models can output the relevant energy values that can be post processed into carbon emissions.
- Are there inputs typically found in BEM software?
  - There are several model inputs in the graphic that show which performance inputs are used such as insulation and COPs values.
- Is the data post processed?
  - There is post processing to develop the input chart and the CO2e emissions chart. It is possible to simplify this graphic and not require a custom aesthetic.
- What is the time step of the data?
  - Annual time step.
- Are multiple energy model runs required?
  - Yes

This graphic would be difficult to standardize for so many model runs that will exceed the requirements of most protocols for model scenarios with the exception of ASHRAE Standard 209 that requires multiple model runs. A standardized protocol version of the this graphic would only include Baseline versus Proposed, and in that scenario a simpler CO2e graphic would achieve the same results.

The final graphic is a two part graphic that documents energy flows from loads through systems and utility demands.



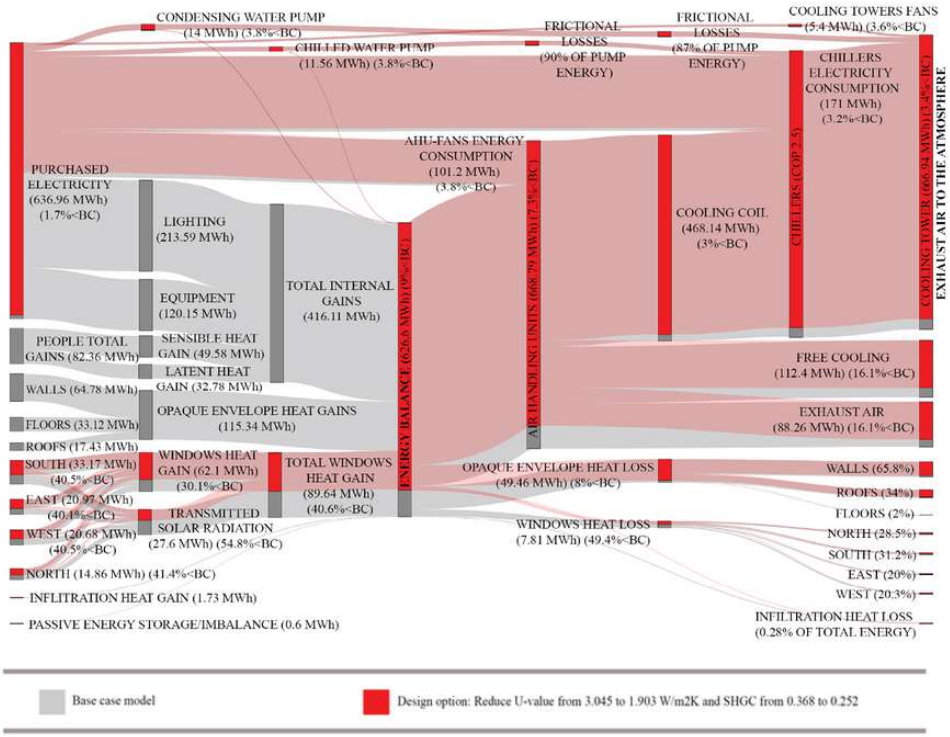


Figure C.7: Energy Loads and Equipment Sankey Diagram (https://projectstasio.com/2017-10-31-solar-roses-57ejy-5jsw2-enm8z-h87ej/)

- Does the graphic support a Task 2 protocol?
  - While this graphic reports many of the same end-uses required by protocols the arrangement of the graphic would be difficult to use for compliance purposes as compared to more typical charts.

    - The graphic also contains a lot of information that is not needed for compliance with most protocols further complicating reading the graphic.
- Are there outputs from an energy modeling engine tested in Task 3?
    - Yes, there are several outputs that would come from modeling engines. However, many of the standard reports would not have the relevant data on an individual software basis.
- Are there inputs typically found in BEM software?
    - There system types from the model would need to be known for the creation of the graphic to accurately define energy flows.
- Is the data post processed?
    - There is post processing to develop the Sankey diagram. It is likely based on a collection of many reports and some aggregated hourly reports from the modeling engine.
- What is the time step of the data?
    - Annual time step.
- Are multiple energy model runs required?
    - There is a Baseline and Proposed model run.

The graphic is useful for design team attempting to diagnose how energy flows through a building and what creates loads on pieces of equipment. Standardizing the graphic for compliance purposes is not recommended as there are simpler graphics that achieve the same goal for energy compliance such as a bar chart.

Appendix D: IES-VE Letter

IBPSA USA BEM Output Reporting Research Project – IESVE Software

21 December 2023

IES Ltd. Position Statement:

Thank you for the opportunity to contribute to IBPSA-USA's Project: "***Review of BPM Protocols and BEM Reporting Output***". We have provided a set of standard IESVE-generated reports, which are hosted on a shared drive, compiled by IBPSA-USA's Building Data Exchange Committee. We wish to offer our feedback for this initiative, since there is a desire to establish an IBPSA-USA consensus and include various stakeholders.

In general, we ***disagree*** with any industry desire to standardize a ***design-based*** BEM protocol or schema, due to the customization that is often required for representing an actual design for a real building or site. The exception to this would be to report very simple BEM results, e.g. for AIA 2030 reporting (Design Data Exchange DDx). Also, the underlying data model of varying BEM engines is uniquely different, with no desire to align these data models. Standardization of BPM protocols/reports will likely stifle innovation from individual BEM software vendors.

IESVE Software includes a range of Standard Reports and Output Variables:

1. Standard IESVE Reports: https://send.iesve.com/index.php/s/3Zcg7Gt92LcWN9k
2. Hundreds of variables are available in VistaPro: https://help.iesve.com/ve2023/vistapro_variables.htm
3. Battery Storage Variables: https://help.iesve.com/ve2023/battery_app_output.htm
4. Water-Energy Nexus Variables: https://help.iesve.com/ve2023/output.htm
5. Energy Costs: https://www.iesve.com/discoveries/view/38846/energy-cost-analysis-in-iesve-using-the-tariff-tool
6. Results by Energy Meters can change dependent upon the energy-code that is being modeled. Outputs (annual/monthly/daily/hourly/sub-hourly) are available by any meter or submeter, by fuel & metric.
7. Python-API for IESVE/APACHE:
    A. Customization of APACHE outputs: https://www.iesve.com/software/python-scripting
    B. API documentation: https://help.iesve.com/ve2023/6_ve_python_api.htm
    C. Libraries include Plotly, Psychrochart, Statsmodels, Openpyxl, Pygmo
    D. Example BEM customization: https://www.bemtoolbox.com/

In general, we ***agree*** with any industry desire to standardize a ***compliance-based*** BEM protocol or schema, due to the known requirements to represent Code-Compliance for a 'proposed' building. IESVE Software already maps to the California Energy Commission's PRF-01 Report Generator schema for Title 24 code compliance in California. Having successfully completed this mapping exercise for multiple code cycles, we can unequivocally state that this process works. We would encourage IBPSA-USA to pursue a similar schema-based (e.g. Python, .JSON) initiative for Standards, Rating Systems and Incentive Programs using modeled energy/costs/carbon results:

- ASHRAE Standard 90.1 PRM (2010, 2013, 2016, 2019, 2022)
- ASHRAE Standard 90.1 ECB (2010, 2013, 2016, 2019, 2022)
- LEED Optimize Energy Performance Credit (v4, v4.1, v5)
- Other AHJ/Utility-specific requirements (e.g. including imports with marginal hourly carbon emission factors)

The schema should *not* post-process hourly energy demand data to other metrics. The intent of the protocol would be that all ***actively maintained*** software tools may choose to map their software tools to the suggested schema. We do not recommend extending the schema to BEM tools that are no longer maintained, nor apply project STASIO to any part of this initiative, since there is little-to-no value related from project STASIO to any given code-compliance schema, rating system schema or incentive program schema.