



**KARPMAN**  
CONSULTING

# Performance Based Compliance Documentation for ASHRAE Standard 90.1 Section 11 and Appendix G

Christina LaPerle PE, BEMP, CEM, CBCP  
Maria Karpman BEMP, LEED AP, CEM

[www.karpmanconsulting.net](http://www.karpmanconsulting.net)

# Learning Objectives

- Understand the reporting requirements of ASHRAE Standard 90.1 Section 11 and Appendix G
- Understand the documentation that must be submitted to code officials for performance-based projects.
- Understand how to fill out the Compliance Form

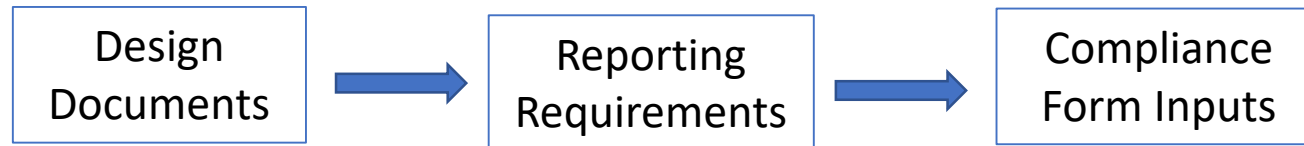
# Agenda

1. ASHRAE 90.1 Reporting Requirements (10 Minutes)
2. General Compliance Form Features and Tab Layout (5 Minutes)
3. Compliance Form Demonstrations
  - a. Basic Information and Informative Tabs (10 Minutes)
    - i. Instructions
    - ii. Dashboard
    - iii. Contact Information
    - iv. General Information
    - v. Energy Sources
  - b. Selected Component Tabs (60 Minutes)
    - i. Lighting
    - ii. Envelope
    - iii. Air-Side HVAC
  - c. Selected Simulation Results Tabs (10 Minutes)
    - i. Simulation Outputs
    - ii. Compliance Calculations
    - iii. Submittal Checklist
4. Questions (20 Minutes)

# Training Format

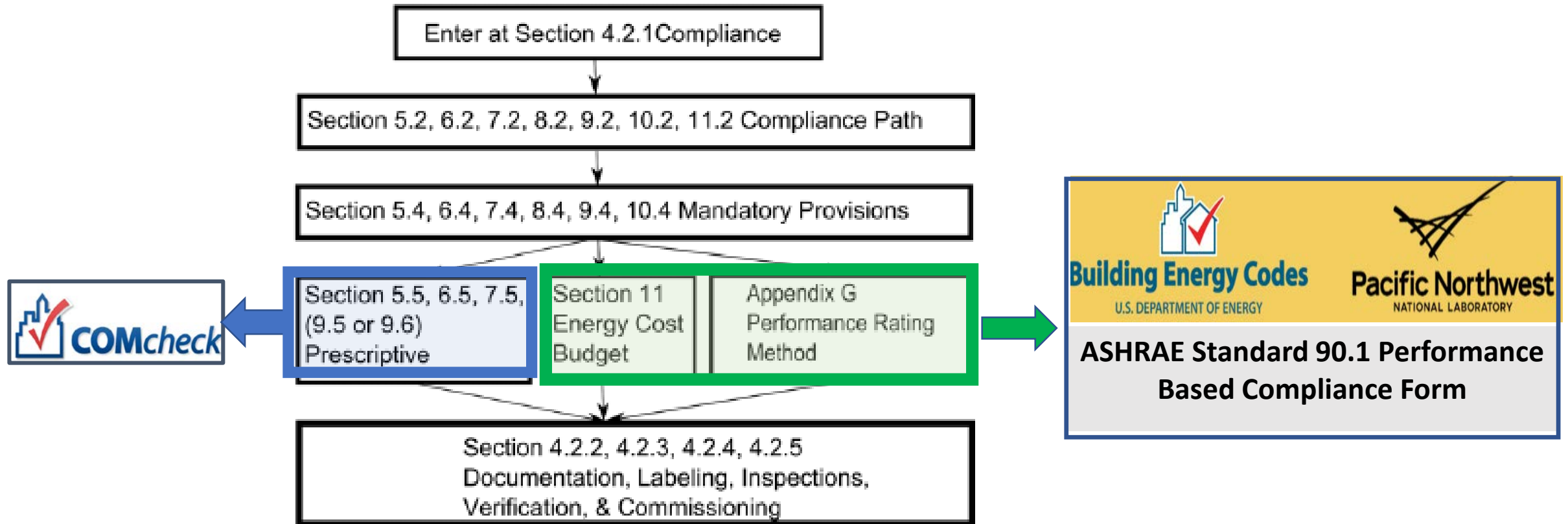
There are two interwoven parts of the training:

- Power Point Presentation
- Compliance Form Demonstration



- The focus of the training is on 90.1 Appendix G, however similar principles and logic applies to Section 11.

# ASHRAE Standard 90.1 Compliance Documentation



# DOE/PNNL Compliance Form Overview

1. Supports ASHRAE 90.1 2016/2019 Section 11 and Appendix G
2. Posted at [DOE Building Energy Codes Program](#) website
3. DOE intends to fund maintenance and development of the customized versions to support modifications adopted by the states (similar to COMCheck) and certain rating authorities
4. Summary of current features
  - MS Excel format
  - helps establish the necessary modeling inputs using built-in code look-ups and calculators
  - allows importing simulation results from BEM tools including DesignBuilder, EnergyPlus, eQUEST, Trane TRACE 3D Plus, Trane TRACE 700, and OpenStudio
  - automates compliance calculations
5. Planned enhancements
  - Integrated QC checks
  - Expanded data import (e.g. from BEM tools or custom modeler tools) and export (e.g. to program administrators' databases)
  - Compliance reports (for printing on drawings) and inspection reports

# 90.1 Documentation Requirements

## Appendix G

### G1.3.2 Application Documentation

Simulated performance shall be documented, and documentation shall be submitted to the *rating authority*. The information shall be submitted in a report and shall include the following:

- a. A brief description of the project, the key *energy efficiency* improvements compared with the requirements in Sections 5 through 10, the *simulation program* used, the version of the *simulation program*, and the results of the *energy analysis*. This summary shall contain the calculated values for the *baseline building performance*, the *proposed building performance*, and the percentage improvement.
- b. An overview of the project that includes the number of stories (above and below *grade*), the typical *floor size*, the uses in the *building* (e.g., office, cafeteria, retail, parking, etc.), the gross area of each use, and whether each use is *conditioned space*.
- c. A list of the *energy*-related features that are included in the design and on which the performance rating is based. This list shall document all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.
- d. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).
- e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of Sections 5.5, 6.5, 7.5, 9.5, and 9.6 (prescriptive provisions).
- f. A table with a summary by end use of the *energy cost savings* in the *proposed building performance*.
- g. A site plan showing all adjacent *buildings* and topography that may shade the *proposed building* (with estimated height or number of stories).
- h. *Building elevations and floor plans* (schematic is acceptable).
- i. A diagram showing the *thermal blocks* used in the computer simulation.
- j. An explanation of any significant modeling assumptions.
- k. Backup calculations and material to support data inputs (e.g., *U-factors* for *building envelope assemblies*, NFRC ratings for *fenestration*, end-uses identified in Table G3.1, "1. Design Model," paragraph [a]).
  1. Input and output reports from the *simulation program* or compliance software, including a breakdown of *energy* use by at least the following components: lights, internal *equipment loads*, *service water-heating equipment*, *space-heating equipment*, *space-cooling* and heat rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of *unmet load hours* for both the *proposed design* and *baseline building design*.
- m. *Purchased energy rates* used in the simulations.
- n. An explanation of any error messages noted in the *simulation program* output.
- o. For any exceptional calculation methods employed, document the predicted *energy savings* by *energy* type, the *energy cost savings*, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.
- p. The reduction in *proposed building performance* associated with *on-site renewable energy*.
- q. The version of the software and the link to the website that contains the ASHRAE Standard 140 results for the version used in accordance with Section G2.2.4.

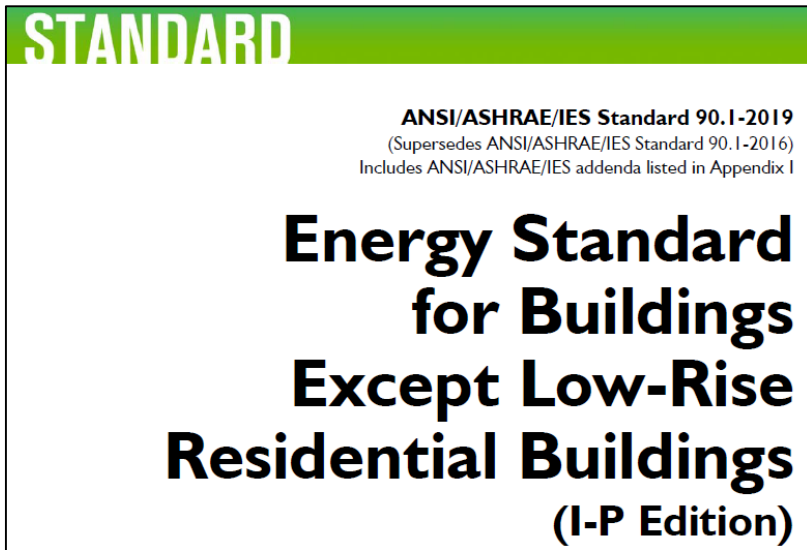
## Section 11

### 11.7.2 Permit Application Documentation

Compliance shall be documented and submitted to the *building official*. The information submitted shall include the following:

- a. The *energy cost budget* for the *budget building design* and the *design energy cost* for the *proposed design*.
- b. The *simulation program* used and the version of the *simulation program*.
- c. An overview of the project that includes the number of stories (above and below *grade*), the typical *floor size*, the uses in the *building* (e.g., office, cafeteria, retail, parking, etc.), the gross area of each use, and whether each use is *conditioned*.
- d. A list of the *energy*-related features that are included in the design and on which compliance with the provisions of Section 11 is based. This list shall document all *energy* features that differ between the models used in the *energy cost budget* and the *design energy cost* calculations.
- e. A list showing compliance for the proposed design with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).
- f. *Building elevations and floor plans*.
- g. A diagram showing the *thermal blocks* used in the computer simulation.
- h. An explanation of any significant modeling assumptions.
- i. Backup calculations and material to support data inputs (e.g., *U-factors* for *building envelope assemblies*, NFRC ratings for *fenestration*, end uses identified in Table 11.5.1, "1. Design Model," paragraph [a]).
- j. The input and output reports from the *simulation program*, including a breakdown of *energy* usage by at least the following components: lights, internal *equipment loads*, *service water-heating equipment*, *space-heating equipment*, *space cooling* and heat-rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of time any loads are not met by the *HVAC system* for both the *proposed design* and *budget building design*.
- k. *Purchased energy rates* used in the simulations.
  1. An explanation of any error messages noted in the *simulation program* output.
- m. For any exceptional calculation methods employed, document the predicted *energy savings* by *energy* type, the *energy cost savings*, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.
- n. The reduction in *design energy cost* associated with *on-site renewable energy*.
- o. The version of the software and the link to the website that contains the ASHRAE Standard 140 results for the version used in accordance with Section 11.4.1.4.

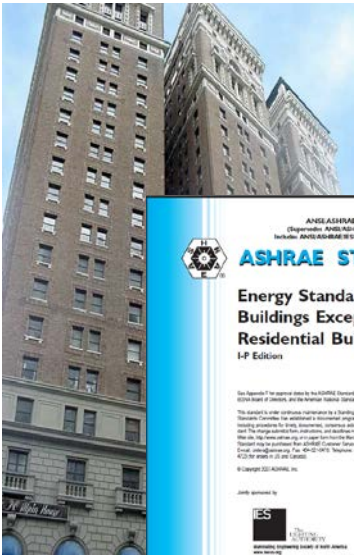
Documentation that must be submitted to code officials or the rating authority is **prescribed in the Standard**



# General Concept of Performance-based Compliance

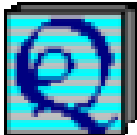


Proposed Design



Baseline/Budget Design

- Developed following the rules of 90.1 Section 11 or Appendix G
  - Same simulation tool, weather file and utility rates



eQUEST



TRACE 3D Plus  
TRACE™ 700



# Key Reporting Requirements of 90.1 Appendix G

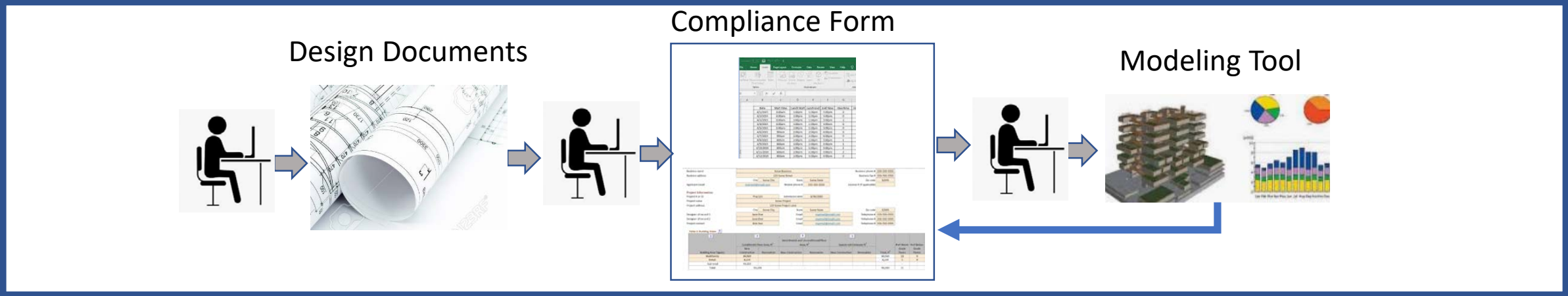
- Features that differ between the baseline and proposed design models
- Aspects of the proposed design that improve over or are less efficient than **90.1 prescriptive requirements**
- A list showing compliance of the proposed design with **90.1 mandatory provisions**
- A summary by end use of the energy cost savings of the proposed design relative to the baseline.
- Input and output reports from the simulation program showing a breakdown of energy by end use and the amount of unmet load hours for the baseline and proposed design
- **Backup calculations** and material to support data inputs

**\*Information not used in the energy simulation**

# Current Documentation Process

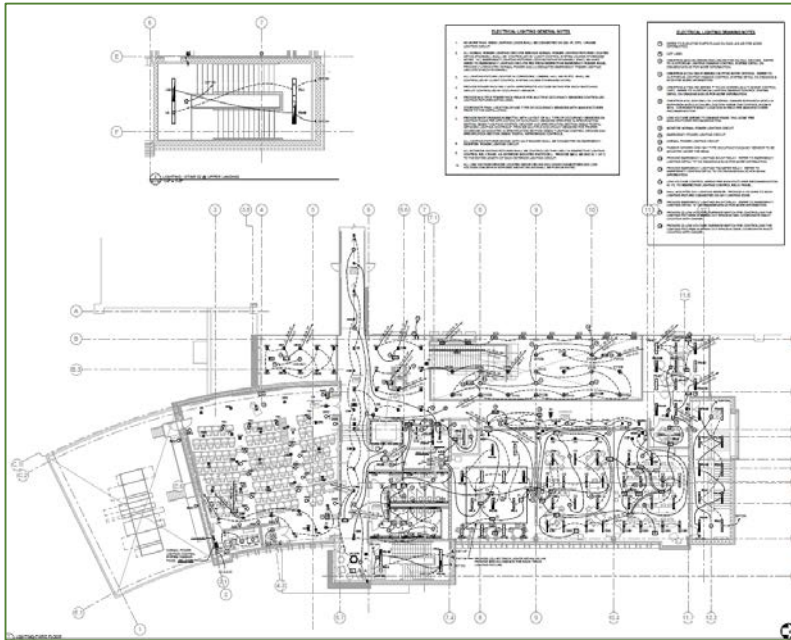


# Streamlined Process using the Compliance Form



# Documentation Process Using Compliance Form

## Design Documents



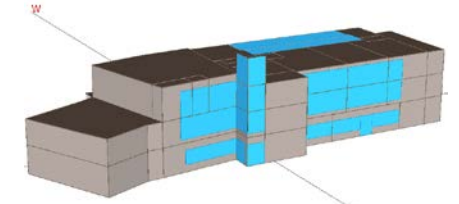
Enter parameters of the proposed design into the Compliance Form

## Compliance Form

- Calculates simulation inputs for proposed design model
- Auto-populates simulation inputs for baseline model
- Auto-populates prescriptive requirements to support reporting

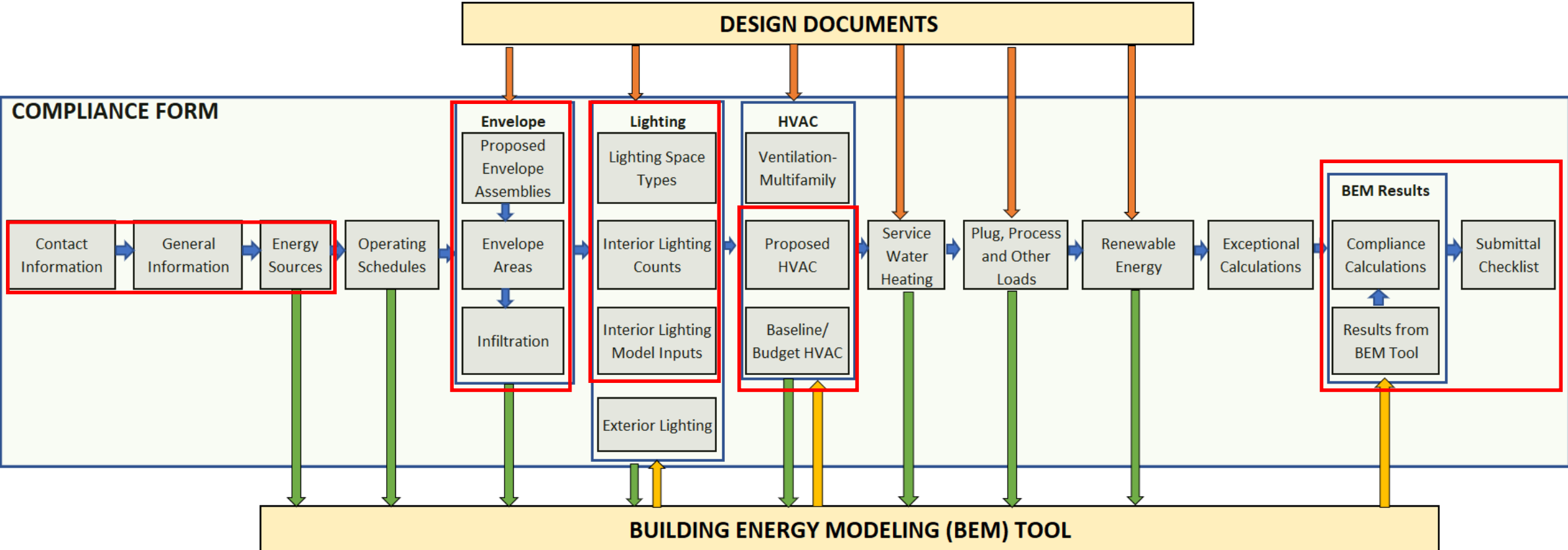


## BEM Tool

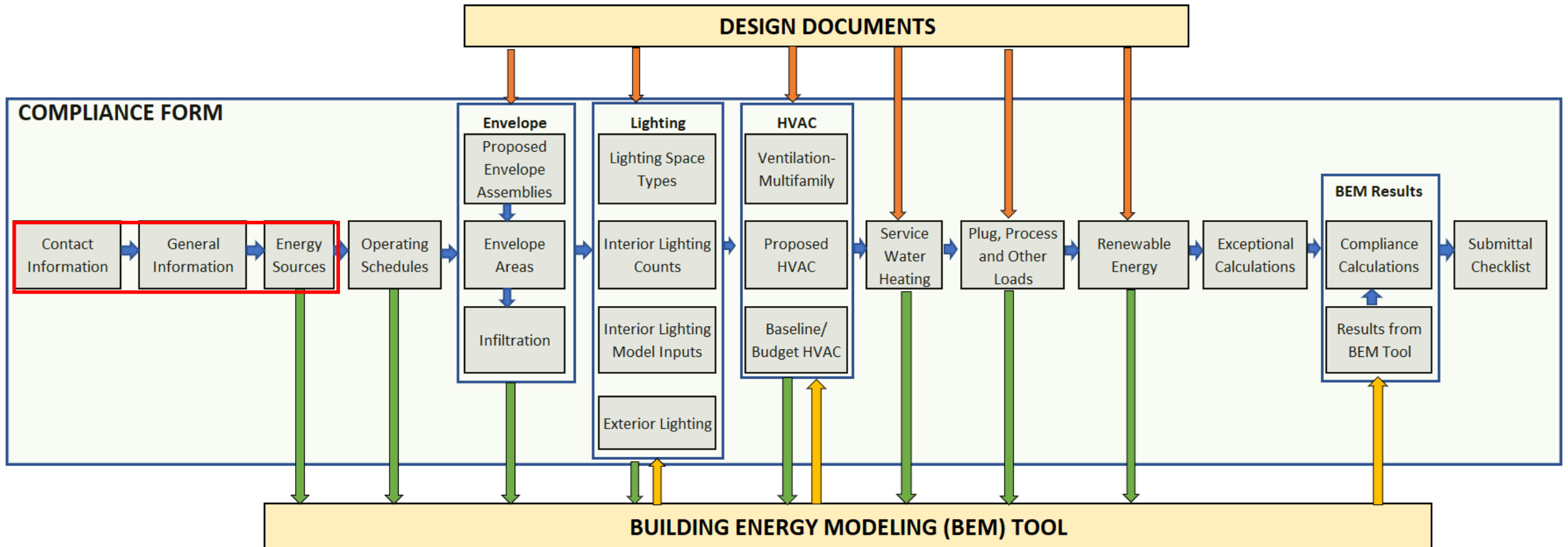


- Transfer model inputs for the proposed design and the baseline into BEM tool
- Import simulation results from BEM tool into the Compliance Form

# Compliance Form Organization



# GENERAL FEATURES AND LAYOUT



# Basic Structure

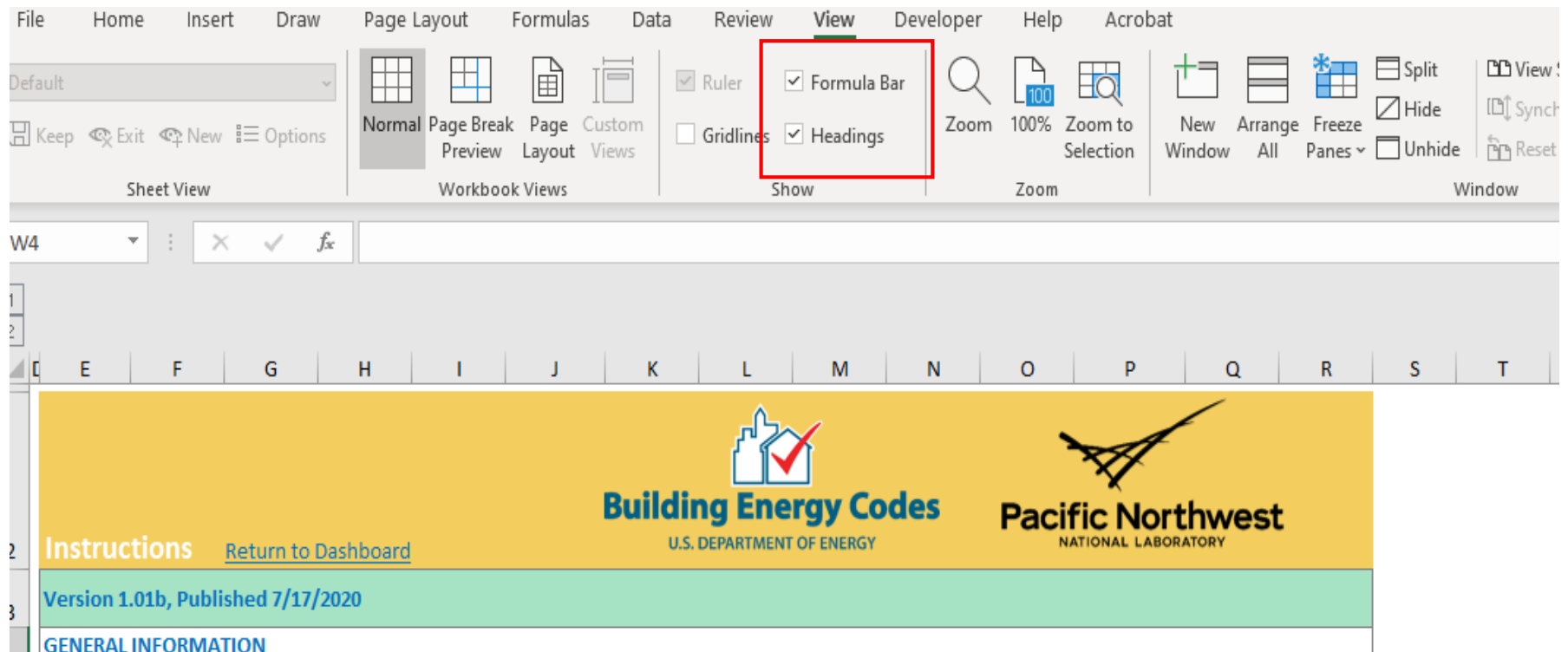
- Informative tabs, design team/modeler input tabs related to the baseline/budget models, tabs with simulation tool outputs and results, and the submittal checklist.

## Tab Color Legend

Informative tabs
Tabs with modeler inputs related to the baseline/budget and proposed models
Tabs with simulation tool outputs and results
Tabs with checklists

# Default Formula Bar and Headings not Shown

- The Compliance Form default setting is to hide the formula bar and the headings. The headings refer to the column (A, B, C, etc.) and row (1, 2, 3, etc.) labels. The screenshot below shows the default configuration.



# Help Text

ate zone

4A

General Information Help - Click on Text to Activate Scroll Bar

b. heated space: an enclosed space within a building that is heated by a heating system whose output capacity relative to the floor area is greater than or equal to the criteria in 90.1 Table 3.2.

c. indirectly conditioned space: an enclosed space within a building that is not a heated space or a cooled space, which is heated or cooled indirectly by being connected to adjacent spaces, provided:

c.1. the product of the U-factors and surface areas of the space adjacent to connected spaces exceeds the combined sum of the product of the U-factors and surface areas of the space adjoining the outdoors, unconditioned spaces, and to or from semiheated spaces (e.g., corridors) or

c.2. that air from heated or cooled spaces is intentionally transferred (naturally or mechanically) into the space at a rate exceeding 3 ach (e.g., atria).

Close

	heated and Uncondit	Area, ft <sup>2</sup>	Construction	Ren
Retail	24,750			



# Default Tab Layout

**General Information** [Return to Dashboard](#) [Adjust Column Widths and Row Heights](#)

**Table of Contents**  
[Energy Model Information](#)  
[Table 1: Building Areas](#)  
[Table 2: Dwelling Units](#)  
[Renovations and Yet to Be Designed Systems and Components](#)

**Notes**  
Please include applicable notes as needed.

This is a 13-story new construction project for a mixed use multifamily building with retail on floors 1-3. The retail and multifamily building areas are fully designed.

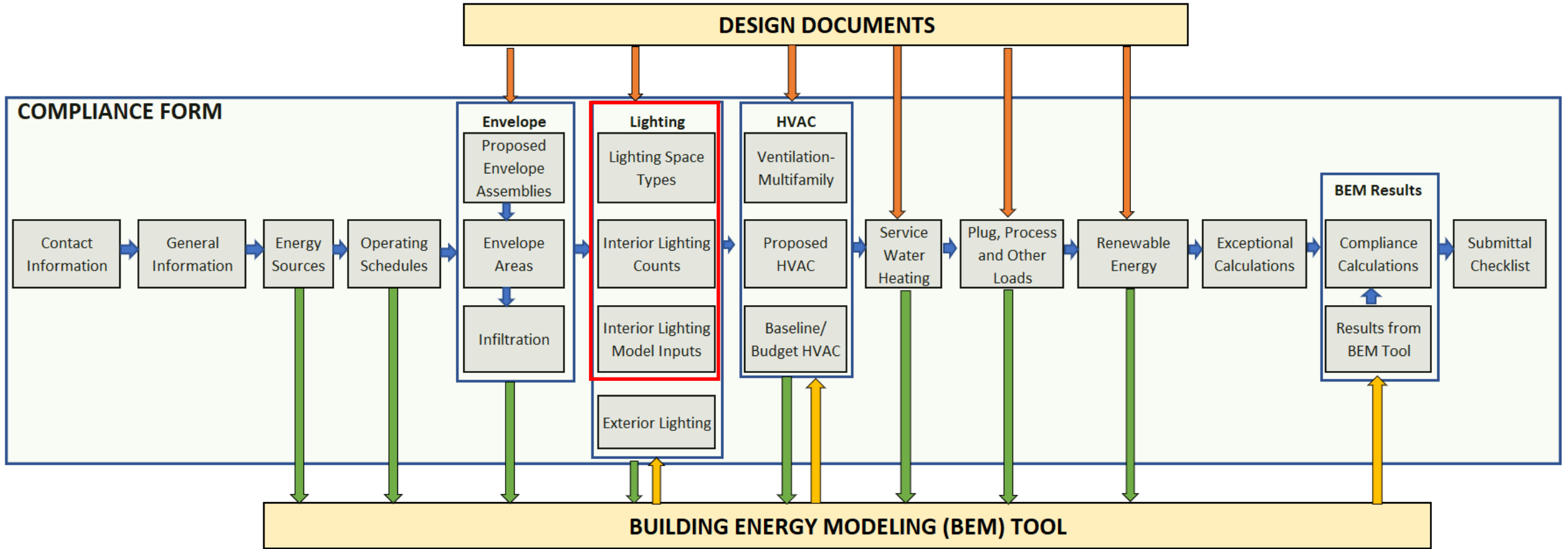
# Dashboard

Compliance Summary	
Compliance Path	Appendix G, Above Code Performance
Energy Modeling Outcome	In Progress
Design Professional Sign-off	No
Modeler Sign-off	No

Tabs Navigator	Design Professional Sign-off			Modeler Sign-off		
	Status	Name	Date	Status	Name	Date
<a href="#">Instructions</a>	N/A	-	-	N/A	-	-
<a href="#">Documentation Process Overview</a>	N/A	-	-	N/A	-	-
<a href="#">Contact Information</a>	Complete	Sam Smith	8/21/2020	Complete	Jones Blake	8/15/2020
<a href="#">General Information</a>	Complete	Johnson Avery	8/15/2020	Complete	Jones Blake	8/13/2020
<a href="#">Energy Sources</a>	Complete	Johnson Avery	8/25/2020	Complete	Jones Blake	8/21/2020
<a href="#">Operating Schedules</a>	Complete	Johnson Avery	8/21/2020	Complete	Jones Blake	8/14/2020
<a href="#">Proposed Envelope Assemblies</a>	Complete	Johnson Avery	8/15/2020	Complete	Jones Blake	8/15/2020
<a href="#">Envelope Areas</a>	Complete	Johnson Avery	8/25/2020	Complete	Jones Blake	8/13/2020
<a href="#">Infiltration</a>	Complete	Johnson Avery	8/21/2020	Complete	Jones Blake	8/21/2020
<a href="#">Lighting Space Types</a>	In Progress	Johnson Avery		In Progress	Jones Blake	
<a href="#">Interior Lighting Counts</a>	In Progress	Johnson Avery		In Progress	Jones Blake	
<a href="#">Interior Lighting Model Inputs</a>	In Progress	Johnson Avery		In Progress	Jones Blake	
<a href="#">Exterior Lighting</a>	In Progress	Johnson Avery		In Progress	Jones Blake	
<a href="#">Ventilation - Multifamily</a>	N/A	-	-	N/A	-	-
<a href="#">Proposed HVAC</a>	In Progress	Johnson Avery		In Progress	Jones Blake	
<a href="#">Baseline HVAC App G</a>	In Progress	Johnson Avery		In Progress	Jones Blake	
<a href="#">Budget HVAC Section 11</a>	N/A	-	-	N/A	-	-
<a href="#">Service Water Heating</a>	Complete	Johnson Avery	8/25/2020	Complete	Jones Blake	8/20/2020
<a href="#">Plug, Process and Other Loads</a>	Complete	Johnson Avery	8/15/2020	Complete	Jones Blake	8/12/2020
<a href="#">Renewable Energy</a>	N/A	-	-	N/A	-	-
<a href="#">Exceptional Calculations</a>	N/A	-	-	N/A	-	-
<a href="#">Results from eQuest</a>	N/A	-	-	In Progress	-	
<a href="#">Compliance Calculations</a>	N/A	-	-	In Progress	-	
<a href="#">Submittal Checklist</a>	In Progress	Johnson Avery		In Progress	Jones Blake	

# Basic Structure – Compliance Form Demo

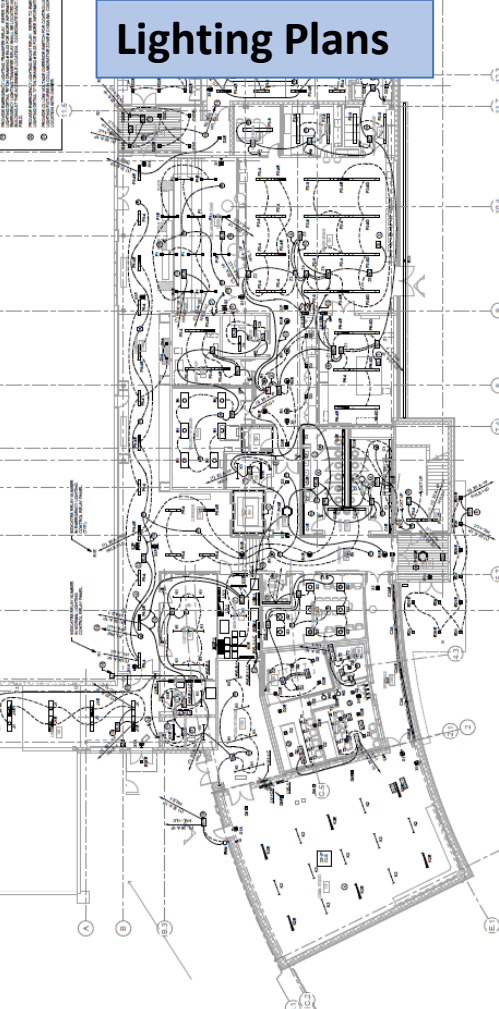
# LIGHTING



# Design Documents → BEM Tool Inputs

## DESIGN DOCUMENTS

## BEM TOOL INPUTS



**Lighting Plans**

TYPE	MANUFACTURER (OR ACCEPTABLE EQUIVALENT)	MODEL	FEATURE DESCRIPTION	VOLTS	LAMPS
100	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	100	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
101	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	101	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
102	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	102	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
103	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	103	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
104	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	104	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
105	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	105	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
106	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	106	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
107	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	107	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
108	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	108	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
109	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	109	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
110	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	110	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE

**Lighting Schedules**

2.3 INDOOR OCCUPANCY AND VACANCY SENSORS

A. Basis of comparison:

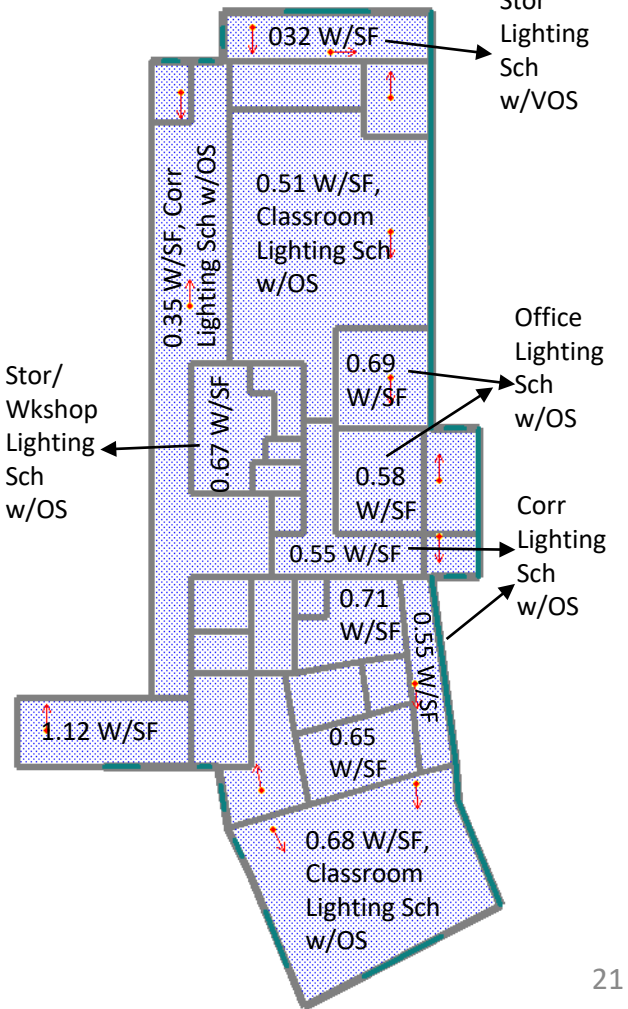
- Hubbell Building Automation, Inc.
- Philips Lighting Controls.

B. General Requirements for Sensors:

- Wall or Ceiling-mounted, solid-state indoor occupancy and vacancy sensors. Passive infrared, ultrasonic and dual technology.
- Separate power pack.
- Hardwired connection to switch.
- Hardwired secondary connection to switch; BMS and lighting control system.
- Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- Operation:
  - Occupancy Sensor: Unless otherwise indicated, turn lights on when coverage area is occupied, and turn them off when unoccupied; with a time delay for turning lights off, adjustable over a minimum range of 1 to 30 minutes.
  - Vacancy Sensor: Unless otherwise indicated, lights are manually turned on and sensor turns lights off when the room is unoccupied; with a time delay for turning lights off, adjustable over a minimum range of 1 to 30 minutes.

**Lighting Specifications**

TYPE	MANUFACTURER (OR ACCEPTABLE EQUIVALENT)	MODEL	FEATURE DESCRIPTION	VOLTS	LAMPS
111	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	111	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE
112	PHILIPS LIGHTING (OR ACCEPTABLE EQUIVALENT)	112	PHILIPS DELUXE MOUNTED LED LUMINAIRE WITH DIMMING DRIVER, FINISHED AS SELECTED BY ARCHITECT.	120V	10 DELUXE LUMINAIRE

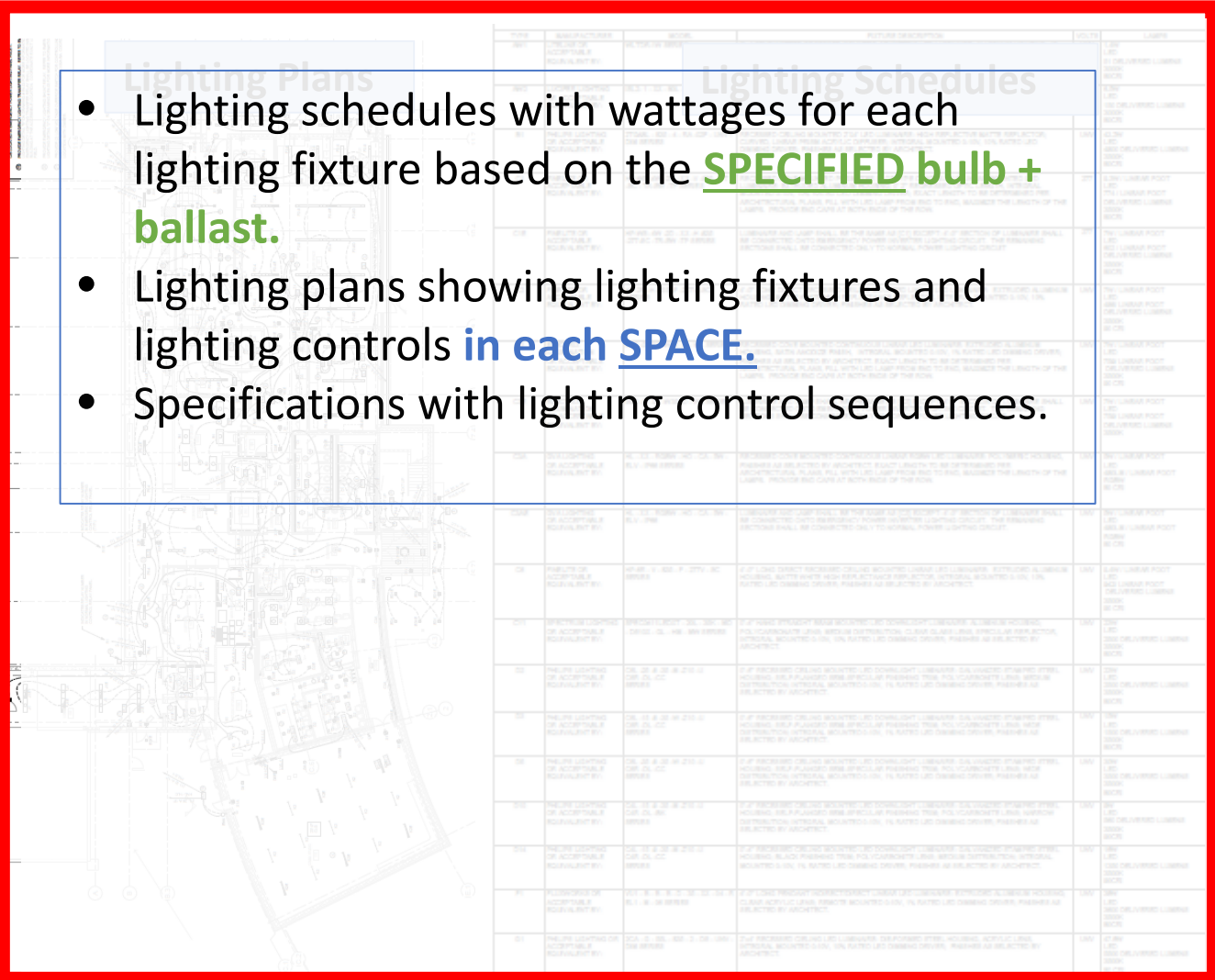


**BEM TOOL INPUTS**

- 0.32 W/SF → Stor Lighting Sch w/VOS
- 0.35 W/SF, Corr Lighting Sch w/VOS
- 0.51 W/SF, Classroom Lighting Sch w/VOS
- 0.67 W/SF → Stor/Wkshop Lighting Sch w/VOS
- 0.69 W/SF → Office Lighting Sch w/VOS
- 0.58 W/SF → Corr Lighting Sch w/VOS
- 0.55 W/SF → Corr Lighting Sch w/VOS
- 0.71 W/SF
- 0.65 W/SF
- 0.68 W/SF, Classroom Lighting Sch w/VOS
- 1.12 W/SF

# Design Documents → BEM Tool Inputs

## DESIGN DOCUMENTS

- 
- Lighting schedules with wattages for each lighting fixture based on the **SPECIFIED bulb + ballast**.
  - Lighting plans showing lighting fixtures and lighting controls **in each SPACE**.
  - Specifications with lighting control sequences.

## BEM TOOL INPUTS

### Proposed Design Model

- Lighting wattage and schedule adjustment credits for each HVAC zone based on the **MAXIMUM rated wattage** of specified lighting fixtures.

### Baseline Design Model

- Lighting wattage and schedule for **each HVAC ZONE** based on the 90.1 lighting power and control allowances and floor area of different types of spaces within this zone.

# Reporting Requirements

## 90.1 G1.3 Documentation Requirements

a. ...the key *energy efficiency* improvements compared with the requirements in Sections 5 through 10....

c. ... all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.

e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of 5.5, 6.5, 7.5, 9.5, and 9.6 (prescriptive provisions).

k. Backup calculations and material to support data inputs...

d. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).

## Compliance Form

**Proposed design** lighting power  
**Baseline design** lighting power  
**Prescriptive 90.1 lighting allowances**

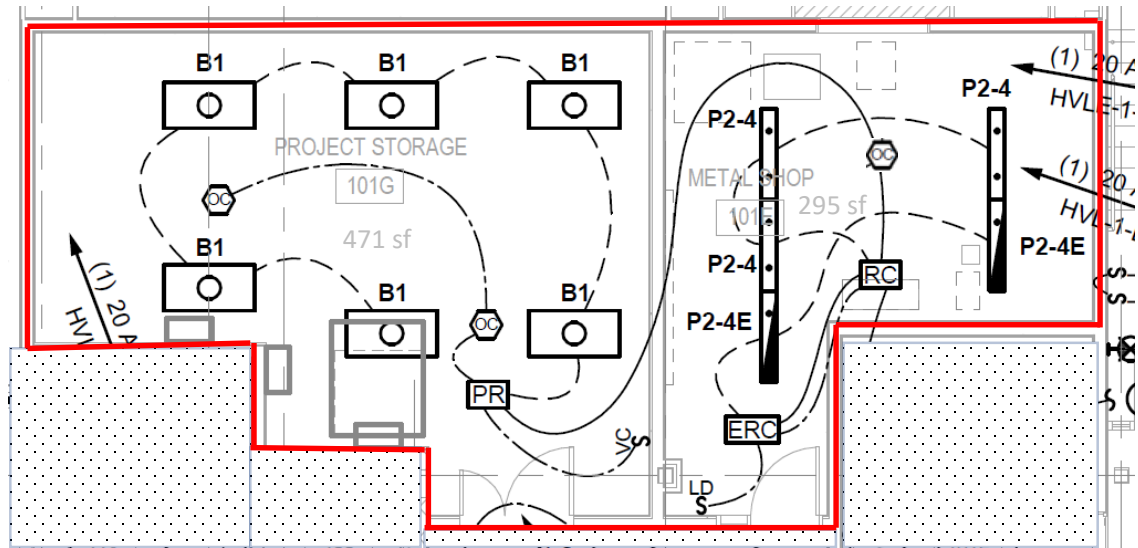
**Proposed design:** fixture counts, wattages and controls in each HVAC zone to document modeled LPDs and schedule credits  
**Baseline design:** floor area by space type within each modeled HVAC zone to document modeled LPDs

Lighting controls specified in the proposed design alongside the **mandatory lighting control requirements**

\*Not a simulation input

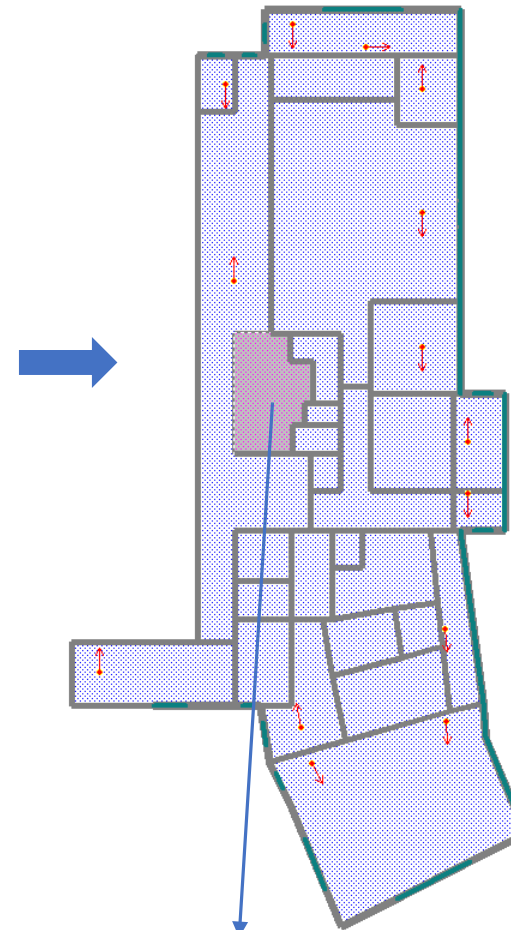
# Lighting Example – HVAC Zones

Prior to entering lighting information in the Compliance Form the building geometry and thermal zoning needs to be created in the BEM tool so that the modeled names of the HVAC zones associated with each space are known.



Red line = HVAC zone boundary.

DRAWING TITLE	
FIRST FLOOR ELECTRICAL LIGHTING PLAN	
SCALE: AS NOTED	DRAWING NO.
DATE: 04/10/18	EL1.01
JOB NO. 152810	



IC1 Core Spc (G.C4)

In this example, there are two different spaces and space types that make up this HVAC zone.

- Project Storage 101G
- Metal Shop 101F

In the model these two spaces comprise thermal zone called "IC1 Core Spc (G.C4)"



# Lighting Example – Lighting Power Density, 101G

## Lighting Schedules

B1	PHILIPS LIGHTING OR ACCEPTABLE EQUIVALENT BY:	2TG48L - 835 - 4 - RA -02F - UNV - DIM SERIES	43.2W LED 4800 DELIVERED LUMENS 3500K 80CRI
----	---	---	--

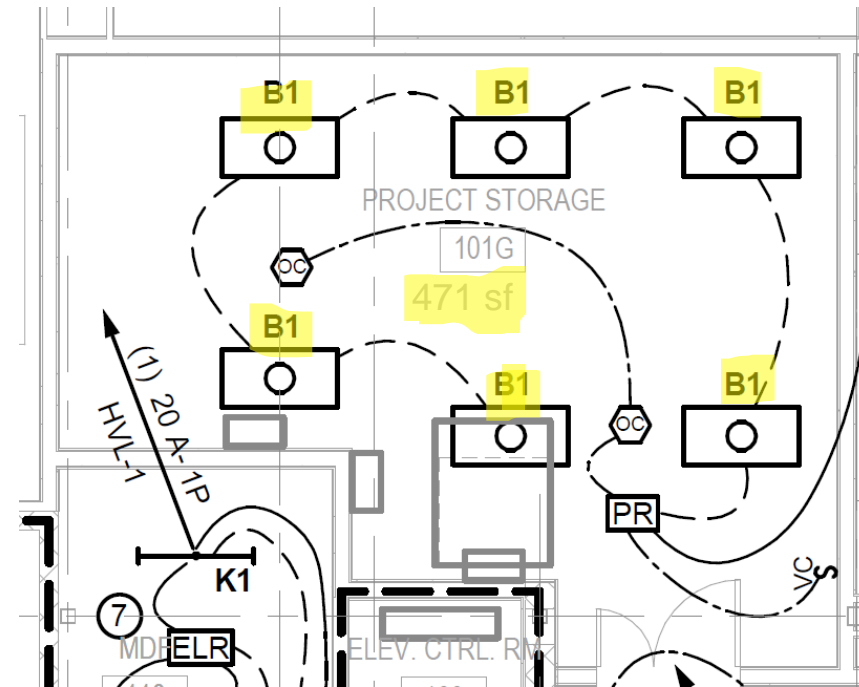
## Fixture Specifications

### 2x4 T-Grid LED troffer, 4800 nominal delivered lumens

		Candlepower	
		Angle	End
Test No.	33531	0	1950
S/MH	1.2	5	1942
Lamp Type	LED	15	1868
Lumens	4633	25	1707
Input Watts	43.2	35	1443
		45	1098
		55	734
		65	434
		75	238
		85	88

Comparative yearly lighting energy cost per 1000 lumens = \$2.24 based on 3000 hrs and \$0.08 per kWh

## Lighting Plans

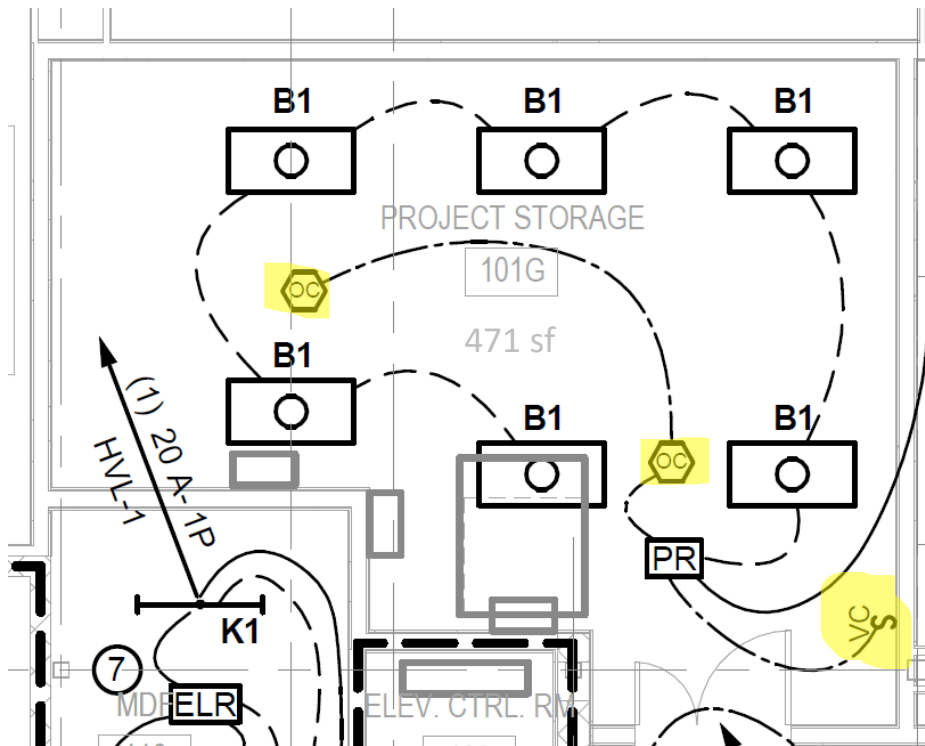


Qty B1 = 6  
Space ft<sup>2</sup> = 471

Maximum Fixture B1 Wattage Confirmed = 43.2

# Lighting Example – Lighting Controls

## Lighting Plans



## Lighting Symbols



VACANCY SENSOR CONTROL SWITCH



OCCUPANCY SENSOR W / POWER PACK  
(CEILING / WALL)

## Project Specifications

- b. Vacancy Sensor: Unless otherwise indicated, lights are manually turned on and sensor turns lights off when the room is unoccupied; with a time delay for turning lights off, adjustable over a minimum range of 1 to 30 minutes.

Space 101G is controlled with a vacancy sensor control switch.

# Lighting Example – Lighting Controls

Table 9.6.1 *Lighting Power Density Allowances Using the Space-by-Space Method and Minimum Control Requirements Using Either Method*

<i>Informative Note:</i> This table is divided into two sections; this first section covers <i>space</i> types that can be commonly found in multiple <i>building</i> types. The second part of this table covers <i>space</i> types that are typically found in a single <i>building</i> type.		The <i>control</i> functions below shall be implemented in accordance with the descriptions found in the referenced paragraphs within Section 9.4.1.1. For each <i>space</i> type: (1) All REQs shall be implemented. (2) At least one ADD1 (when present) shall be implemented. (3) At least one ADD2 (when present) shall be implemented.									
		Local Control (See Section 9.4.1.1[a])	Restricted to Manual ON (See Section 9.4.1.1[b])	Restricted to Partial Automatic ON (See Section 9.4.1.1[c])	Bilevel Lighting Control (See Section 9.4.1.1[d])	Automatic Daylight Responsive Controls for Sidelighting (See Section 9.4.1.1[e] <sup>6</sup> )	Automatic Daylight Responsive Controls for Toplighting (See Section 9.4.1.1[f] <sup>6</sup> )	Automatic Partial OFF (See Section 9.4.1.1[g] [Full Off complies])	Automatic Full OFF (See Section 9.4.1.1[h])	Scheduled Shutoff (See Section 9.4.1.1[i])	
Storage Room											
<50 ft <sup>2</sup>	0.97	6	REQ							ADD2	ADD2
≥50 ft <sup>2</sup> and ≤1000 ft <sup>2</sup>	0.46	6	REQ ✓	ADD1 ✓	N/A		N/A	N/A		REQ ✓	
All other storage rooms	0.46	6	REQ	ADD1	ADD1		REQ	REQ	REQ	ADD2	ADD2

Space G 101G mandatory requirements as defined in 9.4.1.1:

- Local Control (one or more manual lighting controls in the space that controls all of the lighting in the space)
- Restricted to Manual ON or Restricted to Partial Automatic ON
- Side and Toplighting Automatic Daylight Responsive Controls (Not applicable because no fenestration)
- Automatic Full OFF (automatically shut off within 20 minutes of occupants leaving the space)

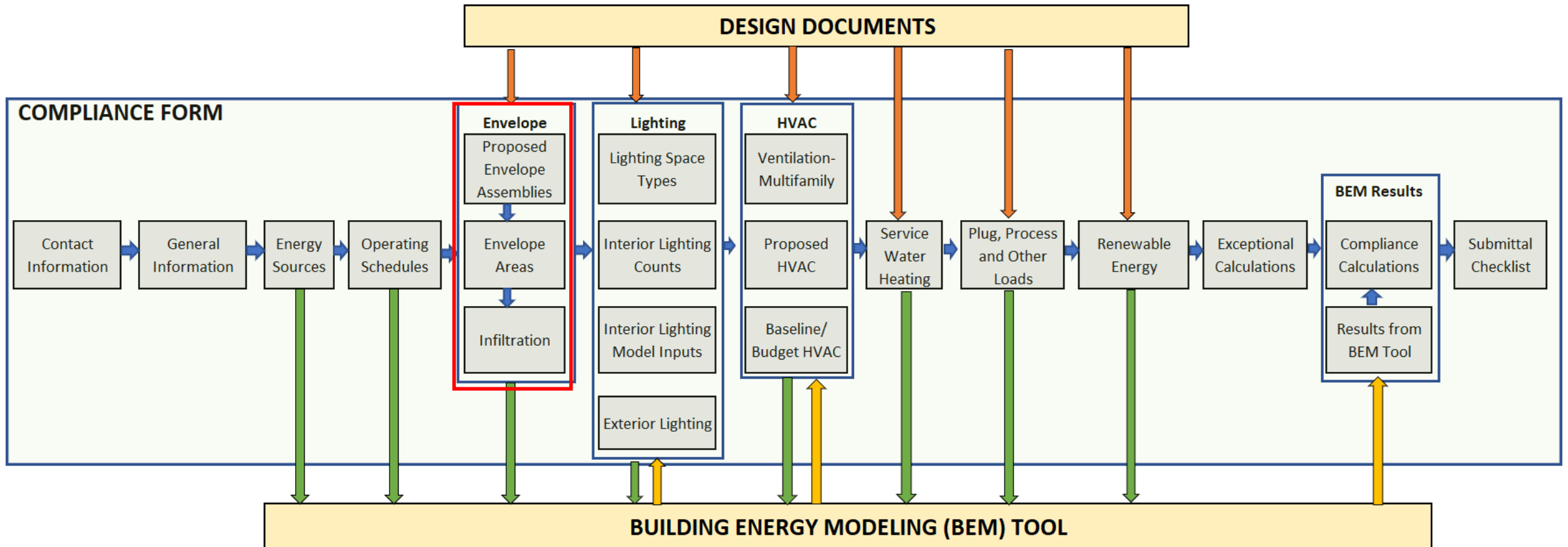
Which of these control functions are included in the design for the space?

# Lighting Example – Compliance Form Demo

# Common Lighting Mistakes

- Choosing the dominate space type associated with the modeled HVAC zone and using that space type to determine the baseline LPD.
- Failure to model proposed designed controls especially daylighting. Often this is because proposed lighting controls are not completely clear on the design drawings.
- Lack of accounting for areas where lighting is unspecified or where the design intent is for the hardwired lighting to be supplemented with receptacle lighting.
- Not modeling the maximum fixture wattage and failure to include all components of the fixture wattage including lamps, ballasts/drivers, transformers, and control devices.

# BUILDING ENVELOPE



# Design Documents → BEM Tool

## DESIGN DOCUMENTS

**Construction Assembly Schedules**

**Elevations**

**Window & Door Schedules**

## BEM TOOL INPUTS

**Modeled Construction Thermal Properties**

	Material Name	Thickness (ft)	Conductivity (Btu/h-ft-°F)	Density (lb/ft3)	Spec. Heat (Btu/lb-°F)	R-Value (h-ft2-°F/Btu)
1	Steel Siding (HF-A3)	0.005	26.0000	480.00	0.100	n/a
2	Air Lay <3/4in Vert (AL11)	n/a	n/a	n/a	n/a	0.900
3	Insul Bd 2in (HF-B3)	0.213	0.0250	2.00	0.200	n/a
4	GypBd 5/8in (GP02)	0.05				
5	MinWool Batt R19 (IN03)	0.17				
6	GypBd 3/4in (GP03)	0.05				
7						
8						
9						
10	n/a					

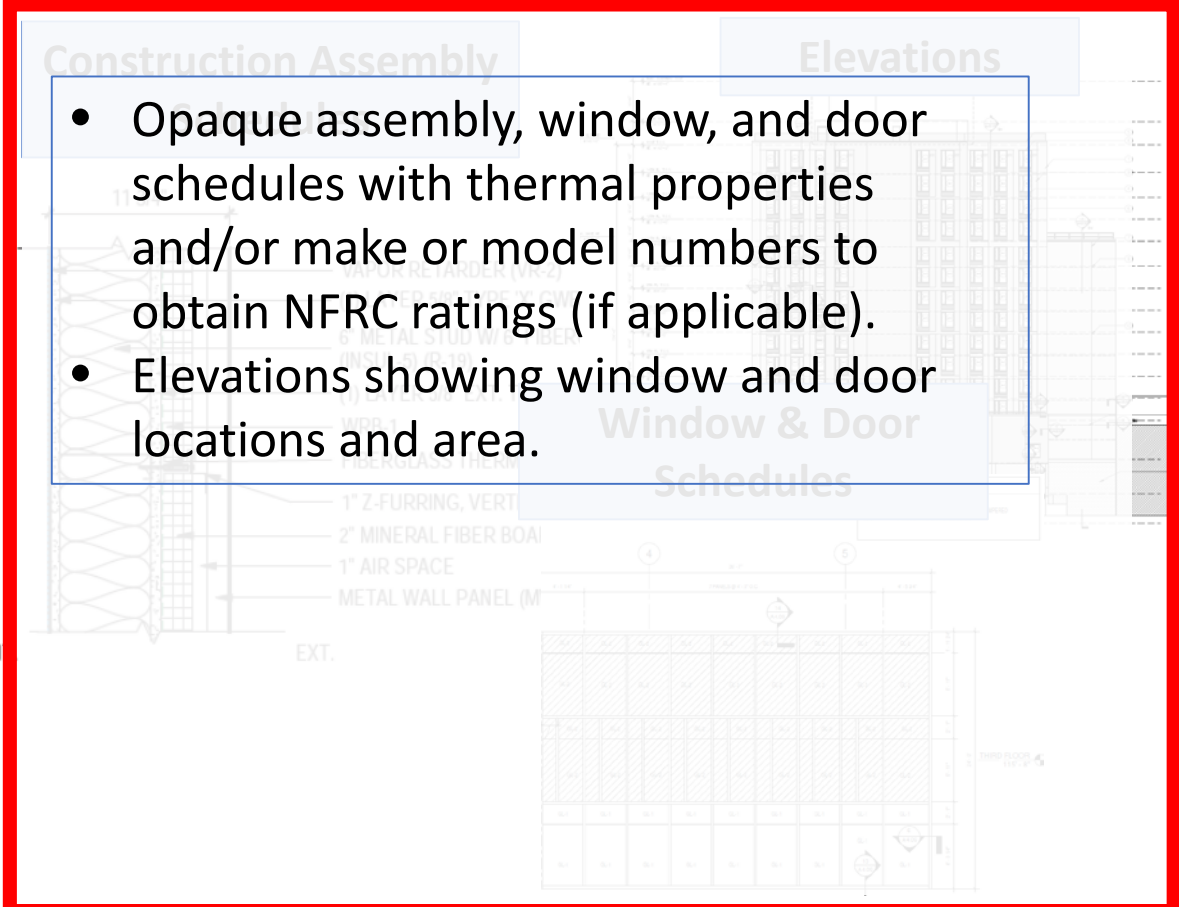
**Modeled Window & Door Thermal Properties**

Window Name: Window\_33\_C8  
 Parent Wall: ICAEast Wall (G.W1.E1)  
 Type of Window: Standard Window  
 Window Glass/Layers: Composite  
 Specification Method: Composite  
 Type of Glass: ICIWindow Type #1 C  
 Diffusing: No

**Modeled Areas & Locations**

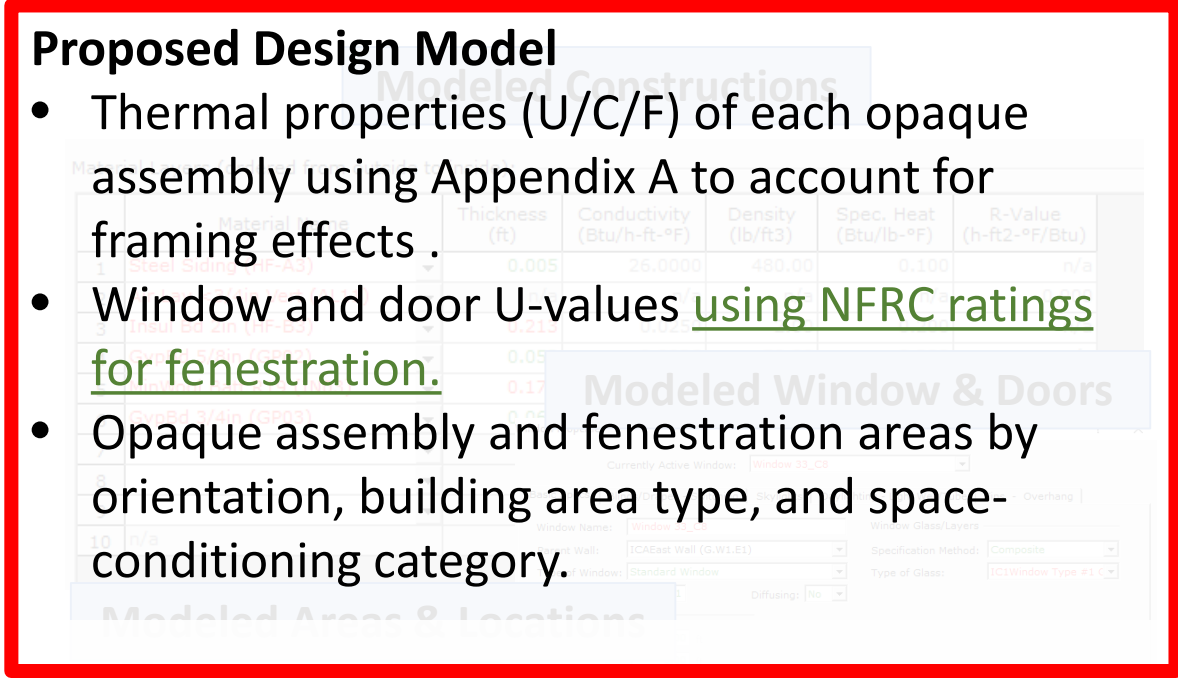
# Design Documents → BEM Tool

## DESIGN DOCUMENTS

- 
- Opaque assembly, window, and door schedules with thermal properties and/or make or model numbers to obtain NFRC ratings (if applicable).
  - Elevations showing window and door locations and area.

## BEM TOOL INPUTS

### Proposed Design Model

- 
- Thermal properties (U/C/F) of each opaque assembly using Appendix A to account for framing effects.
  - Window and door U-values using NFRC ratings for fenestration.
  - Opaque assembly and fenestration areas by orientation, building area type, and space-conditioning category.

### Baseline Design Model

- Opaque assembly and fenestration thermal properties per Tables G3.4-1-8.
- Window to wall ratio per Table G3.1.1-1.



# Reporting Requirements

## 90.1 G1.3 Documentation Requirements

- a. ...the key *energy efficiency* improvements compared with the requirements in Sections 5 through 10...
- c. ... all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.
- e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of 5.5, 6.5, 7.5, 9.5, and 9.6 (prescriptive provisions).

k. Backup calculations and material to support data inputs...

- d. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).

## Compliance Form

**Proposed design** opaque assembly and fenestration thermal properties (e.g. U/C/F/SHGC/VT).

**Baseline design** opaque assembly and fenestration thermal properties.

**Prescriptive 90.1 opaque assembly and fenestration thermal properties**

**Proposed design:** U/C/F-values **calculated per Appendix A** and window to wall ratios and areas.

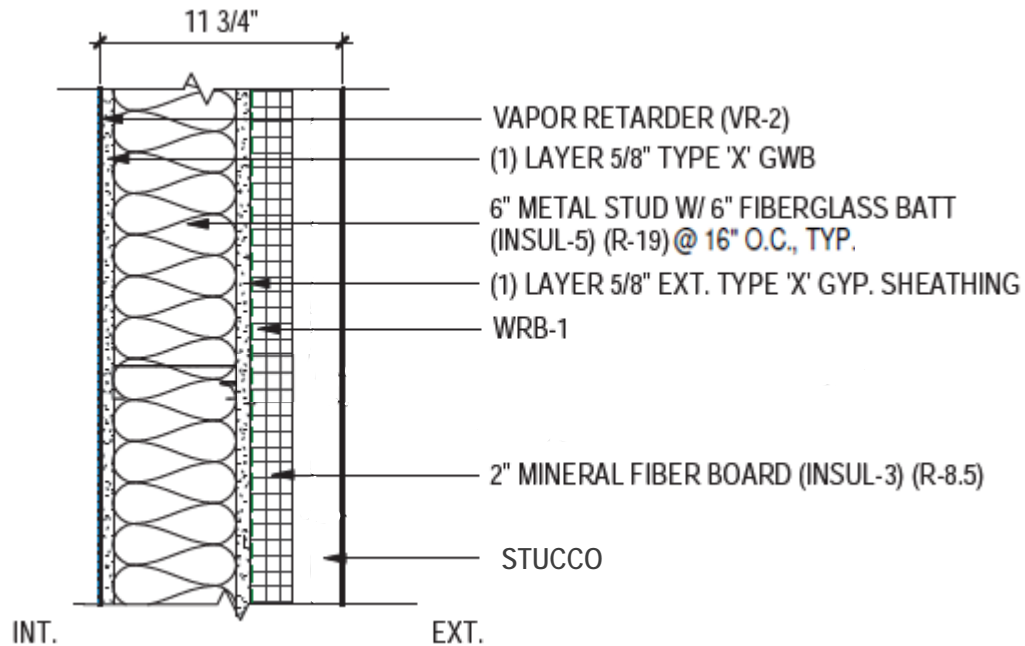
**Baseline design:** U/C/F-values Tables G3.4-1-8 and window to wall ratios and areas.

Not yet supported.

\*Not a simulation input

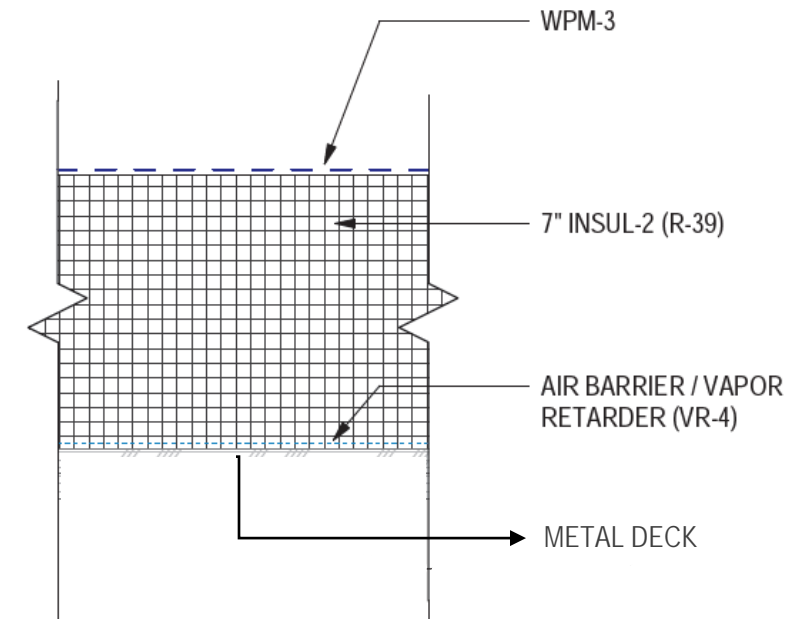
# Envelope Example – Opaque Assemblies

## Exterior Wall Assembly



R-19 cavity insulation and R-8.5 continuous exterior insulation, 6" Metal studs, 16" o.c.

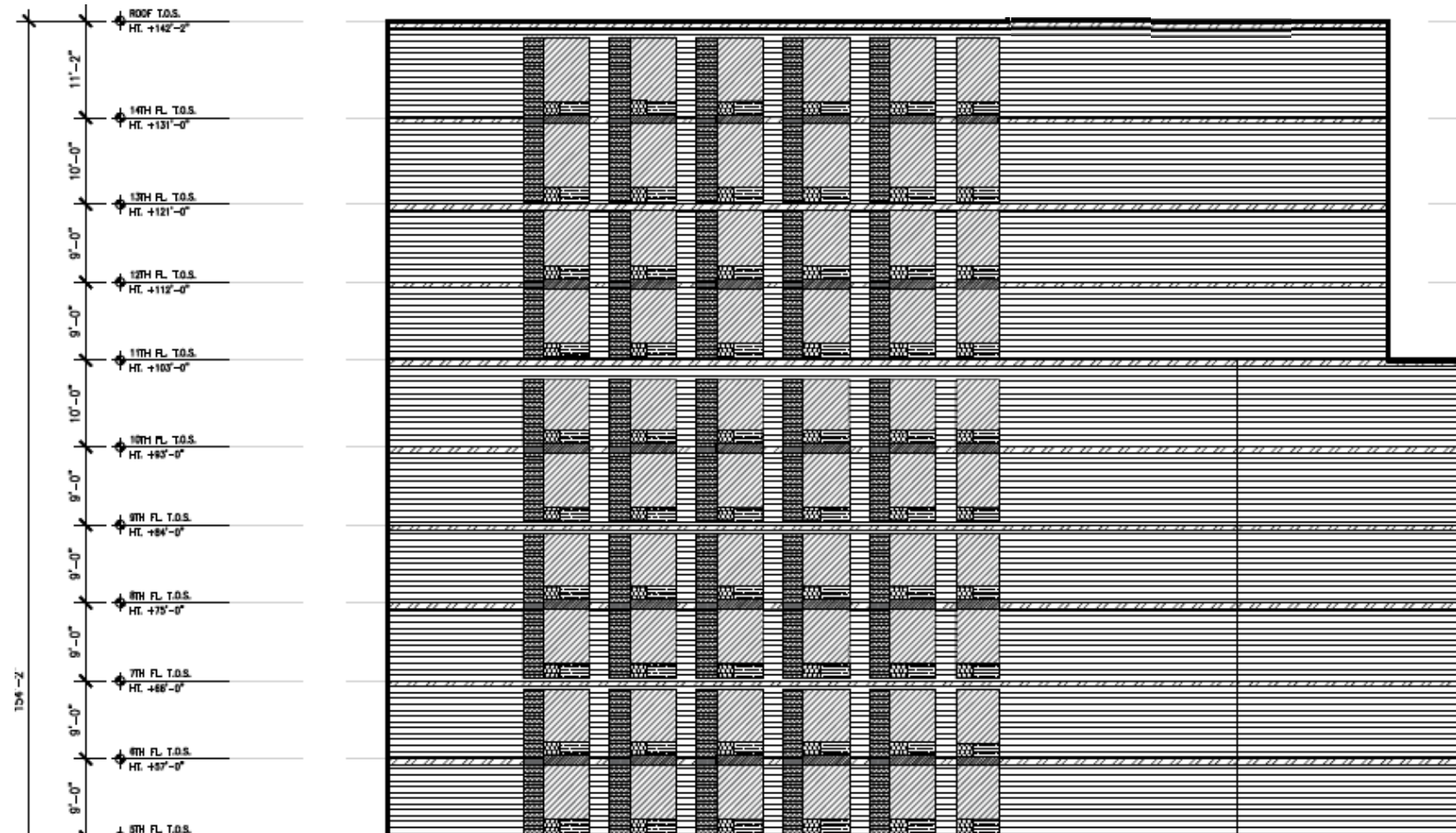
## Roof Assembly



Reflectance: 0.55  
Emittance: 0.75

R-39 continuous insulation entirely above deck. Reflectance 0.55 and emittance 0.75.

# Envelope Example – Areas



 WALL ASSEMBLY TYPE A BRICK ASSEMBLY 8,345 SF  
 WALL ASSEMBLY TYPE A BRICK SLAB EDGE 819 SF

EAST ELEVATION

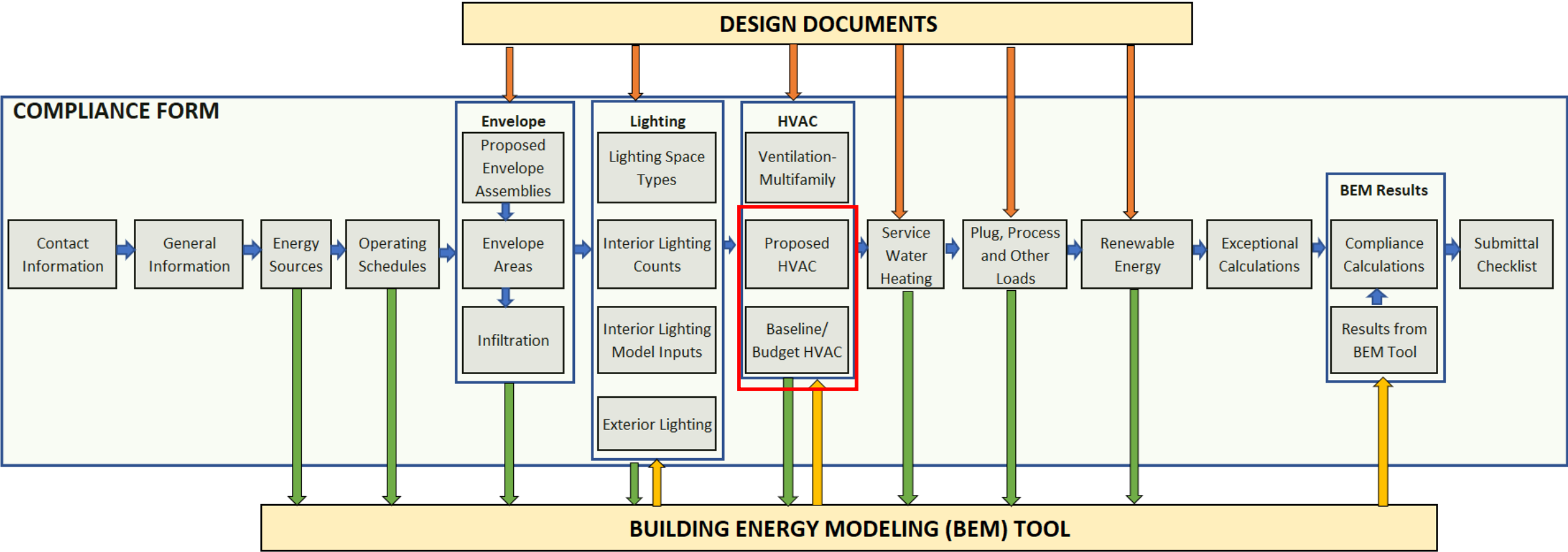
- East  
 Wall assembly type A: 8,345 sf  
 Wall assembly type A slab: 819 sf  
 Window type 1 area: 2,433 sf
  
- West  
 Wall assembly type A: 8,492 sf  
 Wall assembly type A slab: 860 sf  
 Window type 1 area: 2,417 sf
  
- North  
 Wall assembly type A: 5,127 sf  
 Wall assembly type A slab: 865 sf  
 Window type 1 area: 7,084 sf
  
- South  
 Wall assembly type A: 10,688 sf  
 Wall assembly type A slab: 1,095 sf  
 Window type 1 area: 4,546 sf

# Envelope Example – Compliance Form Demo

# Common Envelope Mistakes

- Modeling the center of glass U-value as opposed to the NFRC assembly U-value which includes framing.
- Failure to model or account for in the model uninsulated slab edges that penetrate the wall plane on each floor of the building.
- Not using Appendix A to account for the effects of framing when determining proposed design opaque assembly thermal properties (U/C/F).
- Modeling the same window to wall ratio in the baseline and proposed when the baseline window to wall ratio should be determined based upon 90.1 Table G3.1.1-1 and Table G3.1 #5c.
- Infiltration entered at 75 Pa per 90.1 rather than normal pressure conditions. Or at whatever conditions required by the simulation program

# HVAC



# Design Documents → BEM Tool

## DESIGN DOCUMENTS

## BEM TOOL INPUTS

### Mechanical Equipment Schedules

### Riser Diagrams

### HVAC Plans (Piping, ductwork, etc.)

### HVAC System Types, Sizing & Zoning

### HVAC Controls

Currently Active Systems: AHU-1 System Type: Variable Air Volume

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration |

Outside Air and Economizer | Heat Recovery 1 | Heat Recovery 2 | Natural Ventilation |

Outdoor Ventilation Air

Minimum Outside Air:

Minimum OA Control Method:

Minimum OA Sizing Method:

Minimum Air Schedule:

Outside Air from System:

Air-Side Economizer Cycle

Outside Air Control:

Drybulb High Limit:

Enthalpy High Limit:

Return & Outside Air Deltas

Temperature:

Enthalpy:

Economizer Schedule:

Lockout Compressor:

Economizer Low Limit:

Maximum OA Fraction:

Maximum OA Humidity:

Minimum Humidity:

### HVAC Efficiency & Other Parameters

Currently Active Systems: AC System Type: Pkgd Terminal AC

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration |

Fan Power and Control | Flow Parameters | Night Cycle Control |

Fan Power Parameters for single-duct systems

	Design kW/cfm	Delta T °F	Static in WG	Tot Eff Frac	Mech Eff Frac	Fan EIR = (PLR)
Supply:	0.000834	2.58	n/a	n/a	n/a	n/a
Unused:	n/a	n/a	n/a	n/a	n/a	n/a
Return:	n/a	n/a	n/a	n/a	n/a	n/a

# Design Documents → BEM Tool

## DESIGN DOCUMENTS

- HVAC equipment schedules with capacities, efficiencies, components (e.g. CO<sub>2</sub> sensors), control sequences, and make/model numbers.
- HVAC ducting and piping plans and riser diagrams to determine HVAC zoning and the heating, cooling capacities and air flows cfm (SA, OA, RA, etc.) associated with each HVAC zone.

## BEM TOOL INPUTS

### Proposed Design Model

- HVAC zoning.
- HVAC equipment type, capacity, efficiency, fan power, pumping power, and control sequences associated with each thermal zone.

### Baseline Design Model

- HVAC zoning – same as proposed.
- HVAC equipment type, capacity, efficiency, fan power, pumping power, and control sequences per Section G3.



# Reporting Requirements

## 90.1 G1.3 Documentation Requirements

a. ...the key *energy efficiency* improvements compared with the requirements in Sections 5 through 10...

c. ... all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.

e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of 5.5, 6.5, 7.5, 9.5, and 9.6 (prescriptive provisions).

k. Backup calculations and material to support data inputs...

d. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).

## Compliance Form

**Proposed design** equipment types, capacities, efficiencies, and control sequences .

**Baseline design** equipment types, capacities, efficiencies, and control sequences per Section G3.

**Prescriptive 90.1 control requirements**

**Proposed design:** Fan power, pumping power.

**Baseline design:** Fan power, pumping power, efficiency, controls, number of systems and plants.

HVAC controls and efficiencies alongside **minimum efficiency and control requirements.**

**\*Not a simulation input**

# HVAC Example

UNIT NO.	SERVICE	EVAPORATOR FAN							GAS FURNACE						
		CFM	MINIMUM OA CFM	ESP (IN WG)	TSP (IN WG)	MOTOR			GAS DATA				CAPACITY (MBH)	INLET SIZE (IN)	
						BHP	HP	RPM	TYPE	REQUIRED PRESSURE	INPUT MBH	EAT (°F)			LAT (°F)
RTU-1	OFFICE 1	5,250	525	1.0	2.0	2.64	4.0	1359	NAT.	7 IN. W.G.	300	60	102.1	240	0.75
RTU-2	OFFICE 2	5,250	525	1.0	2.0	2.64	4.0	1359	NAT.	7 IN. W.G.	300	60	102.1	240	0.75

COOLING						CONDENSER		COMPRESSOR			EER	IEER	
CAPACITY (MBH)		EAT		LAT		FACE VEL (FPM)	MIN. NO. OF ROWS	COIL EDB (°F)	QTY. OF FANS	QTY.			CAPACITY CONTROL
TOTAL	SENSIBLE	DB °F	WB °F	DB °F	WB °F								
175.9	135.5	80	64	56.4	56.4	340	6	95	2	2	MODULATING	11.0	17.5
175.9	135.5	80	64	56.4	56.4	340	6	95	2	2	MODULATING	11.0	17.5

FILTER	ELECTRIC DATA			DIMENSIONAL DATA		WEIGHT	BASIS OF DESIGN	
TYPE	V/PH/HZ	MCA	MROPD	LxWxH (IN.)		(LBS.)	MANUF.	MODEL
MERV 8	208/3/60	67.1	90	91.0 X 96.5 X 55.8		2595	DAIKIN MCQUAY	DPS015A
MERV 8	208/3/60	67.1	90	91.0 X 96.5 X 55.8		2595	DAIKIN MCQUAY	DPS015A

## NOTES:

- UNITS SHALL BE HIGH EFFICIENCY TYPE.
- PROVIDE EACH UNIT WITH INTEGRAL DISCONNECT SWITCH AND UNIT MOUNTED CONTROLS ENCLOSURE.
- UNIT SHALL BE EQUIPPED WITH VARIABLE VOLUME CONTROL UTILIZING BUILT IN VFD. MINIMUM FLOW 30%.
- UNIT SHALL OPERATE WITH A CONSTANT 55F SUPPLY AIR TEMPERATURE.
- UNITS TO HAVE 100% OUTSIDE AIR DIFFERENTIAL ENTHALPY CONTROLLED ECONOMIZER FUNCTION WITH HIGH LIMIT SETPOINT OF 75F DB.
- GAS TRAINS SHALL BE APPROVED TO FM, IRI, OR OTHER LOCAL CODE REQUIREMENTS.
- CLOGGED FILTER INDICATOR.
- UNIT SHALL USE R410A REFRIGERANT.
- UNIT SHALL BE PROVIDED FACTORY ROOF CURB WITH CONNECTIONS FOR FIELD SUPPLIED DUCTWORK.
- PROVIDE WITH FACTORY POWERED GFCI 15A, 115V CONVENIENCE OUTLET.

DRAWING NO.

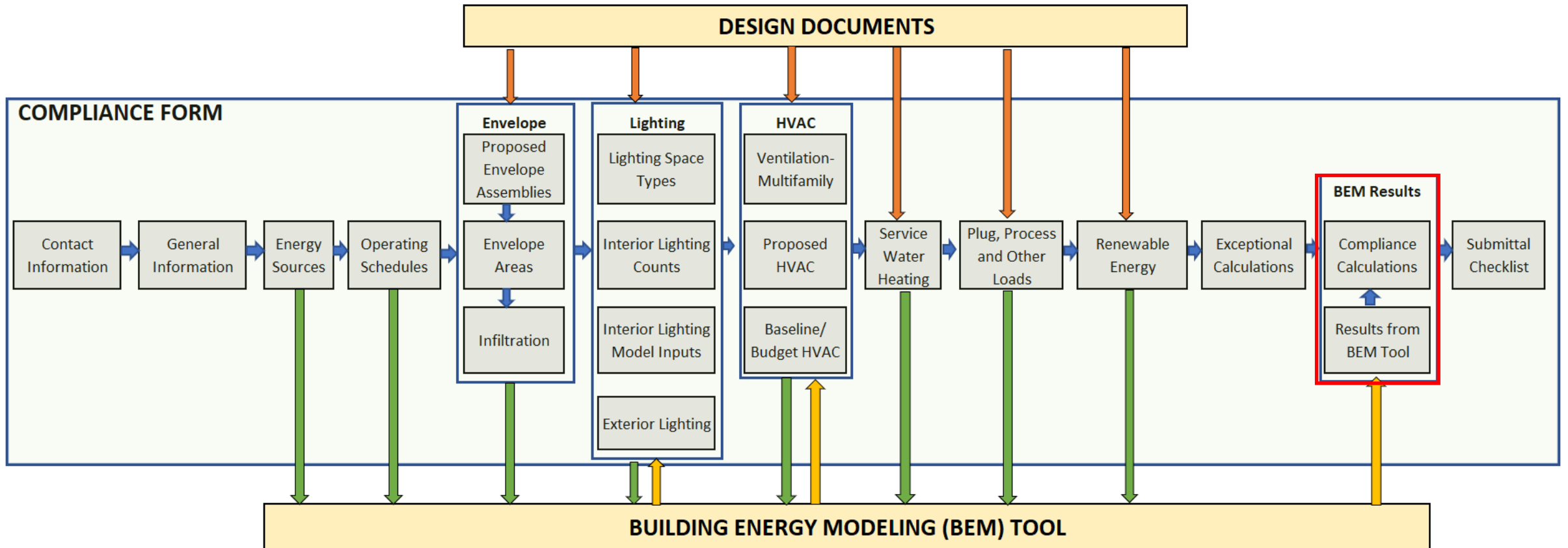
**M-400.00**

# HVAC Example – Compliance Form Demo

# Common HVAC Mistakes

- Modeling the incorrect baseline system types due to incorrect application of G3.1.1 a through h.
- Failure to remove fan power from baseline and proposed HVAC efficiencies (where applicable).
- Modeling the same HVAC controls in the baseline and proposed (e.g. economizers, energy recovery, etc.) instead of following the rules of Section G3.
- Modeling different OA cfm rates in the baseline and proposed models when no exceptions are applicable.

# Simulation Outputs and Compliance Calculations



# Reporting Requirements

## 90.1 G1.3 Documentation Requirements

f. A table with a summary by end use of the *energy* cost savings in the *proposed building performance*.

l. Input and output reports from the simulation program or compliance software, including a breakdown of energy use by at least the following components: lights, internal equipment loads, service water-heating equipment, space-heating equipment, space-cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps). The output reports shall also show the amount of unmet load hours for both the proposed design and baseline building design.

## Compliance Form

Annual baseline and proposed design heating, cooling, lighting, miscellaneous equipment, SWH pumping, heat rejection, and ventilation costs.

Modelers can paste the standard output reports generated by the supported simulation tools into the software specific tabs to import simulation results for the baseline/budget and proposed models.

# Results from <BEM Tool>

- Supported BEM Tools

- DesignBuilder
- EnergyPlus
- eQuest
- Openstudio
- Trace3DPlus
- Trace700

pliance

**Table 2: Baseline and Proposed Design Energy by End Use Excluding Exceptional Calculations and Renewable Energy, in Units of Energy**

**Instructions**

If an end-use has two energy types (e.g. there are both gas-fired and electric heating systems), enter the end-use in two separate rows, one for each energy type.

Import results from simulation reports into Table 2 as follows:

Navigate to the "Results from " tab and follow the instructions on that tab to copy the standard simulation output reports.

Once the "Results from " tab is filled out, click the button below to populate Table 2 with the simulation results.

Update the defaults in the "Modeled Energy Consumption from Results Summary" and "Modeled Peak Demand from Results Summary" columns (to the right of Table 2 starting in column 10).

Some auto-populated values in Table 2 may need to be manually over-written. For example, if the "Fan, interior ventilation" and "Fan, parking garage" enduses are not separately modeled, the values for these enduses should be zero.

...	Results from DesignBuilder	Results from EnergyPlus	Results from eQuest	Results from Openstudio	Results from Trace3DPlus	Results from Trace700	Co
-----	----------------------------	-------------------------	---------------------	-------------------------	--------------------------	-----------------------	----

IESVE and HAP in progress.



# Compliance Calculations

- Compliance outcome is calculated based upon the Results from <BEM Tool> tab inputs.

Table 7: Compliance Calculations

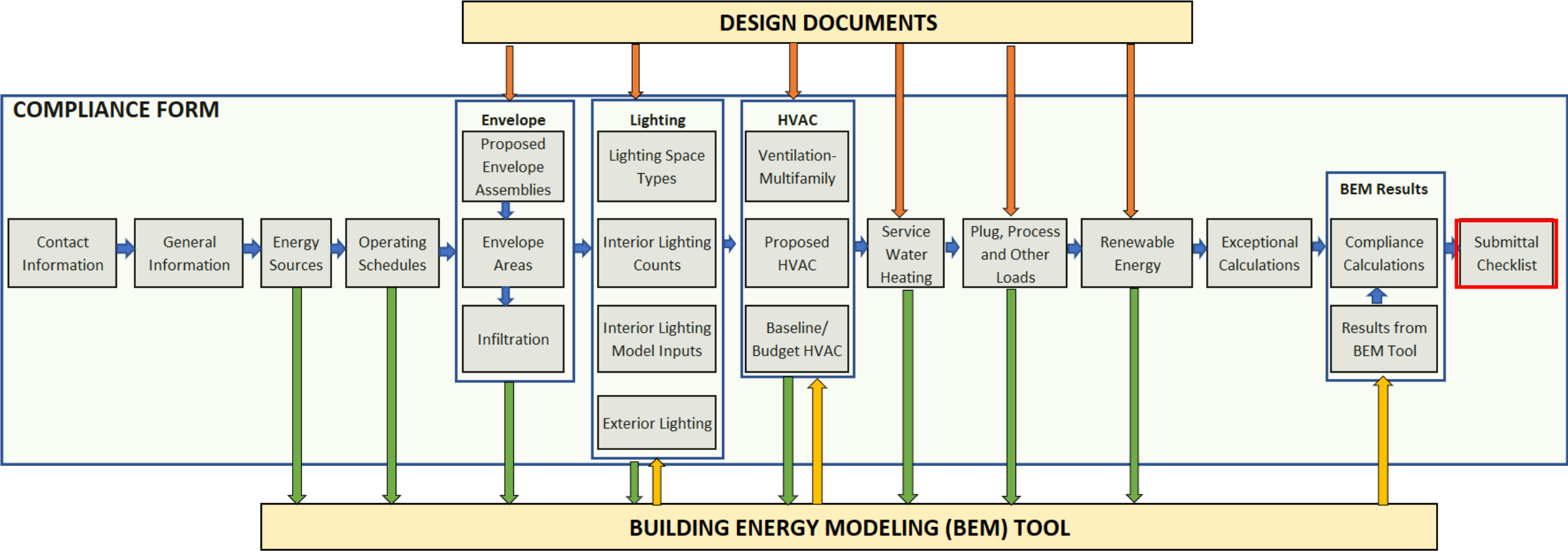
Parameter	Symbol	Performance Metric			
		Cost \$	Site Energy MMBtu	Source Energy MMBtu	GHG Emissions Mt CO <sub>2</sub> e
Proposed building performance before site-generated renewable energy and exceptional calculations	PBP <sub>nre_nec</sub>	\$103,029	3,197	6,721	-
? On-site renewable savings	-	-	-	-	-
? Exceptional calculations savings excluding on-site renewable energy	-	-	-	-	-
Proposed building performance including on-site renewable energy and exceptional calculations	PBP	\$103,029	3,197	6,721	0
Proposed building performance including exceptional calculations and excluding on-site renewables	PBPnre	\$103,029	3,197	6,721	0
Baseline building unregulated energy, GHG emissions, and/or energy cost	BBUEC	\$46,316	976	2,731	-
Baseline building regulated energy, GHG emissions, and/or energy cost	BBREC	\$129,394	4,637	8,831	-
Baseline building performance	BBP	\$175,710	5,612	11,562	-
Building Performance Factor	BPF	0.50	n/a	n/a	n/a
Performance Index Target	PCI <sub>t</sub>	0.63	n/a	n/a	n/a
Performance index without on-site renewable energy and exceptional calculations	PCI <sub>nre_nec</sub>	0.59	0.57	0.58	
Performance index including exceptional calculations	PCI <sub>ec</sub>	0.59	0.57	0.58	
Performance Index including exceptional calculations and on-site renewable energy	PCI	0.59	0.57	0.58	
? Performance Index adjusted based upon ASHRAE 90.1-2019 Section 4.2.1.1	PCI <sub>adjusted</sub>	0.59	0.57	0.58	0.0
% improvement beyond ASHRAE 90.1-2016, excluding on-site renewable energy and exceptional calculations	-	7.2%	n/a	n/a	n/a
% improvement beyond ASHRAE 90.1-2016, inclusive of on-site renewable energy and exceptional calculations	-	7.2%	n/a	n/a	n/a

**PROJECT COMPLIES.** The Performance Cost Index (PCI<sub>adjusted</sub>) does not exceed the Performance Cost Index Target (PCI<sub>t</sub>). The project complies with 90.1 via the Appendix G Performance Rating Method.



# Output Report and Compliance Calculations – Compliance Form Demo

# SUBMITTAL CHECKLIST



# Submittal Checklist

## 90.1 G1.3 Documentation Requirements

- a. A brief description of the project, the key *energy efficiency* improvements compared with the requirements in Sections 5 through 10, the *simulation program* used, the version of the *simulation program*, and the results of the *energy analysis*. This summary shall contain the calculated values for the *baseline building performance*, the *proposed building performance*, and the percentage improvement.
- b. An overview of the project that includes the number of stories (above and below *grade*), the typical *floor* size, the uses in the *building* (e.g., office, cafeteria, retail, parking, etc.), the gross area of each use, and whether each use is *conditioned space*.
- c. A list of the *energy*-related features that are included in the design and on which the performance rating is based. This list shall document all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.
- d. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).
- e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of 5.5, 6.5, 7.5-9.5, and 9.6 (prescriptive provisions).
- f. A table with a summary by end use of the *energy* cost savings in the *proposed building performance*.
- g. A site plan showing all adjacent *buildings* and topography that may shade the *proposed building* (with estimated height or number of stories).
- h. *Building* elevations and *floor* plans (schematic is acceptable).
- i. A diagram showing the *thermal blocks* used in the computer simulation.
- j. An explanation of any significant modeling assumptions.
- k. Backup calculations and material to support data inputs (e.g., *U-factors* for *building envelope* assemblies, NFRC ratings for *fenestration*, end-uses identified in Table G3.1, "1. Design Model," paragraph [a]).
- l. Input and output reports from the *simulation program* or compliance software, including a breakdown of *energy* use by at least the following components: lights, internal *equipment* loads, *service water-heating equipment*, *space-heating equipment*, *space-cooling* and heat rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of *unmet load hours* for both the *proposed design* and *baseline building design*.
- m. *Purchased energy rates* used in the simulations.
- n. An explanation of any error messages noted in the *simulation program* output.
- o. For any exceptional calculation methods employed, document the predicted *energy* savings by *energy* type, the *energy* cost savings, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.
- p. The reduction in *proposed building performance* associated with *on-site renewable energy*.



## Compliance Form

The Submittal Checklist is designed to ensure that submitters provide all documentation as required by 90.1.

# Submittal Checklist– Compliance Form Demo

# QUESTIONS



Michael Rosenberg (PNNL) [Michael.Rosenberg@pnnl.gov](mailto:Michael.Rosenberg@pnnl.gov)

Christina LaPerle (Karpman Consulting) [christina@karpmanconsulting.net](mailto:christina@karpmanconsulting.net)

Maria Karpman (Karpman Consulting) [maria.karpman@karpmanconsulting.net](mailto:maria.karpman@karpmanconsulting.net)