House Energy Doctor

Spring 2019 Project 3

Smart Building Technologies (SBT) that Achieve Energy Efficient Design and Ratings of Commercial Buildings

A collaboration between the University of Arizona College of Electrical and Computer Engineering (ECE), College of Architecture's House Energy Doctor program (HED), and The American University in Cairo's College of Engineering and Architecture (AUC), sponsored by the Center for Middle Eastern Studies (CMES) under the Aspen Institute Stevens Initiative.

I. Introduction:

The Aspen Institute Stevens Initiative is founded upon the principal of giving young people the knowledge, skills, and experiences they need to prosper in an interconnected world. It is an international effort to build career and global competence skills for young people in the United States and the Middle East and North Africa by growing and enhancing the field of virtual exchange: online, international, and collaborative learning.

The University of Arizona Center for Middle Eastern Studies as a recipient of a Stevens Initiative grant collaborated with the College of Electrical Engineering and the College of Architecture, Planning, and Landscape Architecture (CAPLA) House Energy Doctor (HED) program to develop a 5-sessions short curriculum with one Middle Eastern country as an application for collaborative learning in a virtual exchange mode. The College of Engineering and Architecture at the American University in Cairo has been selected for this collaboration.

The "***Smart Building Technologies that achieve Energy Efficiency Design and Ratings in Commercial Buildings***" curriculum has been developed by three professors from both the University of Arizona and the American University in Cairo. Professor Salim Hariri from the University of Arizona's College of Electrical Engineering developed the education sessions on Smart Building Technology. Professor Nader Chalfoun, director of the HED program at the University of Arizona's College of Architecture developed the Energy Efficiency Design and building Rating system. And Professor Khaled Tarbieh developed the last education session on Daylight. This curriculum contributes to the Aspen Institute Stevens Initiative goals as it exemplifies how the Student Action Learning and Mentoring (SALAM) program is utilized to support courses at participating universities by integrating deep and interactive vertical exchange activities into interdisciplinary course curriculum.

II. Project Description:

The "***Smart Building Technologies that achieve Energy Efficiency Design and Ratings in Commercial Buildings***" curriculum is a project that demonstrates how two university curricula from two continents collaborate on the learning of how to examine a commercial building by integrating smart technology and evaluating its energy efficiency compliance with international codes and enhance its efficiency through energy saving strategies. These two participating universities are 1) The University of Arizona (UA) and 2) the American University of Cairo (AUC).

The curriculum will be offered through four two-hour virtual exchange sessions between the TAs of the two courses and the participating students. It is expected that a series of follow up exchange sessions will be conducted outside of the classroom between the students.

The curriculum will focus on the following SIX objectives:

1. Introduce the students to new knowledge related to Smart Building Technology (SBT) including remote control of building parameters.
2. Increase awareness level on energy efficiency strategies
3. Understand the different methods available for rating and testing energy code compliance of commercial buildings
4. Learning to run and operate a computer software that simulates and predicts the energy compliance degree conforming to the specific energy efficiency code for a region
5. Examine and optimize the energy efficiency of commercial buildings by running different strategies to achieve high performance status
6. Develop advanced digital presentations that demonstrates students learning on how to document and present the project findings to their peers, colleagues, and the professional community

Left: Smart Building Technology, center: HED Commercial Building, and right: Daylight Analysis

III. Project Participants:

Teaching

The University of Arizona Electrical Engineering course: "Smart Building Technologies"

- Professor: Salim Hariri hariri@email.arizona.edu
- Teaching Assistants: Pratik Satam: pratiksatam@email.arizona.edu

The University of Arizona HED Course: 461E/561E Sustainable Design and the LEED Initiative

- Professor: Nader Chalfoun chalfoun@email.arizona.edu
- Teaching Assistants: Rachelle Hornby rlhornby@email.arizona.edu

The American University in Cairo Course: ARCH3554 Sustainability in Architectural Design

- Professor: Khaled Tarabieh ktarabieh@aucegypt.edu
- Teaching Assistants: Mirette Khorshid mkhorshed@aucegypt.edu
  Mariam El Hussieny mariam.elhussainy@aucegypt.edu

Administration

Project Lead : Julie Ellison jellison@email.arizona.edu
Project Liaison : Dale LaFleur dlafleur@email.arizona.edu
Lisa Turker lturker@email.arizona.edu
Mohamed Menza: mifahmy@aucegypt.edu

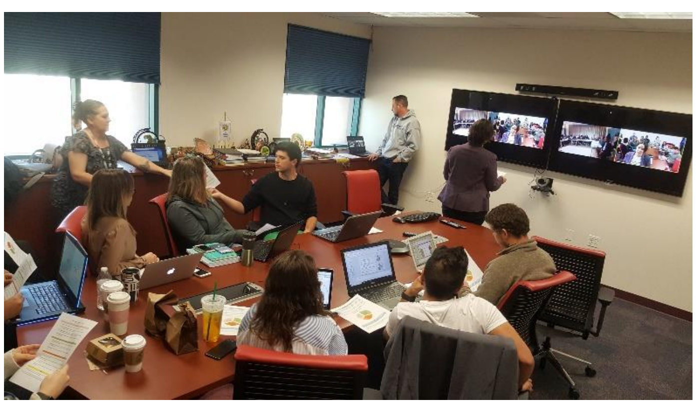
Technology

University of Arizona Information Technology Manager: Lucas Guthrie dlafleur@email.arizona.edu
American University in Cairo Multimedia Services Specialist: Tarek Maghraby tarek_t@aucegypt.edu

IV. Project Schedule and Details:

The "Smart Building Technologies *for Commercial Buildings*" project will be executed during the 2019 Spring Semester. The project is comprised of five major HIVE sessions:

Pre-Session	Thursday Feb 7, 2019	9:00 - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)
Session 1	Thursday Feb 21, 2019	9:00 - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)
Session 2	Thursday Mar 14, 2019	9:00 - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)
Session 3	Thursday Mar 28, 2019	9:00 - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)
Session 4	Thursday Apr 11, 2019	9:00 - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)



HED Students, Fall 2018 HIVE session

CURRICULUM ACTIVITIES

Pre-Session: Initialization of Spring 2019 Project (Faculty and TAs only)

1. Introductions between the universities and organizations from the two countries
2. Faculty will collaborate on the developed and distribute the course curriculum
3. TAs from both universities will prepare a short introduction to the project to recruit the students
4. Participating students will be added to the D2Lcommunity site or any other virtual meeting media.
5. Training session to demonstrate the use of the virtual classroom
6. Course packet distributed for all participating students

Session 1: Introduction to Smart Building Technologies and Exercise #1

1. Introduction to syllabus and projects (faculty and TAs) (10 minutes)
2. Dr. Salim will introduce the “Smart Building Technology” project
3. Following the introduction, a full lecture about the smart building project and the technology being used, Raspberry Pi, micro controllers and sensors.
4. Demonstration on how to write a simple program applied to the Smart Building project that includes how to modify the program to change the color, turn on/off fan, light, etc.
5. A camera in the ECE lab will be pointing at the “Smart House” model to demonstrate the program and so they can see how it affects the house. When they do the experiment remotely next session, they will also be able to see the impact.

Session 2: Students presenting their Smart Building projects + distribution of exercise #2

1. Students presenting exercise #1 while the model will display the results of their presentations on the “Smart House” model.
2. Exercise #2 “achieving code compliance for the HED Office Building” as follows:
   a. Introduction to major energy efficiency strategies to be researched by student team
   b. Introduction to the HED commercial office building and distribution of drawings
   c. Identify ComCheck as the energy efficiency simulation and prediction and assign downloading and installation of ComCheck to benchmark code compliance.
   d. Step by Step input of HED data to ComCheck

Session 3: ASHRAE + Basecase + COMcheck Presentations and Exercise #3

1. Each group of students will demonstrate how they achieved code compliance with the HED commercial office building project
2. Students will receive introduction on daylight by AUC TAs
3. Exercise #3: “Daylight Prediction and Analysis in Commercial Building”

Session 4: HED Compliance and Final Project Presentations

1. Each group of students will present their project on the use of daylight and their conclusion.
2. Faculty and TAs will evaluate the learning principles and pedagogy as conforming to the Stevens Initiative objectives and goals.
3. A certificate of participation will be awarded to participating students from both universities, including the faculty and TAs.

Throughout all the session and between the sessions:

1. Collaboration between the two university teams is encouraged and will emphasis the Stevens Initiative Objectives.
2. Faculty and teaching assistants from both university programs are also encouraged to maintain their dialogue with each other as well as advising and mentoring the students.

V. Project Benefit:

Education Enrichment: Students will have the opportunity to participate in a unique intercultural education experience. This project will establish the third Stevens Initiative collaboration at the University of Arizona. Students will develop skills necessary to collaborate on a global scale and a new learning dimension. Upon completion of the project students will be awarded a certificate of participation, and the ability to add a unique and one-of-a-kind collaborative experience to their resume.

Left: House Energy Doctor students receiving certificates, right: certificates distribute at the American University in Cairo

Cultural Enhancement: Students will also have the opportunity to build professional and personal relationships with the students, faculty, and staff from AUC. This relation will provide the potential to be developed into future travel and exchange endeavors.

American University in Cairo Faculty and Students

Social Entertainment: Each session pizza will be provided to participants, and the final session Middle Eastern cuisine will be provided, enhancing the cross-cultural experience.

APPENDIX

SPRING 2019

- **Pre-Session: Initialization of 2019 Project**
  Thursday Feb 7, 2019 |9:00 AM - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)
- **Session1_Smart Building Technology I**
  Thursday Feb 21, 2019 | 9:00 AM - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)
- **Session2_ Smart Building Technology II**
  Thursday Mar 14, 2019 | 9:00 AM - 11:00 AM Tucson Time (6:00-8:00 Cairo Time)
- **Session3_ ASHRAE+Basecase+ComCheck**
  Thursday Mar 28, 2019 | 9:00 AM - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)
- **Session4_Daylight Analysis**
  Thursday April 11, 2019 | 9:00 AM - 11:00 AM Tucson Time (6:00-8:00 PM Cairo Time)

SESSIONS 1 & 2

SMART BUILDING TECHNOLOGY

Professor **Salim Hariri** hariri@email.arizona.edu
Teaching Assistant **Pratik Satam** pratiksatam@email.arizona.edu

Project name: Smart Building Testbed Training System

Objective: To train students on the Smart Buildings technology.

Introduction
A Smart Building (SB) is a facility whose characteristics change with the time, it can react to the internal and/or external environment changes without human interaction in order to provide comfort to the occupants and, while taking into consideration financial and energetic perspectives. Smart Buildings combine real-time monitoring with event management and data analytics to help managers to optimize the available resources, and enhance reliability, some of their main characteristics are:

- They improve reliability and performance to reduce energy consumption.
- Lower maintenance and management are needed, as consequence, operating costs are reduced.
- Captured data can be used to perform energy analytics.
- All the metrics can be collected in a repository for future analysis.
- Real-time events can be centralized for consolidation, correlation or to initiate certain action when a service is requested.
- Anomalies can be detected by applying analytical rules.
- Analyze historical data to identify trends and perform corrective actions.
- Create scenarios to perform context awareness.

In order to handle all the described characteristics, SBs need to have the capability to be programmed to follow certain rules.

Proposal
The Smart Home Testbed (SHT) at the Autonomic Computing Laboratory at the University of Arizona contains all the characteristics and capabilities of a Smart Building. It can be used to train students and professionals in the SB technology. The target is to build a virtual environment connected to the SBT and make it available to be programmed by anyone (with the right credential) from anywhere. Figure 1 shows the 4-layer architecture for the proposed SBT Training System.

- Perception layer (things): In this layer we find all the sensors (temperature, motion, light, distance) and actuators (fan, door lock, lights) necessary to enable the interaction between physical and virtual worlds. The information obtained by sensors is sent to the gateway to be pre-analyzed.

- Communications layer: In this layer all the information gathered in the gateway is sent to the cloud to be stored and analyzed. This layer is responsible for reliable communication with other local systems and cloud services. We created a secure Gateway with a Raspberry Pi to carry out the communications.
- Services layer: At this layer, all the required computational power is mostly provided using cloud services. This layer is used for remotely monitoring and controlling the system, as well as to store data and analyze large amount of information. We can use any cloud provider (Amazon Web Services, Microsoft Azure, etc.) to store information and to create a web interface.
- Application layer: In this layer the users interact with the whole system, the idea is to have a friendly user interface where users are able to write and execute code. This website will show in real time (video) the results of the executed code.

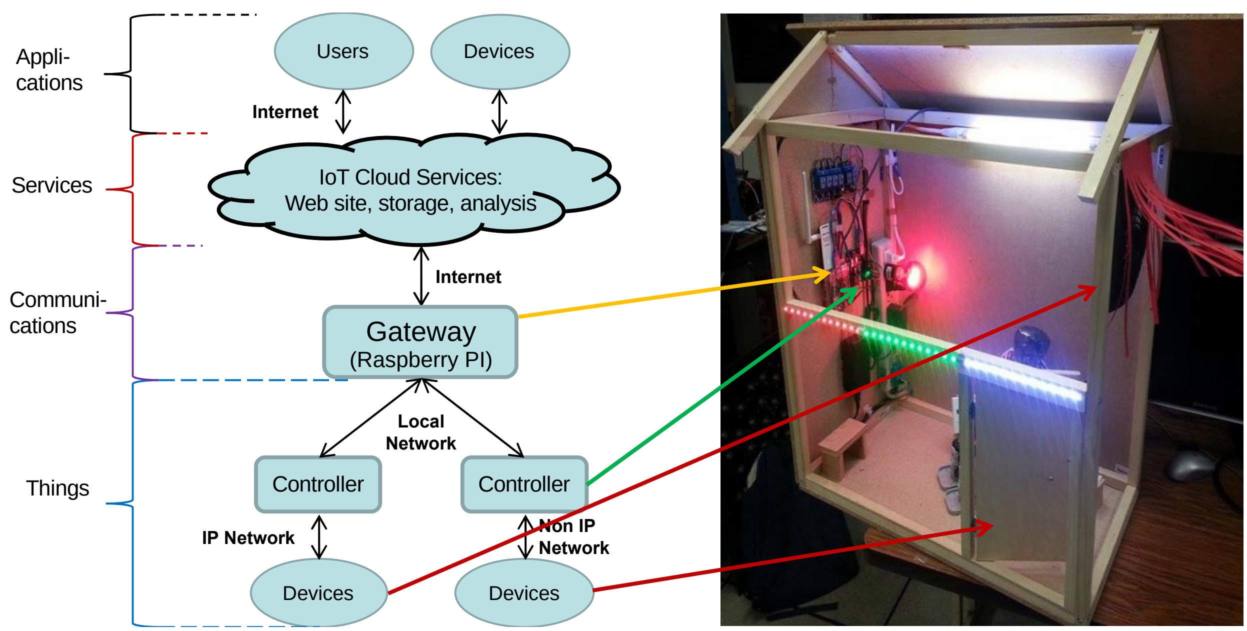


Figure 1. Smart Home Testbed Training System

In this project, students will do the following tasks:

1. Learn about Sensor Technologies used by Smart Buildings that will include Light sensor, Temperature sensor, door opener, etc.
2. Learn about micro controller technology that will be used to remotely control and manage sensors and actuators such as Microduino and Arduino

3. Learn about Micro Server technology that will be the main server that can be programmed to control SB sensors and actuators. Students will learn how to program the server using Raspberry PI technology
4. Learn about wireless network, Wi-Fi that will be used to communicate among all SB sensors, actuators and the Server (Raspberry PI)
5. Write several programs to remotely turn on/off sensors and actuators inside the smart building/house. (

SESSION 3

ASHRAE+HED Basecase +COM*check*

Professor **Nader Chalfoun** chalfoun@email.arizona.edu
Teaching Assistant **Rachelle Hornby** rlhornby@email.arizona.edu

1. Introduction to COMcheck

When adopted, implemented, and enforced, stronger energy codes mean more energy-efficient buildings. For consumers, conserving energy through energy-efficient buildings means lower energy bills. For the environment and our Nation, conserving energy lowers our demand for fossil fuels and our dependence on imported energy, decreases our need for new power generation, and reduces pollution.

The U.S. Department of Energy (DOE) is working to improve the energy efficiency of the Nation's buildings through new technologies and better building practices. DOE's ***Building Energy Codes Program*** is an information resource on national model energy codes. DOE work with other government agencies, state and local jurisdictions, national code organizations, and industry to promote stronger building energy codes and help states adopt, implement, and enforce those codes.

DOE is involved in five major areas to help improve the energy efficiency of residential and commercial buildings:

1. help develop improved national model energy codes
2. help develop improved Federal building energy codes
3. develop and distribute easy-to-use compliance tools and materials
4. provide financial and technical assistance to help states adopt, implement, and enforce building energy codes
5. collaborate with stakeholders to address industry needs and provide information on compliance products and training and energy code-related news

DOE's $37.5 million investment in its ***Building Energy Codes Program*** has resulted in energy savings of nearly $1 billion per year. The efforts have improved the energy efficiency of nearly 3 billion square feet of new commercial floor space and nearly 4 million new households. The cumulative energy cost savings from the Program is estimated to be over $4.2 billion as of 2001 - enough to provide all of the energy requirements for over 3 million homes for a year. Every $1 spent on the Program has yielded more than $105 in annual energy savings.

The ***Building Energy Codes Program*** is helping to continue this trend. Program activities are projected to reduce the Nation's primary energy use in 2010 by $7 billion in residential buildings and $3.3 billion in commercial buildings. By 2030, consumers are projected to save $5.3 billion in energy costs, the environment is projected to benefit from a reduction in carbon emissions of 13.2 MMton, and the Nation is projected to reduce its primary energy use by 718 TBtu annually.

DOE develop and distribute compliance tools and materials that make it easier for designers, builders, product manufacturers, and code officials to comply with energy codes based on the

IECC or ASHRAE/IESNA Standard 90.1 requirements. The RES*check*™ (Formerly MEC*check*™), COM*chec*™, and COM*check*-Plus™ compliance products include software and accompanying user's guides, videos, training materials, and compliance manuals.

<u>COM*check*™ :</u>

The COMcheck product group makes it easy for architects, builders, designers, and contractors to determine whether new commercial or high-rise residential buildings, additions, and alterations meet the requirements of the IECC and ASHRAE Standard 90.1, as well as several state-specific codes. COMcheck also simplifies compliance for building officials, plan checkers, and inspectors by allowing them to quickly determine if a building project meets the code. COMcheck Desktop can be downloaded and installed directly to your desktop, while COMcheck-Web™ is accessible directly from the website without having to download and install.

COM*check* 4.4.2.5

How does COMcheck clarify and simplify commercial energy codes?

COMcheck offers an easy-to-understand process for demonstrating compliance with all commercial energy code requirements for envelope, lighting, and mechanical systems. It eliminates calculation tasks other than determining square footages and requires no specialized technical knowledge of commercial codes. When applied to simple buildings, it is self-contained, requiring no additional resources or reference books. Finally, COMcheck uses terminology familiar to the design, construction and enforcement communities.

What are the limitations of COMcheck?

COMcheck is intended for commercial buildings. The current software version includes requirements for simple and complex HVAC systems. Infrequently used code provisions, such as credits for automatic lighting controls for day lighting, are not included in COMcheck.

Where can COMcheck be utilized?

Jurisdictions that have adopted or incorporated ASHRAE/IES 90.1-2007/2010/2013 or the 2009, 2012, and 2013 2006 IECC as their code or who have adopted codes based these codes can use COMcheck. As with any code-related question, the adopting jurisdiction is the final authority.

INPUT INFORMATION

How do I know whether I am expected to enter an area or a perimeter length?

The column for entering dimensional data on the Envelope screen has the heading Gross Area or Perimeter. All envelope assemblies are entered as areas except for concrete slab-on-grade assemblies, which are entered as the length of exposed perimeter in feet. Instructions for most input fields can be accessed by pressing the <F1> key when that field is current. In addition, when the user is required to input a perimeter length, the unit "ft" is displayed next to the input field.

What is the difference between cavity and continuous insulation?

The terms cavity and continuous insulation are used throughout the COMcheck-EZ software to distinguish between insulation that is affected by thermal bridging (cavity) and insulation that is not affected (continuous). Cavity insulation is insulation installed in the cavities between structural members, such as wood studs, metal framing, and Z-clips, while continuous insulation runs continuously over structural members and is free of significant thermal bridges. Continuous insulation typically is rigid foam board. For additional information on this and other topics, click on the relevant input field and press <F1> to view the help messages.

Can I trade over-compliance on the Envelope result for under-compliance on the Lighting result, and vice versa?
COMcheck-EZ displays compliance results at the bottom of the screen for Envelope and Lighting. **Trade-offs between major sections of the code are not supported by the COMcheck-EZ software**. The COMcheck-Plus™ software does support this kind of trade-off. For more information about commercial compliance approaches see our Commercial Compliance FAQs.

Q: What do the colors used in input and compliance fields mean?
Colors used in input fields have the following meaning:

- Black text on white text indicates the data is editable by the user.
- Black text on gray text indicates the data was calculated by the program and is not directly editable by the user.
- Red text on white text indicates data is either missing or not within a valid range.
- White text on red is displayed in the U-factor field of an envelope assembly which violates a mandatory code requirement. A building DOES NOT comply if any U-factor field violates mandatory requirements, even if overall compliance is achieved and the compliance message states that the building passes.

Colors used in compliance fields have the following meaning:

- Red compliance results indicate the design does not comply.
- Green compliance results indicate the design complies.
- The letters TBD (to be determined) indicate you have provided insufficient data for the compliance calculation to be performed. To determine which data is invalid, look for fields with red text on white. In addition to providing inputs for all red on white fields, you must select at least one building use type on the Project screen before compliance can be determined.

Q: What buildings are covered by the COMcheck products?
COMcheck products provides an optional way to demonstrate energy code compliance with commercial and high-rise residential buildings (greater than three stories). You can use COMcheck to demonstrate energy code compliance in the design and construction of most types of commercial and high-rise residential buildings.

Applicable building types include:

- offices
- retail, grocery, and wholesale stores
- restaurants
- assembly and conference areas
- industrial work buildings
- commercial or industrial warehouses
- schools and churches
- theaters
- apartment buildings and condominiums with four or more habitable stories
- hotels and motels

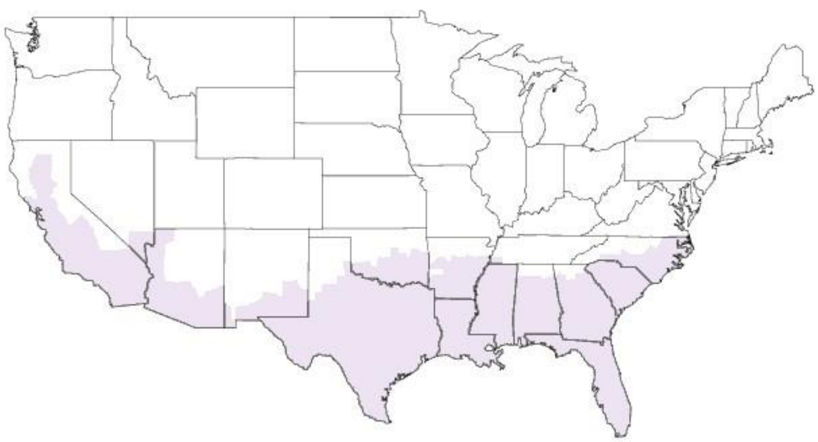
COMcheck new release features:

Solar Heat Gain Coefficient (SHGC) FAQs

If you have questions about the most recent energy code and solar heat gain coefficients (SHGC), the following frequently asked questions may help. If you have additional questions feel free to contact our technical support staff (techsupport@becp.pnl.gov).

In Chapter 5 of the 2000/2001 IECC, Section 502.1.5, the code states that in locations with heating degree-days (HDD) less than 3500 (Climate Zones 7 or less), the area-weighted average SHGC of all glazed fenestration products (including the effect of any permanent exterior solar shading devices) in the building shall not exceed 0.4. The following map shows locations with less than 3500 HDDs.

Locations Below 3,500 HDD



a: What is a SHGC?

Solar Heat Gain Coefficient (SHGC) measures how well a product blocks heat caused by sunlight. The SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed, then subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's SHGC, the less solar heat it transmits.

The relationship between SGHC and SC is
SHGC = SC*0.87.

b: How do I find the SHGC for my windows?

The solar heat gain coefficient (SHGC) may be found on the National Fenestration Rating Council (NFRC) label affixed by the window manufacturer prior to purchase. Most residential windows are rated by NFRC and most new residential windows should have an NFRC label. If a window does not have a label (either because it has not been rated or because the label has been removed), you can either ask the window manufacturer to supply you this information or look up your specific window in the NFRC products directory at www.nfrc.org.

c. What is a U-Factor?

A: U-factor measures how well a product prevents heat from escaping. The rate of heat loss is indicated in terms of the U-factor of a window assembly. U-factor ratings generally fall between 0.20 and 1.20. The insulating value is indicated by the R-value, which is the inverse of the U-factor. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value. The U-factor is included in the energy performance rating (label) offered by the National Fenestration Rating Council (NFRC).

Product Type	Glass Only	Operable					Fixed					Curtain Wall		
Frame Type	n/a	Alum w.o. Therm Break	Alum with Therm Break	Re-inforced Vinyl/ Alum Clad Wood	Wood/ Vinyl	Insul Fibrglas /Vinyl	Alum w.o. Therm Break	Alum with Therm Break	Re-inforced Vinyl/ Alum Clad Wood	Wood/ Vinyl	Insul Fibrglas /Vinyl	Alum w.o. Therm Break	Alum with Therm Break	Struct Glzg
Glazing Type	Cntr-of-Glass													
Single Glazing														
1/8 in. glass	1.04	1.27	1.08	0.90	0.89	0.81	1.13	1.07	0.98	0.98	0.94	1.22	1.11	1.11
1/4 in. acrylic/polycarbonate	0.88	1.14	0.96	0.79	0.78	0.71	0.99	0.92	0.84	0.84	0.81	1.08	0.96	0.96
1/8 in. acrylic/polycarbonate	0.96	1.21	1.02	0.85	0.83	0.76	1.06	1.00	0.91	0.91	0.87	1.15	1.04	1.04
Double Glazing														
1/4 in. airspace	0.55	0.87	0.65	0.57	0.55	0.49	0.69	0.63	0.56	0.56	0.53	0.79	0.68	0.63
1/2 in. airspace	0.48	0.81	0.60	0.53	0.51	0.44	0.64	0.57	0.50	0.50	0.48	0.73	0.62	0.57
1/4 in. argon space	0.51	0.84	0.62	0.55	0.53	0.46	0.66	0.59	0.53	0.52	0.50	0.75	0.64	0.60
1/2 in. argon space	0.45	0.79	0.58	0.51	0.49	0.43	0.61	0.54	0.48	0.48	0.45	0.70	0.59	0.55
Double Glazing, e=0.40 surface 2 or 3														
1/4 in. airspace	0.49	0.82	0.61	0.53	0.51	0.45	0.64	0.58	0.51	0.51	0.49	0.74	0.63	0.58
1/2 in. airspace	0.40	0.75	0.54	0.48	0.45	0.40	0.57	0.50	0.44	0.44	0.41	0.66	0.55	0.51
1/4 in. argon space	0.43	0.78	0.57	0.50	0.47	0.41	0.59	0.53	0.46	0.46	0.44	0.69	0.57	0.53
1/2 in. argon space	0.36	0.72	0.52	0.45	0.43	0.37	0.53	0.47	0.41	0.40	0.38	0.63	0.51	0.47
Double Glazing, e=0.20 surface 2 or 3														
1/4 in. airspace	0.45	0.79	0.58	0.51	0.49	0.43	0.61	0.54	0.48	0.48	0.45	0.70	0.59	0.55
1/2 in. airspace	0.35	0.71	0.51	0.44	0.42	0.36	0.53	0.46	0.40	0.39	0.37	0.62	0.51	0.46
1/4 in. argon space	0.38	0.74	0.53	0.46	0.44	0.38	0.55	0.48	0.42	0.42	0.40	0.64	0.53	0.49
1/2 in. argon space	0.30	0.67	0.47	0.41	0.39	0.33	0.48	0.41	0.36	0.35	0.33	0.57	0.46	0.42
Double Glazing, e=0.10 surface 2 or 3														
1/4 in. airspace	0.42	0.77	0.56	0.49	0.47	0.41	0.59	0.52	0.46	0.45	0.43	0.68	0.57	0.52
1/2 in. airspace	0.32	0.69	0.49	0.42	0.40	0.35	0.50	0.43	0.37	0.37	0.35	0.59	0.48	0.44
1/4 in. argon space	0.35	0.71	0.51	0.44	0.42	0.36	0.53	0.46	0.40	0.39	0.37	0.62	0.51	0.46
1/2 in. argon space	0.27	0.65	0.45	0.39	0.37	0.31	0.46	0.39	0.33	0.33	0.31	0.55	0.44	0.39
Double Glazing, e=0.05 surface 2 or 3														
1/4 in. airspace	0.41	0.76	0.55	0.48	0.46	0.40	0.58	0.51	0.45	0.44	0.42	0.67	0.56	0.51
1/2 in. airspace	0.30	0.67	0.47	0.41	0.39	0.33	0.48	0.41	0.36	0.35	0.33	0.57	0.46	0.42
1/4 in. argon space	0.33	0.70	0.49	0.43	0.41	0.35	0.51	0.44	0.38	0.38	0.36	0.60	0.49	0.44
1/2 in. argon space	0.25	0.63	0.44	0.38	0.36	0.30	0.44	0.37	0.32	0.31	0.29	0.53	0.42	0.38
Triple Glazing														
1/4 in. air spaces	0.38	0.72	0.51	0.44	0.43	0.38	0.55	0.48	0.42	0.41	0.40	0.63	0.52	0.47
1/2 in. air spaces	0.31	0.67	0.46	0.40	0.39	0.34	0.49	0.42	0.36	0.35	0.34	0.57	0.46	0.41
1/4 in. argon spaces	0.34	0.69	0.48	0.42	0.41	0.35	0.51	0.45	0.39	0.38	0.36	0.60	0.49	0.43
1/2 in. argon spaces	0.29	0.65	0.44	0.38	0.37	0.32	0.47	0.40	0.34	0.34	0.32	0.55	0.45	0.39
Triple Glazing, e=0.20 [a]														
1/4 in. air spaces	0.33	0.69	0.47	0.41	0.40	0.35	0.50	0.44	0.38	0.37	0.36	0.59	0.48	0.42
1/2 in. air spaces	0.25	0.62	0.41	0.36	0.35	0.30	0.43	0.37	0.31	0.30	0.29	0.52	0.41	0.35
1/4 in. argon spaces	0.28	0.65	0.44	0.38	0.37	0.32	0.46	0.40	0.34	0.33	0.32	0.54	0.44	0.38
1/2 in. argon spaces	0.22	0.60	0.39	0.34	0.33	0.28	0.41	0.34	0.29	0.28	0.27	0.49	0.38	0.33
Triple Glazing, e=0.20 [b]														
1/4 in. air spaces	0.29	0.65	0.44	0.38	0.37	0.32	0.47	0.40	0.34	0.34	0.32	0.55	0.45	0.39
1/2 in. air spaces	0.20	0.58	0.38	0.32	0.31	0.27	0.39	0.33	0.27	0.26	0.25	0.48	0.37	0.31
1/4 in. argon spaces	0.23	0.61	0.40	0.34	0.33	0.29	0.42	0.35	0.30	0.29	0.28	0.50	0.39	0.34
1/2 in. argon spaces	0.17	0.56	0.36	0.30	0.29	0.25	0.37	0.30	0.25	0.24	0.23	0.45	0.34	0.29
Triple Glazing, e=0.10 [a]														
1/4 in. air spaces	0.27	0.64	0.43	0.37	0.36	0.31	0.45	0.39	0.33	0.32	0.31	0.54	0.43	0.37
1/2 in. air spaces	0.18	0.57	0.36	0.31	0.30	0.25	0.37	0.31	0.25	0.25	0.23	0.46	0.35	0.29
1/4 in. argon spaces	0.21	0.59	0.39	0.33	0.32	0.27	0.40	0.34	0.28	0.27	0.26	0.48	0.38	0.32
1/2 in. argon spaces	0.14	0.54	0.33	0.28	0.27	0.23	0.34	0.28	0.22	0.21	0.20	0.42	0.32	0.26

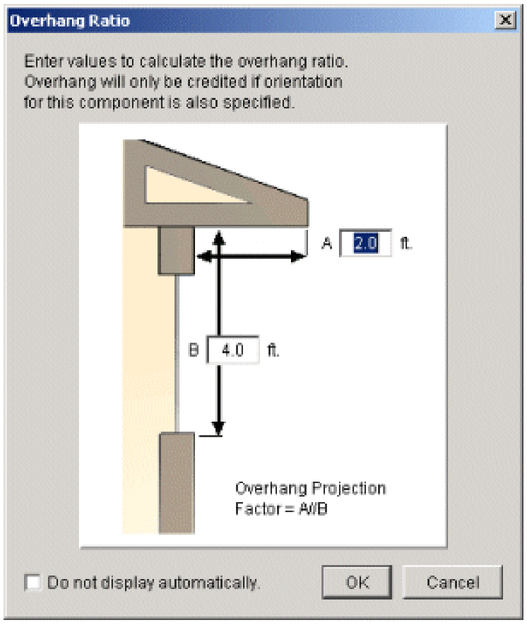
Sample table of windows U-Factors

U-Factor

Values are based onthe 2005 ASHRAEHandbook ofFundamentals, Table30-4.Interpolate betweenemissivities whenneeded. Whenmanufacturer's datais not available,assume that glasswith a pyrolytic (hard)coating has anemmisivity of 0.40and glass with asputtered (soft)coating has anemissivity of 0.10.Krypton gas fills, orkrypton/argoncombinations

can besubstituted for argon.For glazing airspacebetween ¼ inch and½ inch, use ¼ inch.For glazing airspaceover ½ inch, use ½inch.d: What is a Projection Factor?

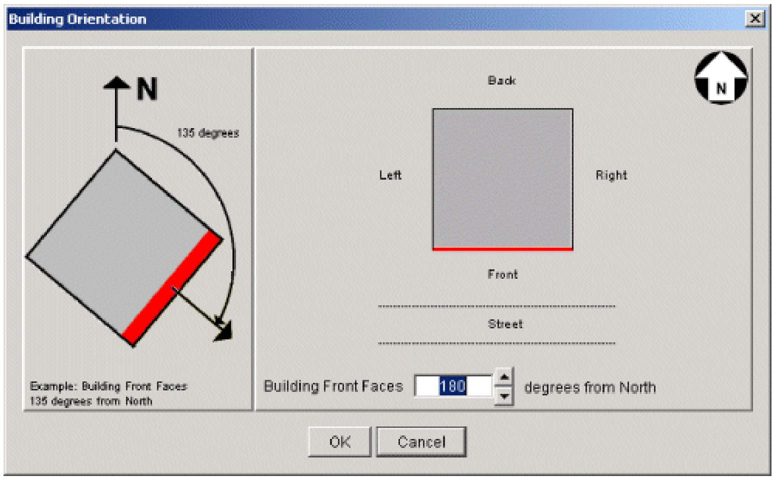
The projection factor enables you to characterize the shading impact of horizontal overhangs or canopies that project outward from the plane of the window. The projection factor is the ratio of the distance the overhang projects from the window surface to its height above the sill of the window it shades. In the figure shown, A/B = Projection Factor (2/4 = .5).



e. How do I demonstrate compliance with the SHGC requirements in the IECC?
If all your windows have an SHGC less than or equal to 0.4, then simply stating this fact on your compliance documentation should be adequate. If your windows do not meet this requirement, the software program now has an option for inputting SHGC, orientation, and overhang projection factors. This option is available for locations with Heating Degree Days (HDD) of less than 3500 and the trade-off credit is only given when orientation is specified. No other building components can be traded against SHGC. COM*check* retains the original intent of the SHGC requirement in the IECC, which was to not only reduce overall energy consumption, but to reduce the peak cooling load imposed by residences on electric utilities. In southern climates, cooling loads at peak times are becoming a very significant problem.

You may also use the area-weighted average SHGC if most of your windows meet the 0.4 requirement, but some do not. Just note the calculated average on the compliance documentation.

Orientation Option Inputs
The latest version of COM*check* allows the user to input the orientation of the building. This feature allows you to specify the angle of the building relative to North.



Skill Development Exercise 2

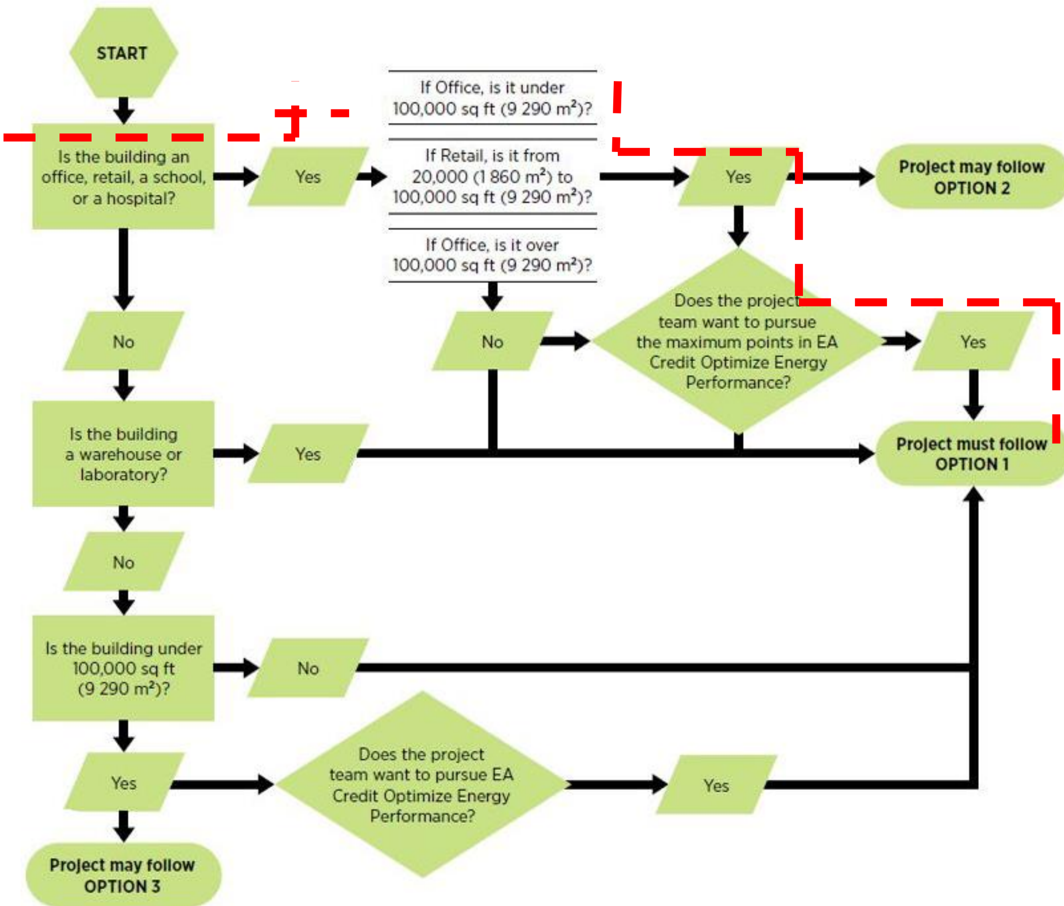
"The Worst Design Allowed by Code"

In this exercise you will attempt to comply our 7,920ft² "House Energy Doctor©" commercial office building located in Tucson, Arizona with the minimum energy performance code (or the worst case accepted by code).

Minimum Energy Performance

Intent: To reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency for the building and its systems.

We have 3 options: Which option should we choose? (We will not consider options 2 or 3)



Requirements for Option 1: Whole Building Energy Performance:(We will not consider options 2 or 3)

Demonstrate an improvement of 5% for new construction in the proposed building performance rating compared with the baseline building performance rating. Calculate the baseline building performance according to ANSI/ASHRAE/IESNA Standard 90.1–2010, Appendix G, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.), using a simulation model.

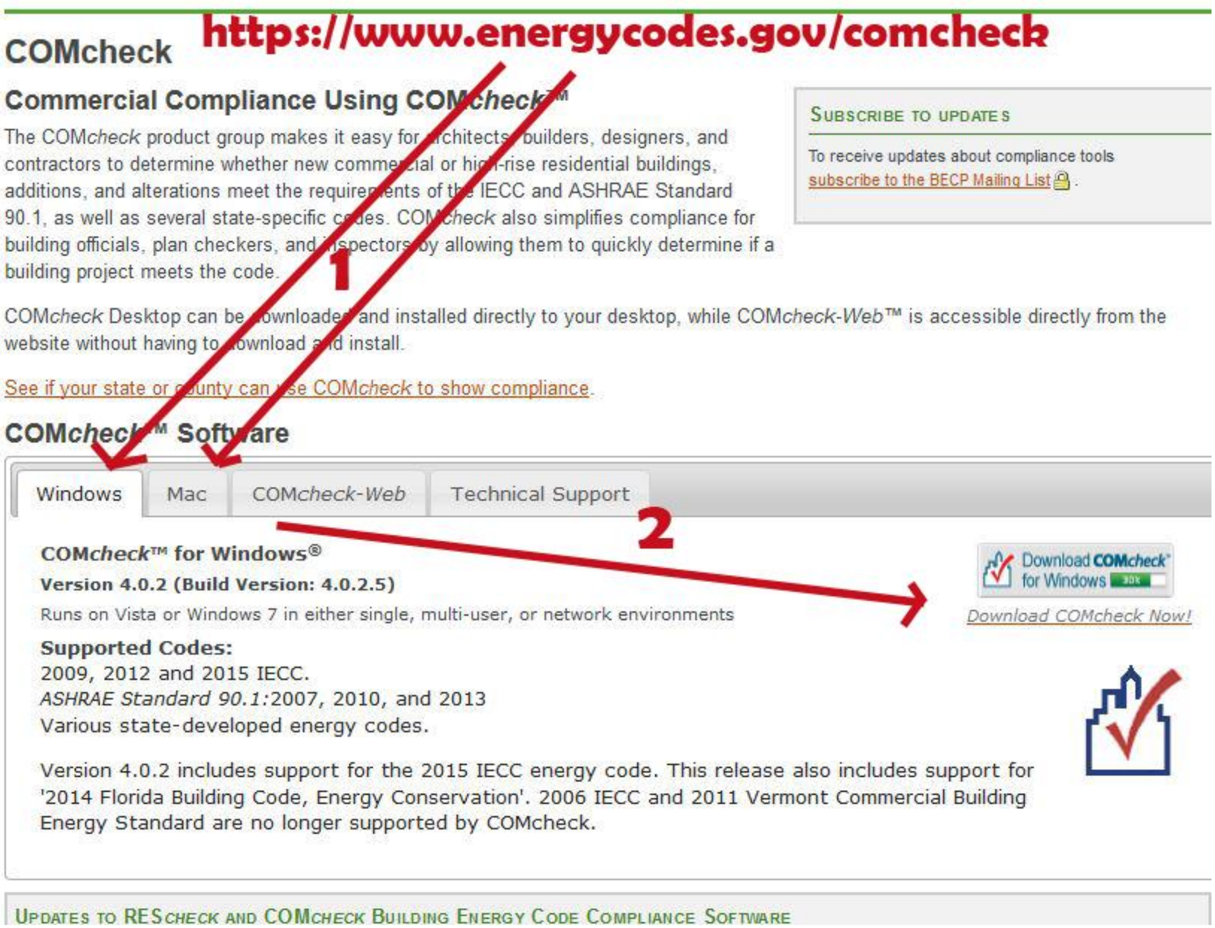
Tucson Data: *(ASHRAE 90.1, 2010 Table D-1 p.155)*

Latitude=32.13°N Longitude=110.93°W
Elevation=2,584ft
HDD65=1,678 CDD50=6,921

Start:

Consider the House Energy Doctor basecase 7,920ft² double story office building located in Tucson, Arizona and perform the following:

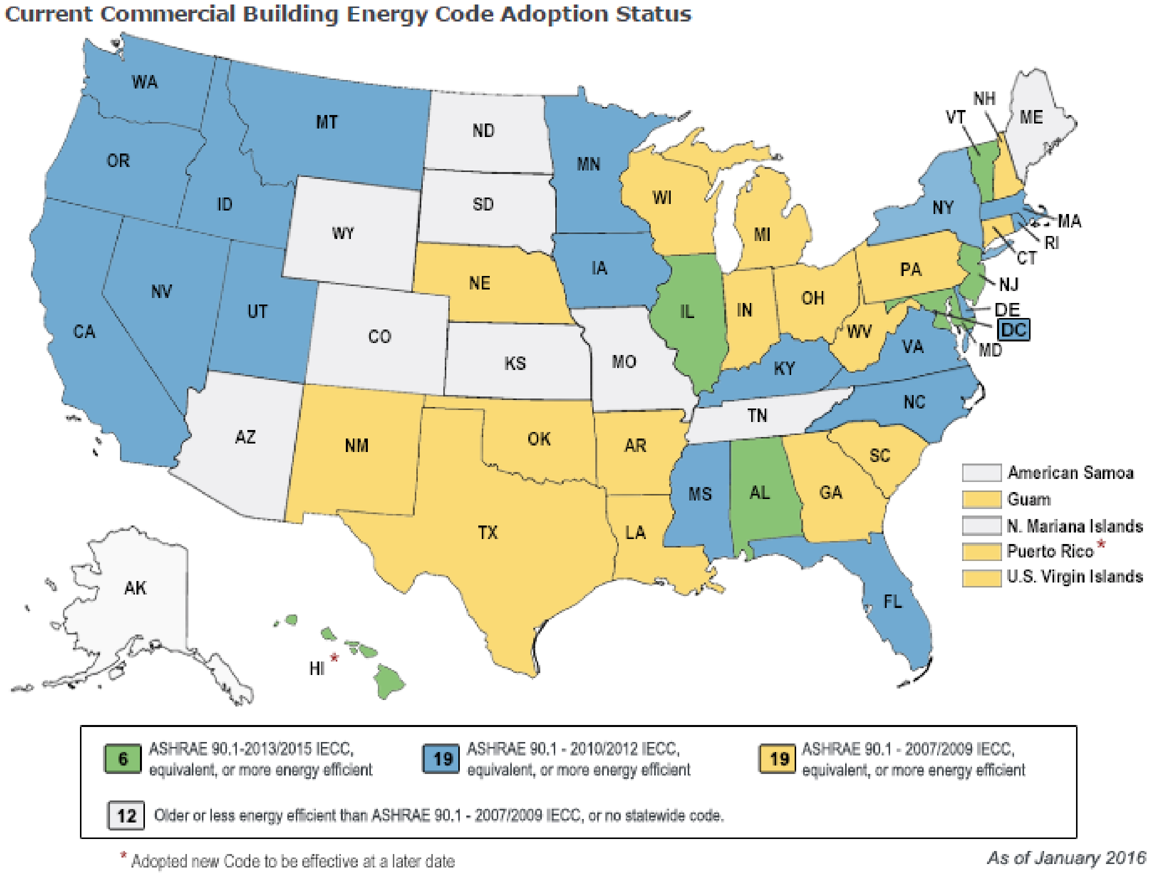
1. Input the basecase building data into the newest COM*check* code compliance computer software. you can download the latest version of the software from the COM*check website:* [*https://www.energycodes.gov/cvomcheck*](https://www.energycodes.gov/cvomcheck)



2. Use Tucson location and the Pima County IECC2012 code in COM*check* to predict and check if the basecase complies with that code.

3. Change the code to ASHRAE 90.1 2010, observe the deficiencies

4. Adjust the input values to achieve 90.1 2010 compliance



5. "Save" your PDF report (not .cck) and prepare a presentation for our next class meeting.

Exercise 2 Appendices

1. **HED Office Building Drawings**
2. **Basecase Building Schedule Table**
3. **ASHRAE 2010 Mandatory Tables**
4. **COMcheck Step-by-step**

1. HED Office Building

The basecase design is the "House Energy Doctor©" 7,920ft² commercial office building located on 4444 E. Broadway Blvd. in Tucson Arizona. The building is a two story steel stud and frame construction. Hight of each floor is 10' + 5' plenum. The entrance is a double height atrium (34 feet high) topped with a 4'X4" skylight and has a 19' 6" high X 23' wide double-glazed fixed window facing south. There are two entrances: from south is a 8" high X 23' wide double glazed sliding entrance door and from the north is 8' high X 8' wide double glazed sliding door.

General View

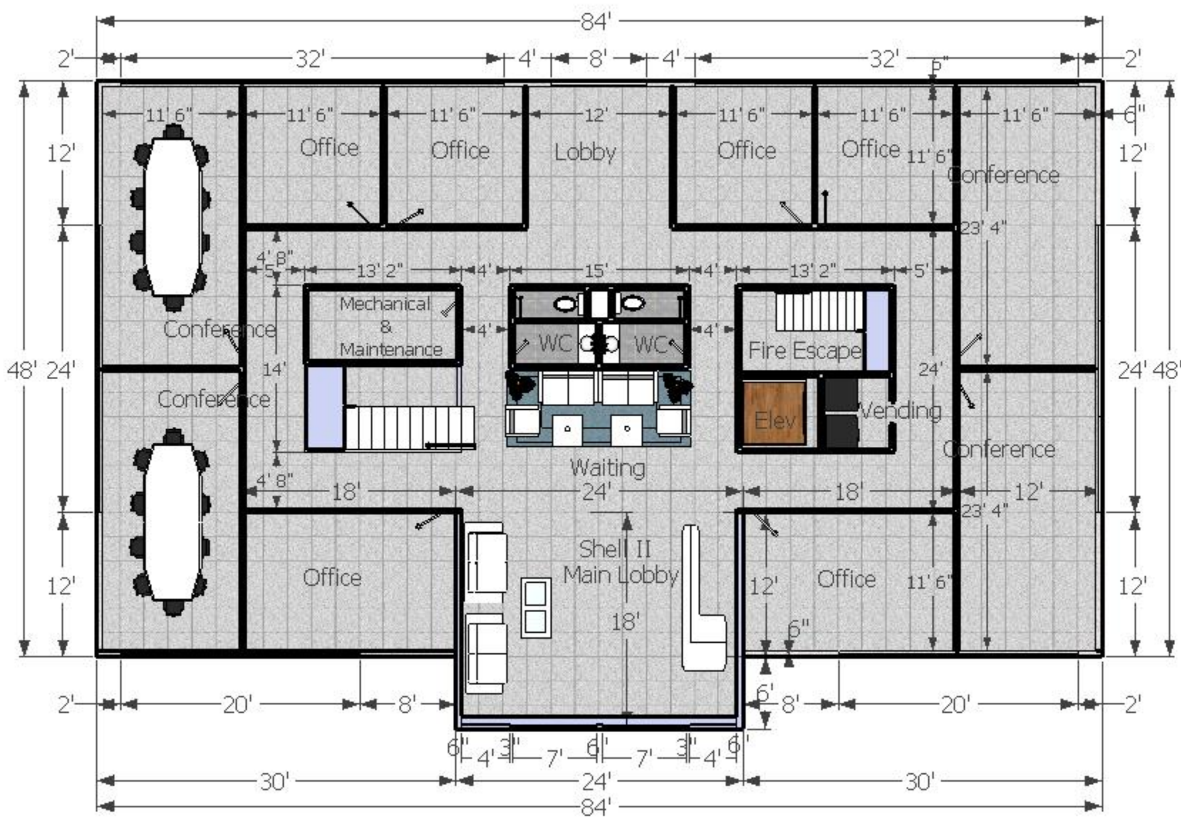
Note the bicycle racks, the proximity to a bus station, and the designated parking lots for alternative fuel cars are all credits for LEED NC.

Street Level View

Main Lobby

North View

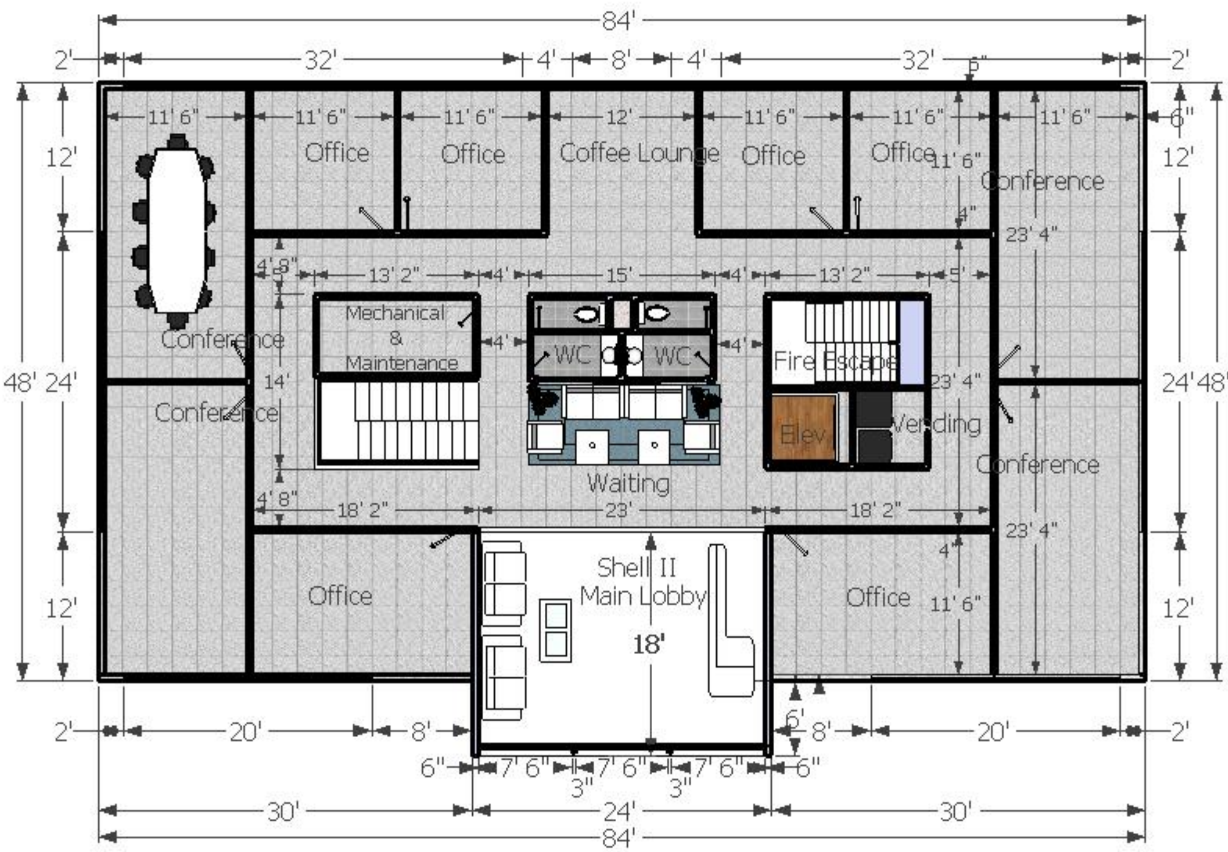
3-D View of the Ground Floor Level: showing the main lobby, bicycle racks, bus station and east parking



Ground Floor Plan: showing the conference rooms arranged along the east and west sides of the building while the office spaces are arranged at the north and south sides for daylight and views. The entrance is through the main lobby while another secondary entrance is located on the north side.

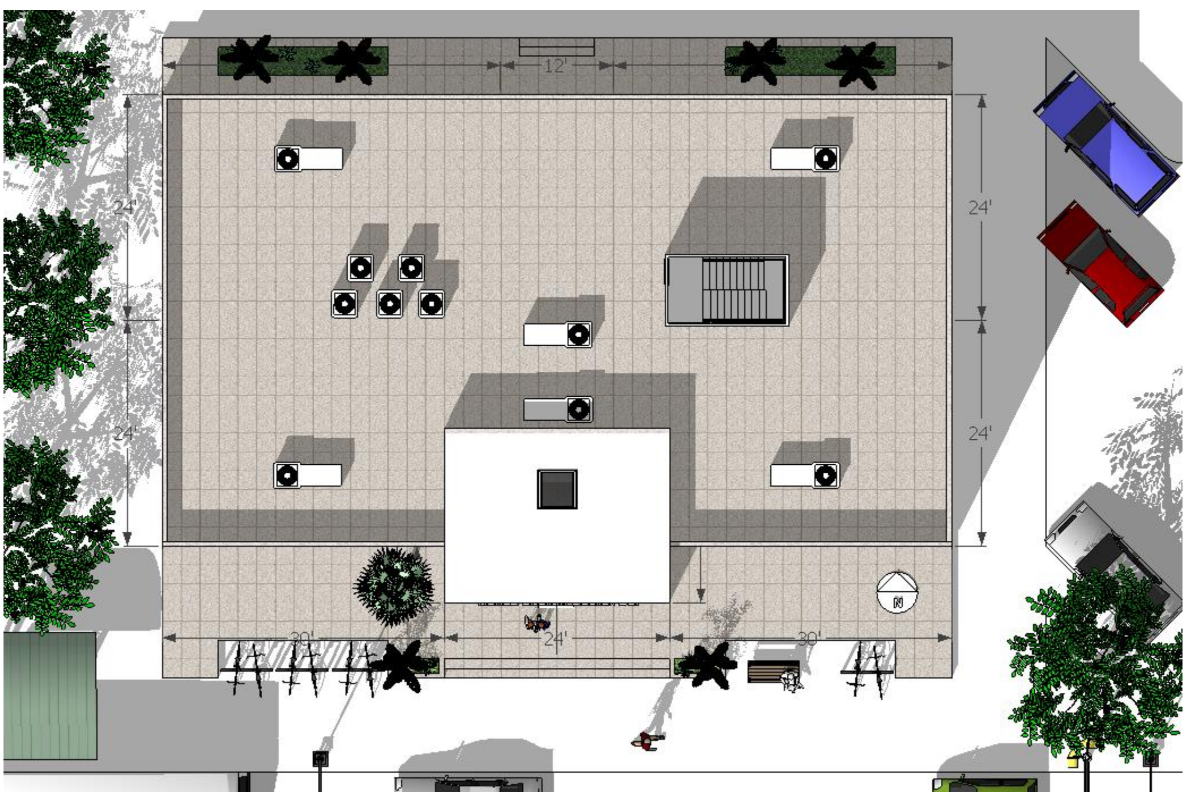
NOTE:
1. You need 2 building exits if occupancy is more than 50 people (7,920 ft²/200 ft² per person) = 39.6 or 40 persons
2. Toilets count is "1 toilet/10 people" so we need 4 toilets. Each floor will have 1 male and 1 female toilet

3-D View of the Upper Level



First Floor Plan: showing the conference rooms arranged along the east and west sides of the building while the office spaces are arranged at the north and south sides for daylight and views. The waiting area overlooks the double height south facing atrium.

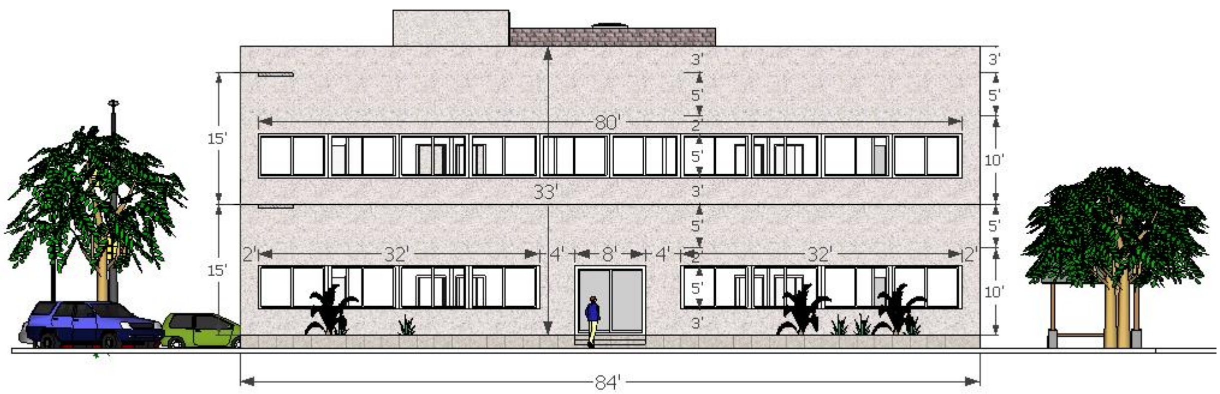
Roof View



Roof Plan: There are 6 packaged and 5 split-unit Single zone ducted return DX Coils heat pumps on the accessible roof. All units are <65,000 BTUh or 5.4 tons [65,000 ÷ 12,000 = 5.4 tons]. The cooling efficiency is SEER 13.00 and the Heating COP is 3.43 [Note: SEER X 0.9 = EER & EER ÷ 3.415 = COP & EIR = 1 ÷ COP].

South Facade

West Facade

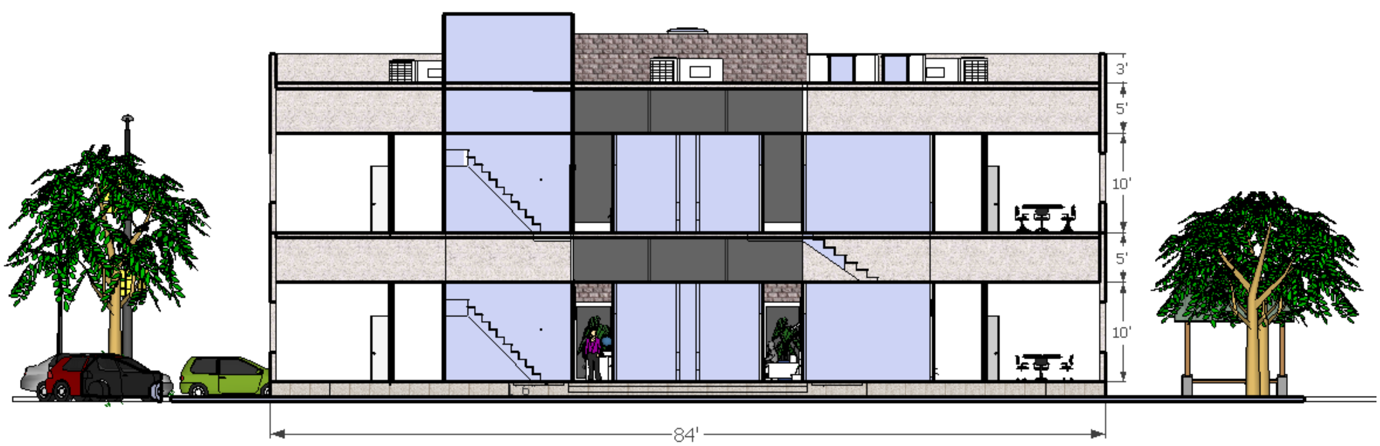


North Facade

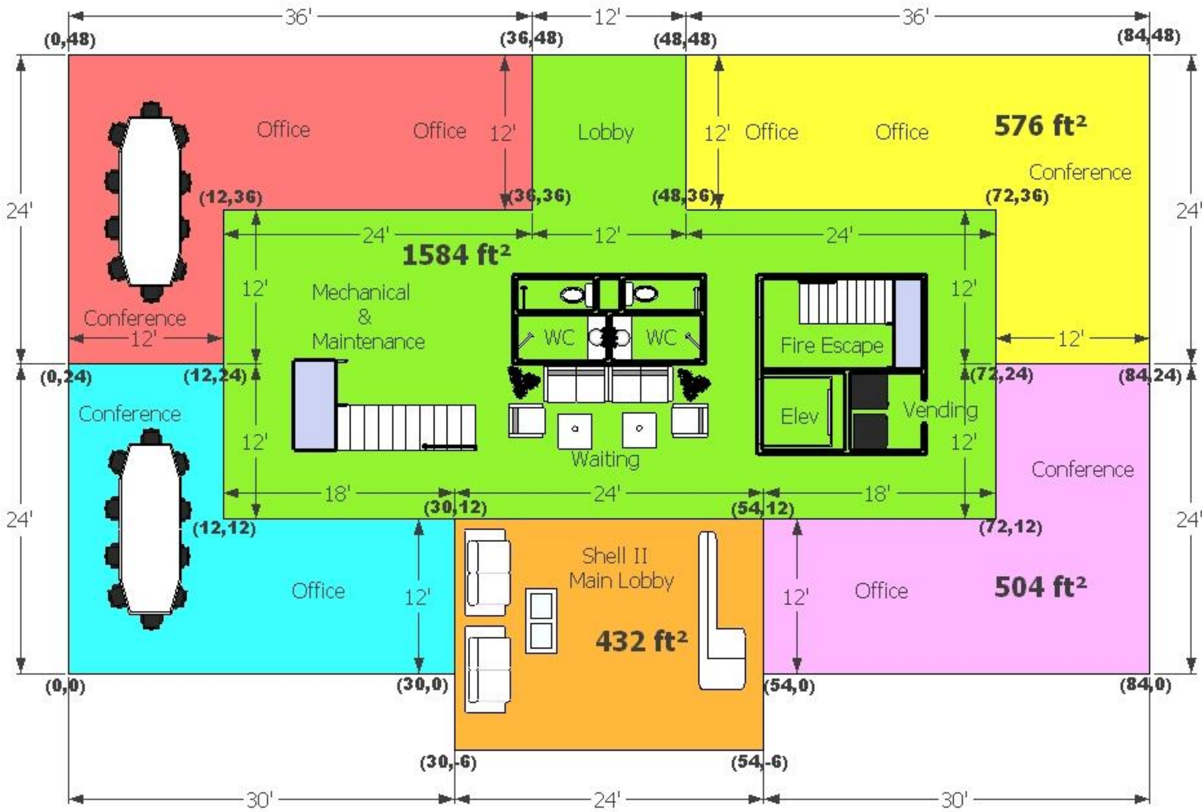
East Façade

North-South Section through Main Lobby

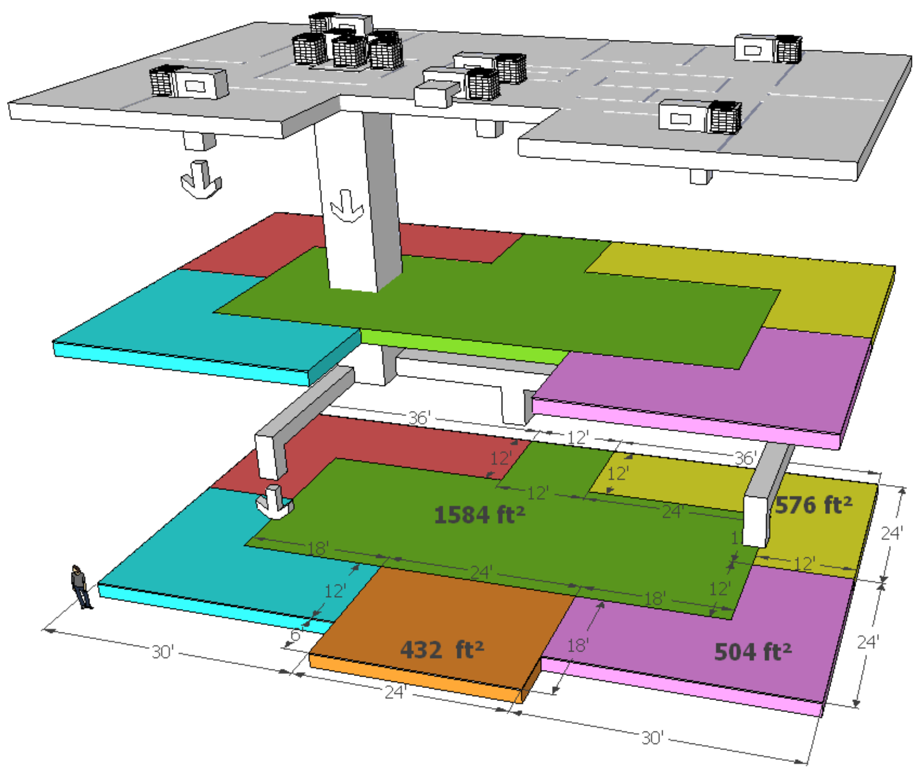
West-East Section through Main Lobby

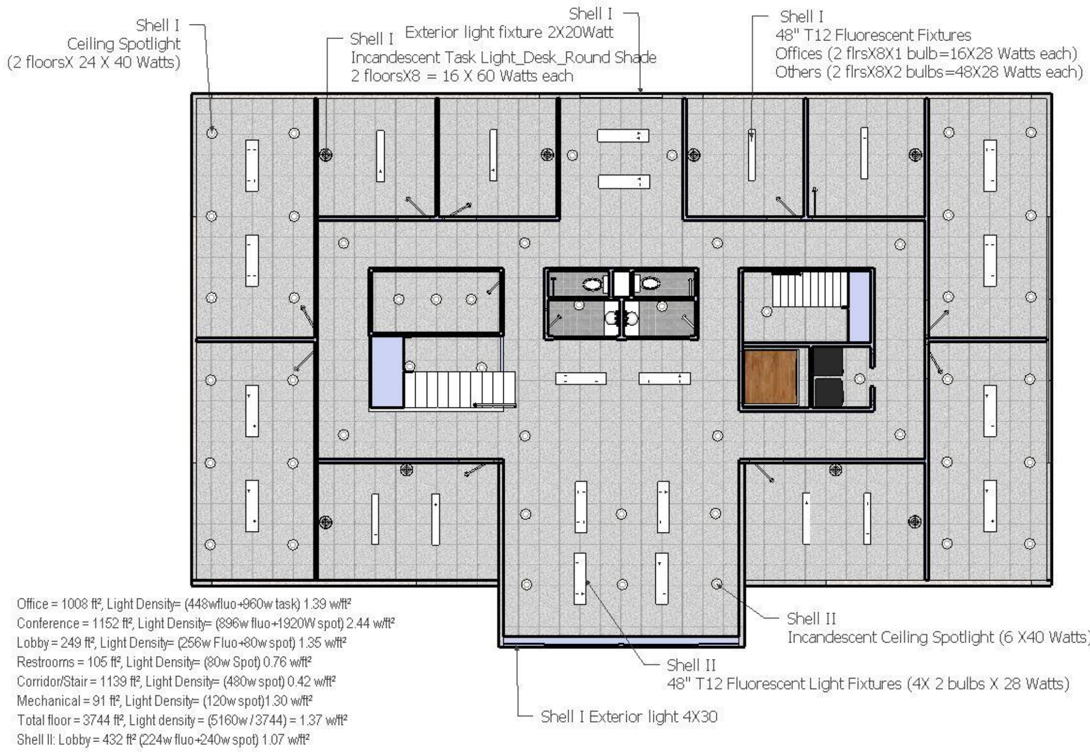


East-West Section through Service Area

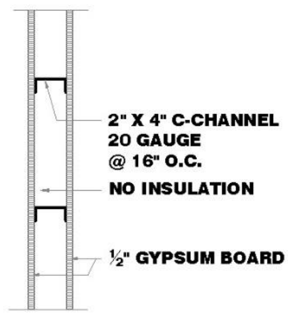


Thermal Zones
Selected Building Details

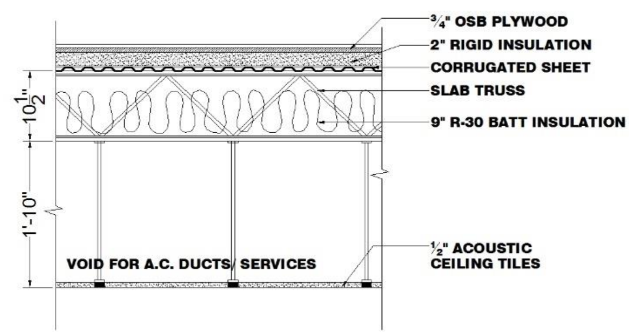




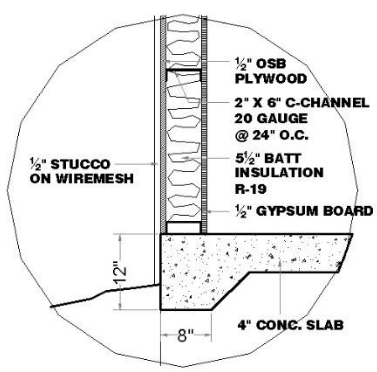
Lighting Plan



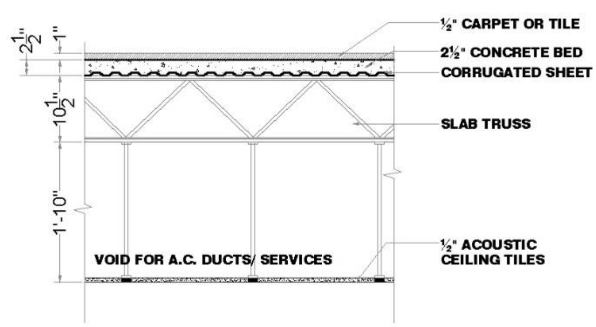
INTERNAL PARTITION DETAIL



ROOF DETAIL



SLAB & WALL DETAIL



FLOOR DETAIL

2. Proposed Basecase Building Schedule *(in compliance with ASHRAE 90.1, 2010 baseline)*

1	**Building: Name:** House Energy Doctor Office Building **Address:** 4444 E. Broadway Blvd. Tucson, AZ 85711
2	**City:** **Location:** Tucson (Lat. 32.13, Long. 110.93, elev. 2,584) **Degree Days:** HDD65=1,678 & CDD50=6,921 *(ASHRAE Standard 90.1, 2010 Page 151)* **Utility Rates:** Electric= 0.09 $/KWh – Natural Gas= 1.1 $/Therm
3	**Climate Zone:** "2B" for Pima *(ASHRAE Standard 90.1, 2007 Page 110)*

		SHELL I		***SHELL II***	**TOTALS**
4	**Orientation**	South		South	
5	**Volume** Conditioned Space	74,880 ft³/floor (84X48- shell2 (24X12)X20		14,688 ft³ (24X18X34)	89,568
6	**Areas**				
	Roof	3,744 ft² (84X48)-shell2(24X12)		416 ft² (24X18)-skylight(4X4)	4,160 ft²
	Conditioned Floor Area	7,488 ft² (3,744 ft²/flr) (84X48)-shell2(24X12) X2		432 ft² (24X18)	**7,920 ft²**
	Carpeted Area	3,744 ft² (1,872 ft²/flr) (48X12X2)+((36+24)X12) X2		None	3,744 ft²
	Tiled Area	3,744 ft² (1,872 ft²/flr) (3,744-1,872) X2		432 ft² (24X18)	4,176 ft²
	Walls: (include windows, but no plenums) South	1,200 ft² (84-24X10X2)		816 ft² (24X34)	2,016 ft²
	West	960 ft² (48X10X2)		252 ft² (6X34)+(12X4)	1,212 ft²
	North	1,680 ft² (84X10X2)		96 ft² (24X4)	1,776 ft²
	East	960 ft² (48X10X2)		252 ft² (6X34)+(12X4)	1,212 ft²
	Total walls	**4,800 ft²**		**1,320 ft²**	**6,120 ft²**
	Plenum Area	2,400 ft² (5+5X240)		0.0	2,400 ft²
	Gross (Walls + Plenums)	**7,200 ft²**		**1,320 ft²**	**8,520 ft²**
	Windows: (area & % of wall)				
	South	400 ft² (4X(20X5))	33.33 % of south wall	502.75 ft² (3X(7.5X19.5))+(2X(4X8))	902.75 ft²
	West	240 ft² (2X(24X5))	25.00 % of west wall	--	240 ft²
	North	720 ft² (80X5+2X(32X5))	42.80 % of north wall	--	720 ft²
	East	240 ft² (2X(24X5))	25.00 % of east wall	--	240 ft²
	Total windows	**1,600 ft²** (Total must be =<40% of gross wall area including plenums)	**22.2 % of Gross**	**502.75 ft² 38.09 % of Gross** (=<40% of gross wall area)	**2,102.75ft²** 24.6%***
	Skylight	--		16 ft²	16 ft²
	Doors (Sliding all glass)	64 ft² (8X8) (facing north)		112 ft² (2X(7X8)) (south)	176 ft²
	Perimeter	240 L.F. (84+48+84+48-24)		36 L.F.	276 L.F.
	Internal Doors	304 ft²/floor [10X(3X6'9")+6X(2'6"X6'9")]		None	304 ft²
	Partition Walls	1,736 ft²/floor [(18X2+48X2+24X2+12X6)X10]-304		240 ft²/floor (12X2X10)	1,976 ft²
7	**Ratios**				
	Total Glass to Floor area	21.4 % (1,600 ÷ 7,488 X 100)		116.4 % (502.75 ÷ 432)X100	26.6%
	South Glass to Floor area	5.3 % (400 ÷ 7,488 X 100)		116.4 % (502.75 ÷ 432)X100	11.4%
	Area by type to Floor area	-Offices = 26.9% (1008 ft²) -Corridor & Stairs = 30.4 % (1139 ft²) -Lobby/Waiting = 6.7 % (249 ft²) -Restrooms= 2.8% (105 ft²) -Conference = 30.8 % (1152 ft²) -Mechanical=2.4 % (91 ft²)		-Lobby/Waiting = 100 % (432 ft²)	

8	**Insulation:** *(ASHRAE Standard 90.1, 2007 Table 5.5-2 for Climate Zone 2(A,B))* • Roof: Metal frame, 24" o.c., built-up, **R-20** continuous insulation above deck ext. board insulation, no rad. barrier • Walls (Exterior): **R-13**, metal frame, 2"X6", 24" o.c., stucco, no ext. board insulation, R-13 batt • Walls (Interior): steel studs, 2"X4", 16" o.c., gypsum boards, no insulation • Slab: 4" earth contact slab-on-grade, no perimeter insulation (carpeted & no carpet) • Doors: (interior): R-0.69 (U-value=1.45) • Windows: Sngl clear, Alum. w/o Brk, U-value=0.7 all, S.C.=0.21, VT=0.85, frame width=1.3", SHGC=0.25 (all) • Skylight: Acrylic plastic with curb VT=0.65, aluminum frame no break, U-value=1.9, SHGC=0.39 (SHGC=SCX0.87, so SC=0.45)
9	**Shortwave Reflectance:** Roof: Medium Abs=0.7, Walls: Medium Abs=0.6 [All roof surfaces will be modeled with a reflectivity of 0.3 ((*ASHRAE 90.1, 2010* Table G3.1, page 213)
10	**Infiltration:** Perimeter = 0.038 CFM/ft² (external wall area) & Core=0.001 CFM/ft² (floor area)
11	**HVAC Type: System #4 PSZ-HP** *(As specified in Appendix G, Table G3.1.1A and shall conform with descriptions in Table G3.1.1B Page 213)*. **HVAC Size:** • 6 packaged (5 for Shell 1 & 1 for shell 2) and 5 split-unit Single zone ducted return DX Coils heat pumps located on the accessible roof. • All units are <65,000 Btuh (or 5.4 tons i.e. 65,000 ÷ 12,000 = 5.4 tons) constant volume, all electric type. **Efficiency:** [Note: SEER X 0.9 = EER & EER ÷ 3.415 = COP & EIR = 1 ÷ COP] [Also, to convert HSPF to a COP divide by 3.412] • Cooling Efficiency is SEER 13.00 *Table 6.8.1B, page 64* • Heating Efficiency is HSPF = 7.7 *Table 6.8.1B, page 66* **Fan Schedules:** 7am to 6 pm no weekends & no holidays, operates 1 hr before and after, Fan mode = continuous, no Fan Night Cycling **Economizer:** Not required since our building is <15,000ft² located in climate zone 2b (see table G3.1.2.6B) If required it should be: Drybulb Temperature, High Limit Shutoff=75°F **Thermal Zones:** Building is divided into 6 thermal zones: NW, NE, SE, SW, Core & Atrium (move counterclockwise when creating them in eQUEST) **Thermostat:** Occupied: Cool=76°F, Heat=68°F -Unoccupied: Cool= Cool=76°F, Heat=68°F i.e. (no night setbacks)
12	**Lighting Power Density (LPD):** *two ways to comply:* • Building Area Type : for "Office" =1.0 W/ft² (no specific area type) *(Table 9.5.1, page 64) or* • Space-by-Space method: Office=1.1, Conf. or Lobby=1.3, Restrooms=0.9,Corridor/transition=0.5 & Mech=1.5 *(Table 9.6.1 Page 83)*
13	**Equipment Load:** Total 1.3 w/ft² (0.75 w/ft² offices, 0.25 w/ft² lobby reception, 0.1 w/ft² restrooms, 0.1 w/ft² conference), & 0.1 w/ft² mechanical
14	**Domestic Water Heating:** Electric, Input rating 4.3Kw, 50 gal, supply temp=135°F, no recirculation, Energy Factor 0.86, tank insulation=R-12
15	**Building Operation:** 7am to 6pm, Closed: Sat + Sun + 10 default holidays
16	**Building Capacity:** (7,920 ft²/200 ft² per person)= 39.6 or 40 persons

******* Vertical fenestration areas shall equal that in the *proposed design* or 40% of gross above grade wall area, whichever is smaller, and shall be distributed on each face of the building in the same proportions in the proposed design. (ASHRAE 90.1, 2010 page 213) (i.e. you cannot show savings from reducing window area)

3. ASHRAE 2010 Mandatory Tables

TABLE D-1 US and US Territory Climatic Data *(continued)*

State City	Latitude	Longitude	Elev., ft	HDD65	CDD50	Heating Design Temperature	Cooling Design Temperature		No. Hrs. 8 a.m.–4 p.m.
							Dry-Bulb	Wet-Bulb	
						99.6%	1.0%	1.0%	55 < Tdb < 69
(Arizona cont.)									
Prescott	34.57 N	112.43 W	5205	4995	2875	15	91	60	725
Tucson WSO AP	32.13 N	110.93 W	2584	1678	6921	31	102	65	716
Winslow WSO AP	35.02 N	110.73 W	4890	4776	3681	10	93	60	634
Yuma WSO AP	32.67 N	114.60 W	206	927	8897	40	109	72	697
Arkansas (AR)									
Blytheville AFB	35.97 N	89.95 W	256	3656	5133	12	95	77	N.A.
Camden	33.60 N	92.82 W	116	2953	5309	N.A.	N.A.	N.A.	N.A.
Fayetteville	36.00 N	94.17 W	1250	4040	4452	6	93	75	N.A.
Ft Smith WSO AP	35.33 N	94.37 W	449	3478	5078	13	96	76	547
Hot Springs	34.52 N	93.05 W	680	3181	5243	N.A.	N.A.	N.A.	N.A.
Jonesboro	35.88 N	90.70 W	390	3504	5118	N.A.	N.A.	N.A.	N.A.
Little Rock FAA AP	34.73 N	92.23 W	257	3155	5299	16	95	77	626
Pine Bluff	34.22 N	92.02 W	215	3016	5467	N.A.	N.A.	N.A.	N.A.
Texarkana FAA AP	33.45 N	94.00 W	361	2295	6152	20	95	77	N.A.
California (CA)									
Bakersfield WSO AP	35.42 N	119.05 W	495	2182	6049	32	101	69	848
Blythe FAA Airport	33.62 N	114.72 W	390	1144	8789	N.A.	N.A.	N.A.	N.A.
Burbank Hollywood	34.20 N	118.37 W	774	1204	5849	39	95	69	N.A.
Chico University Farm	39.70 N	121.82 W	185	2953	4454	N.A.	N.A.	N.A.	N.A.
Crescent City	41.77 N	124.20 W	40	4397	1628	N.A.	N.A.	N.A.	N.A.
El Centro	32.77 N	115.57 W	–30	1156	8132	N.A.	N.A.	N.A.	N.A.
Eureka WSO City	40.80 N	124.17 W	60	4496	1529	N.A.	N.A.	N.A.	N.A.
Fairfield/Travis AFB	38.27 N	121.93 W	62	2556	4223	31	94	67	N.A.
Fresno WSO AP	36.77 N	119.72 W	328	2556	5350	30	101	70	785
Laguna Beach	33.55 N	117.78 W	35	2157	3881	N.A.	N.A.	N.A.	N.A.
Livermore	37.67 N	121.77 W	480	2909	3810	N.A.	N.A.	N.A.	N.A.
Lompoc	34.65 N	120.45 W	95	2651	3240	N.A.	N.A.	N.A.	N.A.
Long Beach WSO AP	33.82 N	118.15 W	34	1430	5281	40	88	67	1502
Los Angeles WSO AP	33.93 N	118.38 W	100	1458	4777	43	81	64	1849
Merced/Castle AFB	37.37 N	120.57 W	187	2687	4694	30	97	69	N.A.
Monterey	36.60 N	121.90 W	385	3125	2574	N.A.	N.A.	N.A.	N.A.

TABLE 5.5-2 Building Envelope Requirements for Climate Zone 2 (A, B)*

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.218	R-3.8 c.i.
Metal Building[a]	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above-Grade						
Mass	U-0.151[b]	R-5.7 c.i.[b]	U-0.123	R-7.6 c.i.	U-0.580	NR
Metal Building	U-0.093	R-16.0	U-0.093	R-16.0	U-0.113	R-13.0
Steel-Framed	U-0.124	R-13.0	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.107	R-6.3 c.i.	U-0.087	R-8.3 c.i.	U-0.322	NR
Steel-Joist	U-0.052	R-19.0	U-0.052	R-19.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.450		U-0.500		U-1.450	

Fenestration	Nonresidential Assembly Max. U	Nonresidential Assembly Max. SHGC	Residential Assembly Max. U	Residential Assembly Max. SHGC	Semiheated Assembly Max. U	Semiheated Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.75	SHGC-0.25 all	U-0.75	SHGC-0.25 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[d]	U-0.70		U-0.70		U-1.20	
Metal framing (entrance door)[d]	U-1.10		U-1.10		U-1.20	
Metal framing (all other)[d]	U-0.75		U-0.75		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–1.98	$SHGC_{all}$–0.36	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–1.90	$SHGC_{all}$–0.39	U_{all}–1.90	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.90	$SHGC_{all}$–0.34	U_{all}–1.90	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–1.36	$SHGC_{all}$–0.36	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR

*The following definitions apply: c.i. = *continuous insulation* (see Section 3.2), NR = no (insulation) requirement.

[a]When using R-value compliance method, a thermal spacer block is required; otherwise use the *U-factor* compliance method. See Table A2.3.

[b]Exception to Section A3.1.3.1 applies.

[c]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.

[d]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance *doors*.

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.82
Convention center	1.08
Courthouse	1.05
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.61
Exercise center	0.88
Fire station	0.71
Gymnasium	1.00
Health-care clinic	0.87
Hospital	1.21
Hotel	1.00
Library	1.18
Manufacturing facility	1.11
Motel	0.88
Motion picture theater	0.83
Multifamily	0.60
Museum	1.06
Office	0.90
Parking garage	0.25
Penitentiary	0.97
Performing arts theater	1.39
Police station	0.96
Post office	0.87
Religious building	1.05
Retail	1.40
School/university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse	0.66
Workshop	1.20

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method

Common Space Types[a]	LPD, W/ft²	RCR Threshold
Atrium		
First 40 ft in height	0.03 per ft (height)	NA
Height above 40 ft	0.02 per ft (height)	NA
Audience/Seating Area—Permanent		
For auditorium	0.79	6
For Performing Arts Theater	2.43	8
For Motion Picture Theater	1.14	4
Classroom/Lecture/Training	1.24	4
Conference/Meeting/Multipurpose	1.23	6
Corridor/Transition	0.66	Width<8 ft
Dining Area	0.65	4
For Bar Lounge/Leisure Dining	1.31	4
For Family Dining	0.89	4
Dressing/Fitting Room for Performing Arts Theater	0.40	6
Electrical/Mechanical	0.95	6
Food Preparation	0.99	6
Laboratory		
For Classrooms	1.28	6
For Medical/Industrial/Research	1.81	6
Lobby	0.90	4
For Elevator	0.64	6
For Performing Arts Theater	2.00	6
For Motion Picture Theater	0.52	4
Locker Room	0.75	6
Lounge/Recreation	0.73	4
Office		
Enclosed	1.11	8
Open Plan	0.98	4
Restrooms	0.98	8
Sales Area (for accent lighting, see Section 9.6.2(b))	1.68	6
Stairway	0.69	10
Storage	0.63	6
Workshop	1.59	6

Building-Specific Space Types	LPD, W/ft²	RCR Threshold
Automotive		
Service/Repair	0.67	4
Bank/Office		
Banking Activity Area	1.38	6
Convention Center		

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method *(continued)*

Building-Specific Space Types	LPD, W/ft²	RCR Threshold
Audience Seating	0.82	4
Exhibit Space	1.45	4
Courthouse/Police Station/Penitentiary		
Courtroom	1.72	6
Confinement Cells	1.10	6
Judges' Chambers	1.17	8
Penitentiary Audience Seating	0.43	4
Penitentiary Classroom	1.34	4
Penitentiary Dining	1.07	6
Dormitory		
Living Quarters	0.38	8
Fire Stations		
Engine Room	0.56	4
Sleeping Quarters	0.25	6
Gymnasium/Fitness Center		
Fitness Area	0.72	4
Gymnasium Audience Seating	0.43	6
Playing Area	1.20	4
Hospital		
Corridor/Transition	0.89	Width < 8 ft
Emergency	2.26	6
Exam/Treatment	1.66	8
Laundry/Washing	0.60	4
Lounge/Recreation	1.07	6
Medical Supply	1.27	6
Nursery	0.88	6
Nurses' Station	0.87	6
Operating Room	1.89	6
Patient Room	0.62	6
Pharmacy	1.14	6
Physical Therapy	0.91	6
Radiology/Imaging	1.32	6
Recovery	1.15	6
Hotel/Highway Lodging		
Hotel Dining	0.82	4
Hotel Guest Rooms	1.11	6
Hotel Lobby	1.06	4
Highway Lodging Dining	0.88	4
Highway Lodging Guest Rooms	0.75	6
Library		
Card File and Cataloging	0.72	4
Reading Area	0.93	4
Stacks	1.71	4

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method *(continued)*

Building-Specific Space Types	LPD, W/ft²	RCR Threshold
Manufacturing		
Corridor/Transition	0.41	Width < 8 ft
Detailed Manufacturing	1.29	4
Equipment Room	0.95	6
Extra High Bay (>50 ft Floor to Ceiling Height)	1.05	4
High Bay (25–50 ft Floor to Ceiling Height)	1.23	4
Low Bay (<25 ft Floor to Ceiling Height)	1.19	4
Museum		
General Exhibition	1.05	6
Restoration	1.02	6
Parking Garage		
Garage Area	0.19	4
Post Office		
Sorting Area	0.94	4
Religious Buildings		
Audience Seating	1.53	4
Fellowship Hall	0.64	4
Worship Pulpit, Choir	1.53	4

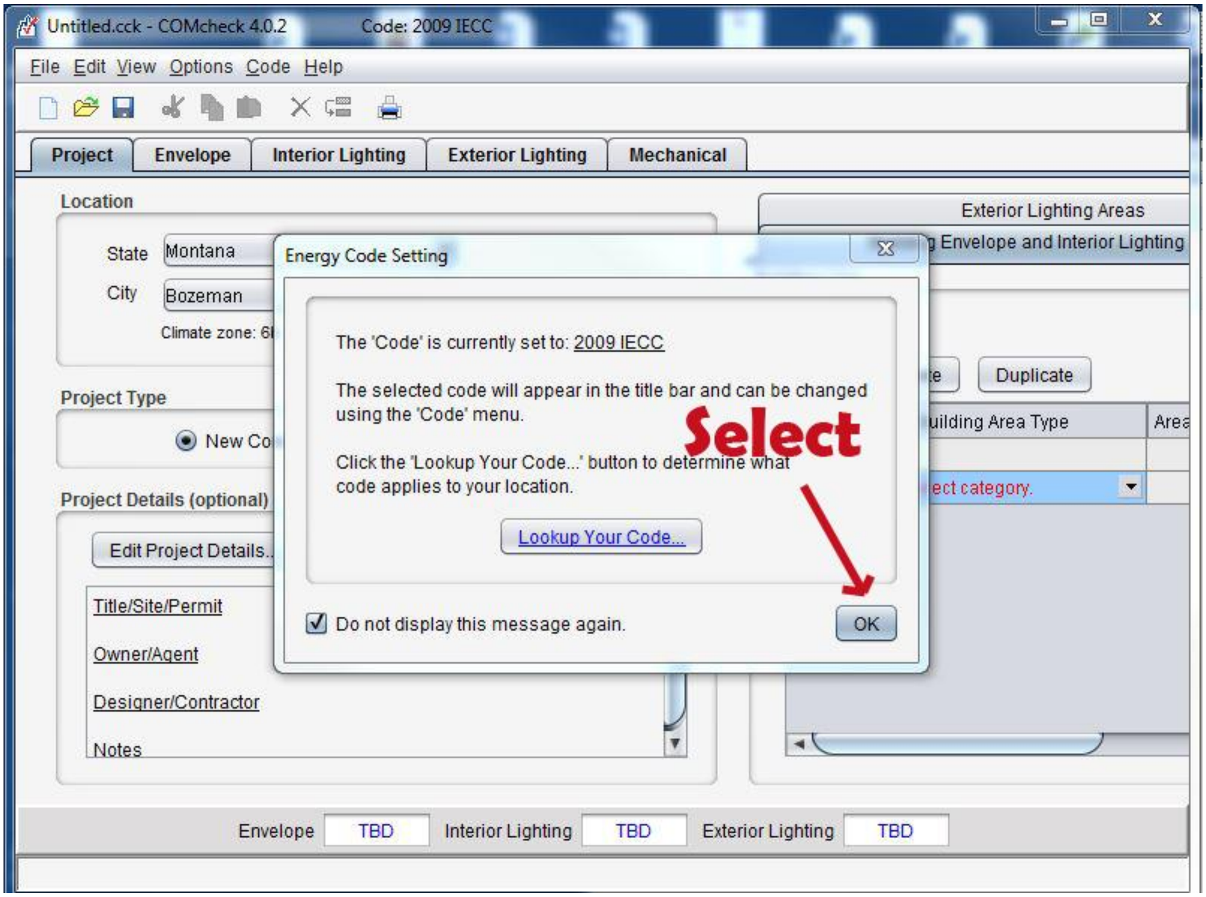
TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method *(continued)*

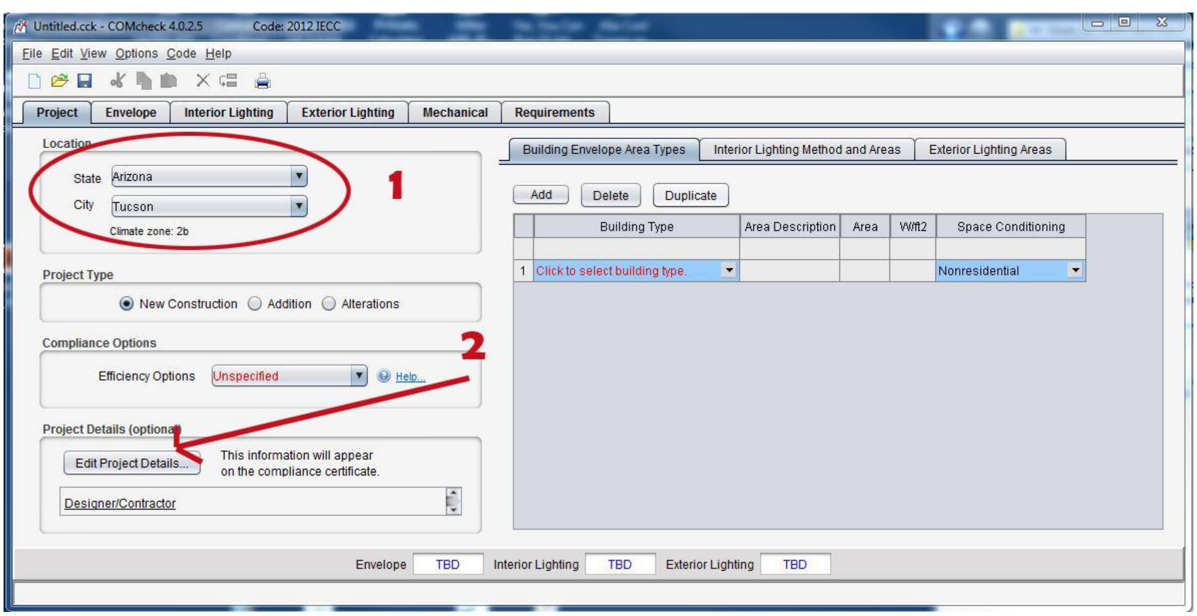
Building-Specific Space Types	LPD, W/ft²	RCR Threshold
Retail		
Dressing/Fitting Room	0.87	8
Mall Concourse	1.10	4
Sales Area (for accent lighting, see Section 9.6.3(c))	1.68	6
Sports Arena		
Audience Seating	0.43	4
Court Sports Arena—Class 4	0.72	4
Court Sports Arena—Class 3	1.20	4
Court Sports Arena—Class 2	1.92	4
Court Sports Arena—Class 1	3.01	4
Ring Sports Arena	2.68	4
Transportation		
Air/Train/Bus—Baggage Area	0.76	4
Airport—Concourse	0.36	4
Audience Seating	0.54	4
Terminal—Ticket Counter	1.08	4
Warehouse		
Fine Material Storage	0.95	6
Medium/Bulky Material Storage	0.58	4

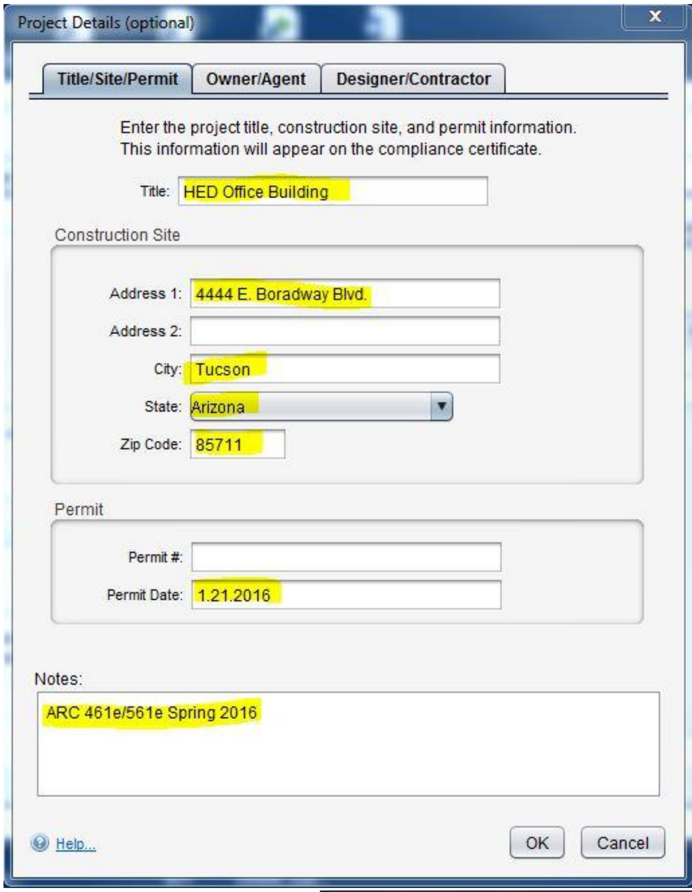
[a] In cases where both a common *space* type and a building-specific type are listed, the building specific *space* type shall apply.

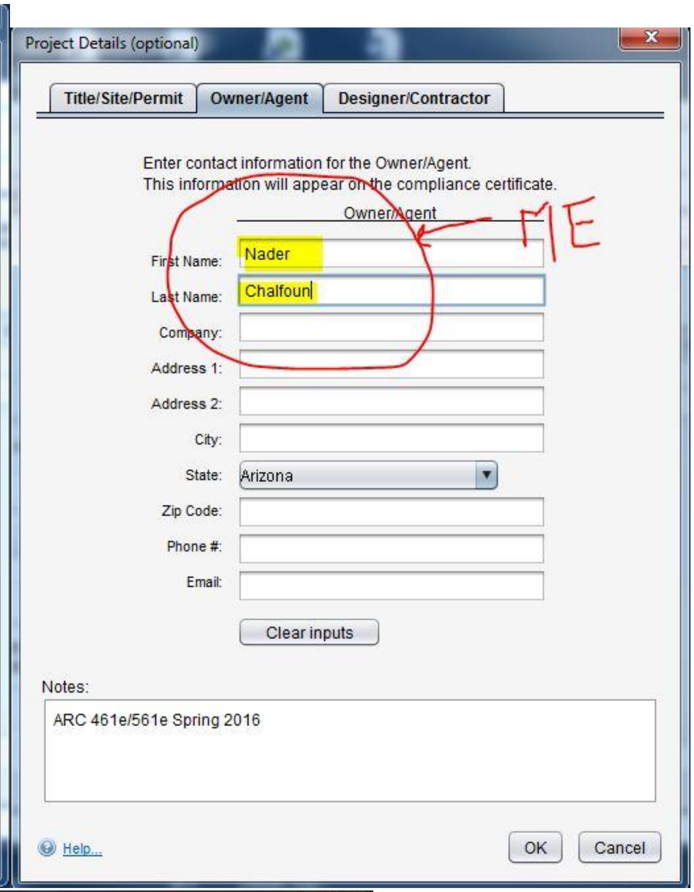
4. COMcheck, Step-by-step

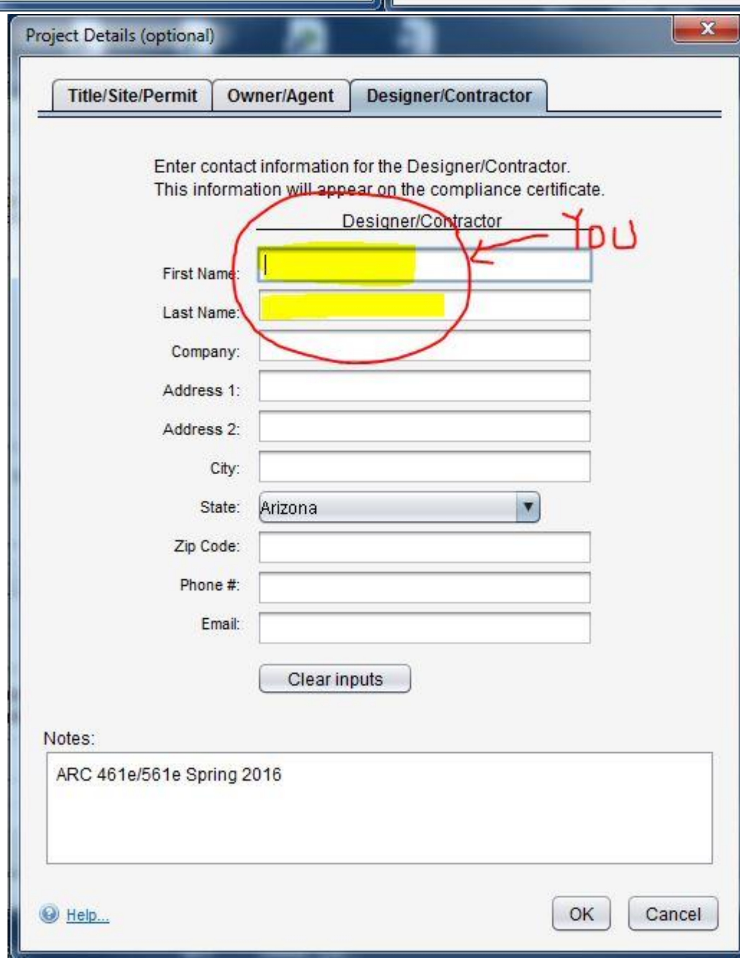
Remember, you must first select the proper location (Arizona, Pima) and the proper code: We will start with Pima County required IECC 2012

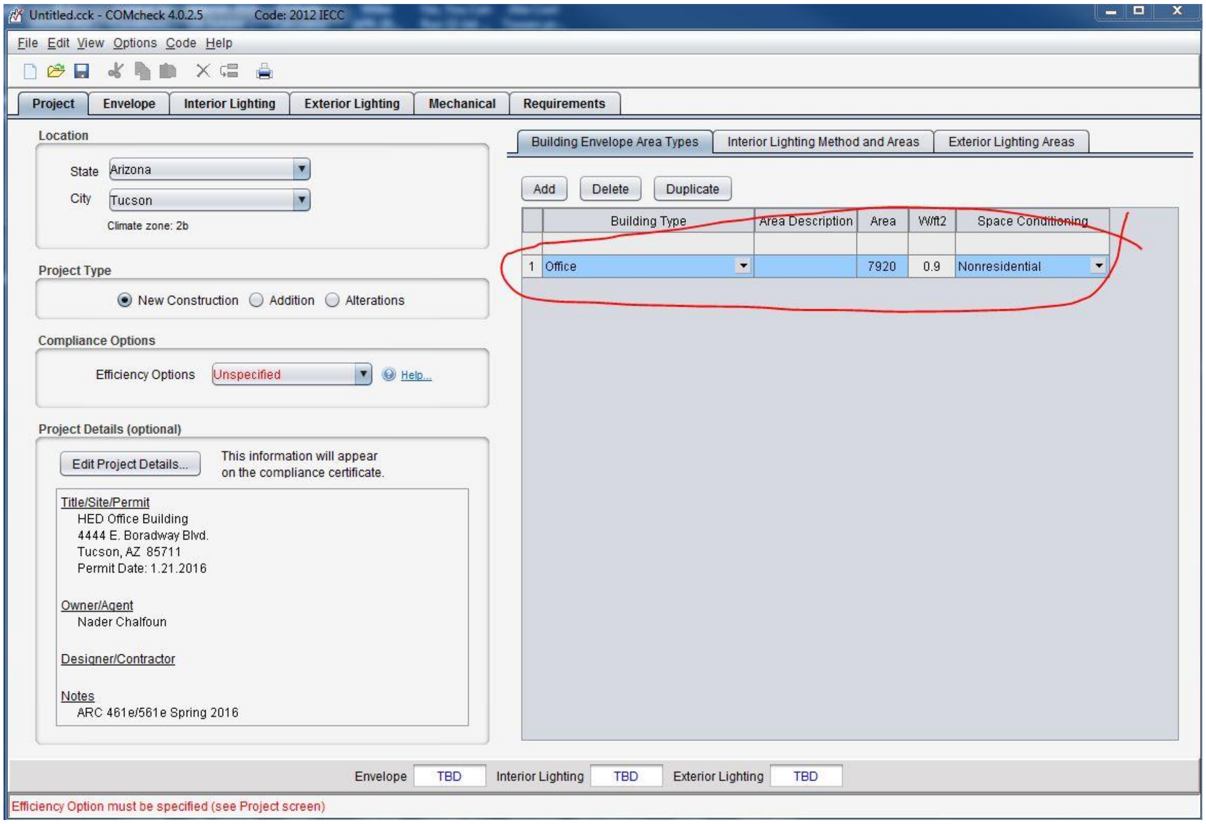


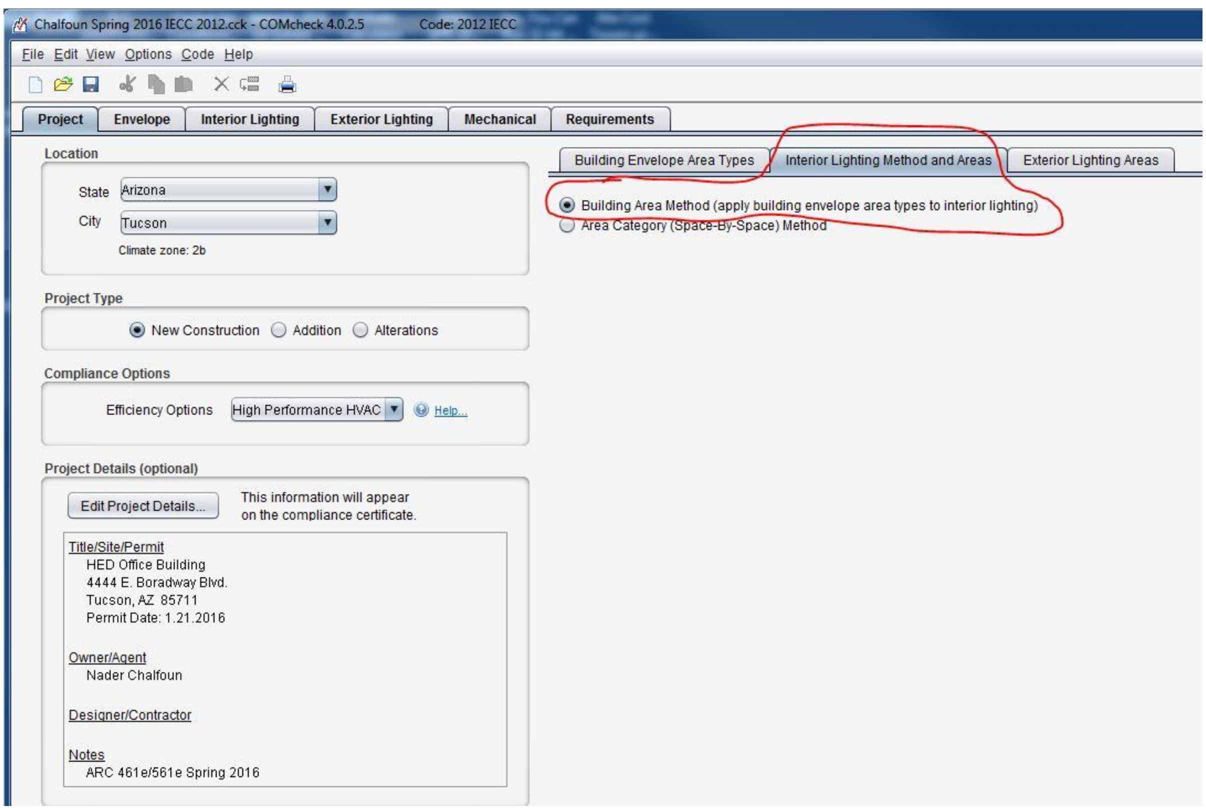


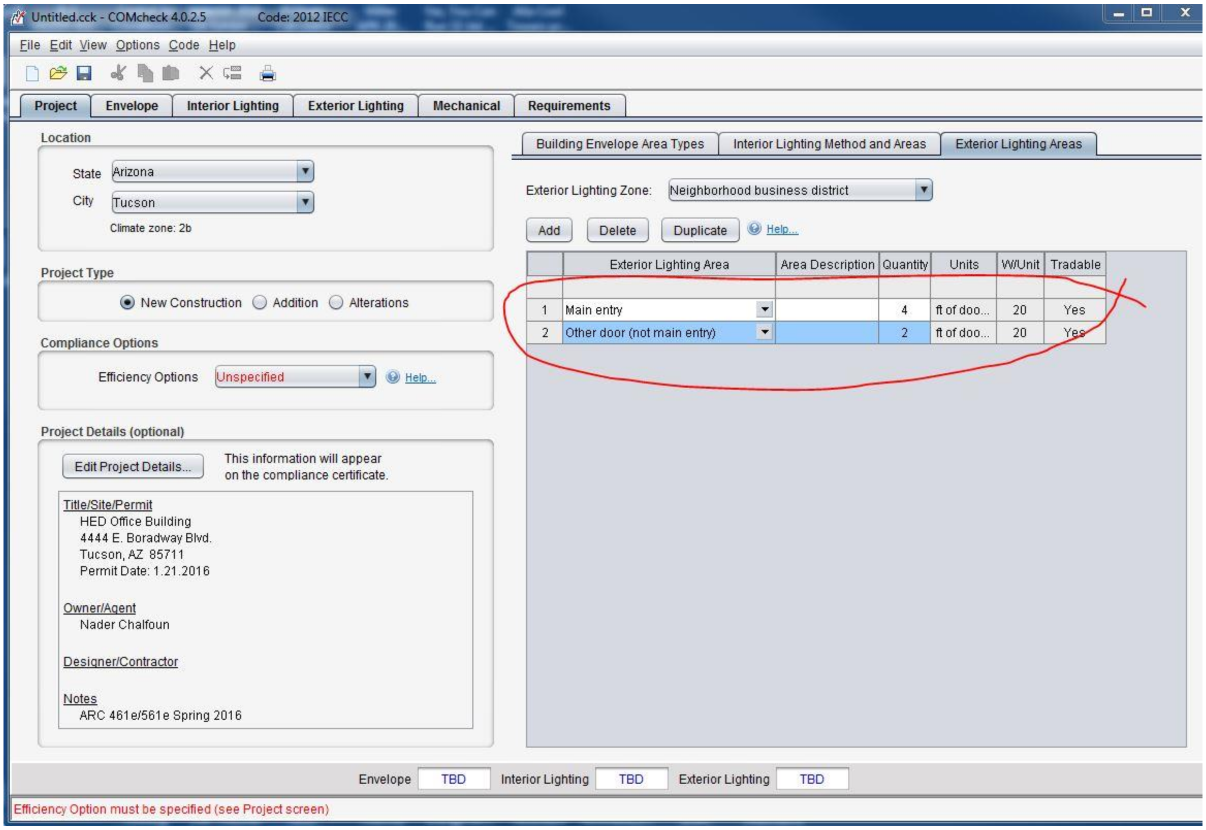

Project Details (optional)
Title/Site/Permit
Owner/Agent
Designer/Contractor
Enter the project title, construction site, and permit information.
This information will appear on the compliance certificate.
Title: HED Office Building
Construction Site
Address 1: 4444 E. Boradway Blvd.
Address 2:
City: Tucson
State: Arizona
Zip Code: 85711
Permit
Permit #:
Permit Date: 1.21.2016
Notes:
ARC 461e/561e Spring 2016
Help...
OK
Cancel

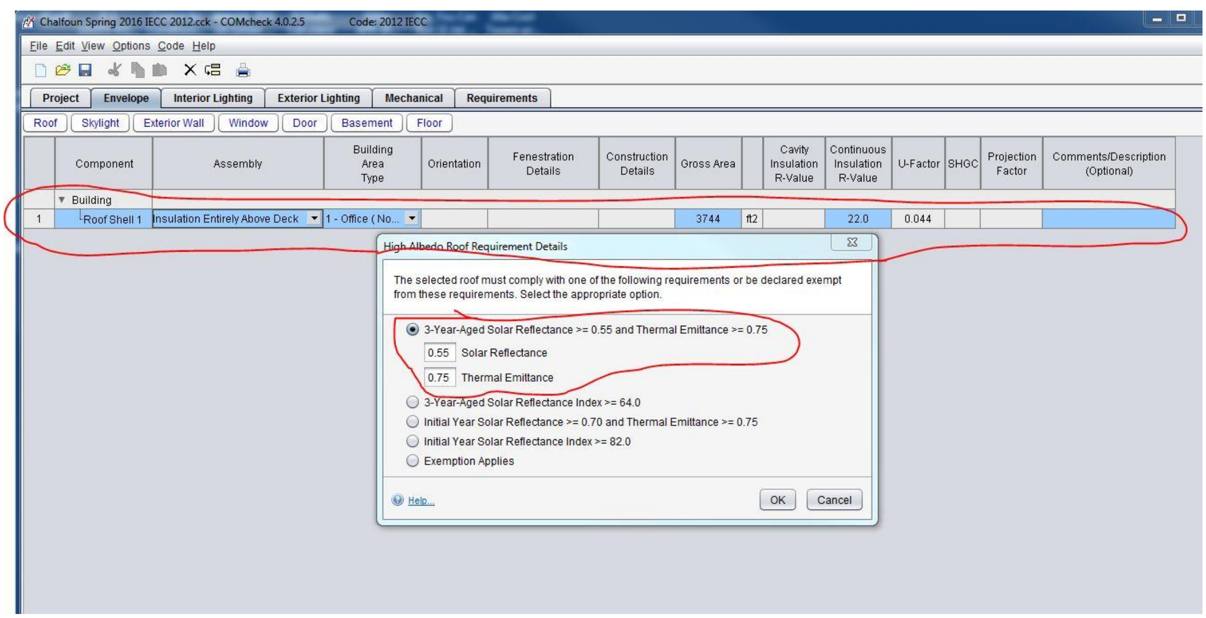

Project Details (optional)
Title/Site/Permit
Owner/Agent
Designer/Contractor
Enter contact information for the Owner/Agent.
This information will appear on the compliance certificate.
Owner/Agent
ME
First Name: Nader
Last Name: Chalfoun
Company:
Address 1:
Address 2:
City:
State: Arizona
Zip Code:
Phone #:
Email:
Clear inputs
Notes:
ARC 461e/561e Spring 2016
Help...
OK
Cancel

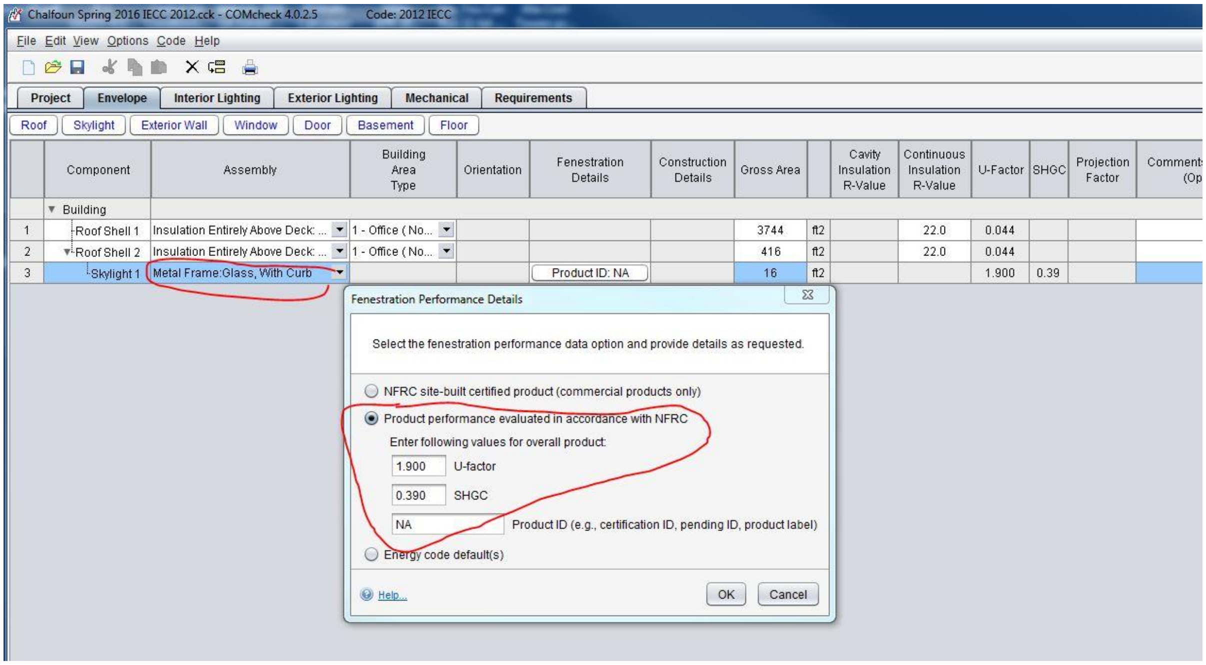

Project Details (optional)
Title/Site/Permit
Owner/Agent
Designer/Contractor
Enter contact information for the Designer/Contractor.
This information will appear on the compliance certificate.
Designer/Contractor
YOU
First Name:
Last Name:
Company:
Address 1:
Address 2:
City:
State: Arizona
Zip Code:
Phone #:
Email:
Clear inputs
Notes:
ARC 461e/561e Spring 2016
Help...
OK
Cancel

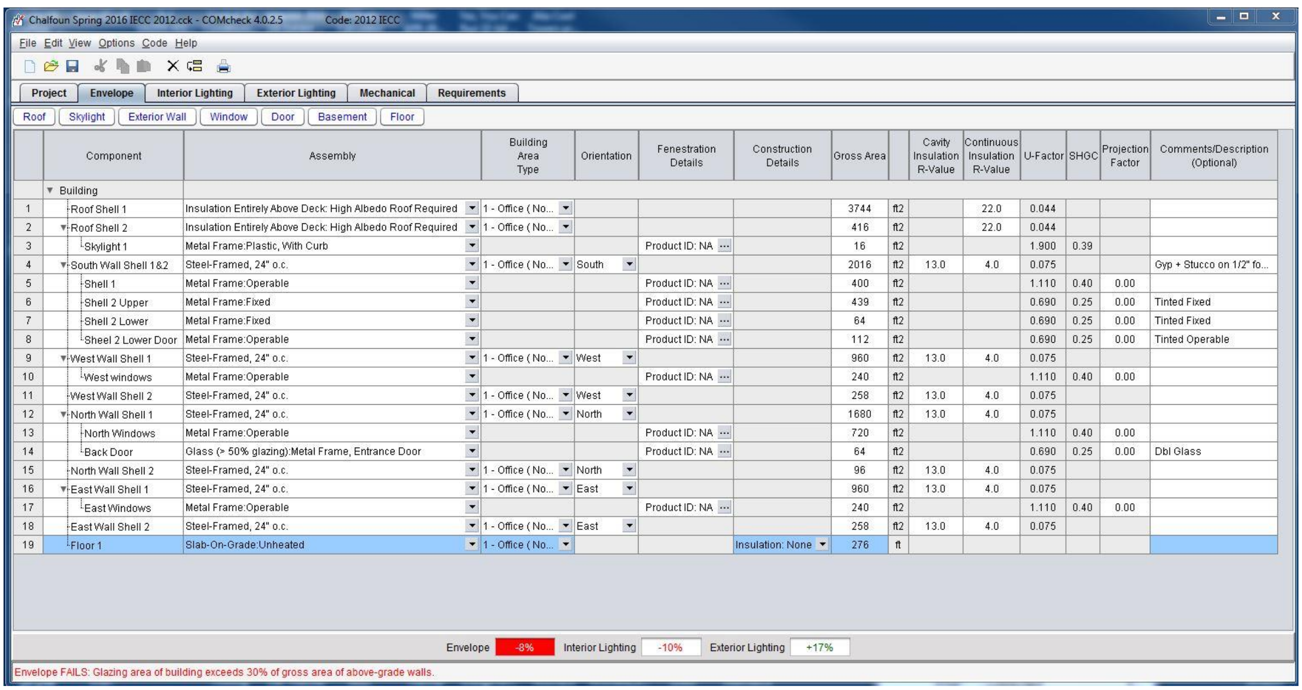

Untitled.cck - COMcheck 4.0.2.5
Code: 2012 IECC
File Edit View Options Code Help
Project
Envelope
Interior Lighting
Exterior Lighting
Mechanical
Requirements
Location
State Arizona
City Tucson
Climate zone: 2b
Project Type
New Construction
Addition
Alterations
Compliance Options
Efficiency Options
Unspecified
Help...
Project Details (optional)
Edit Project Details...
This information will appear on the compliance certificate.
Title/Site/Permit
HED Office Building
4444 E. Boradway Blvd.
Tucson, AZ 85711
Permit Date: 1.21.2016
Owner/Agent
Nader Chalfoun
Designer/Contractor
Notes
ARC 461e/561e Spring 2016
Building Envelope Area Types
Interior Lighting Method and Areas
Exterior Lighting Areas
Add
Delete
Duplicate
Building Type
Area Description
Area
W/ft2
Space Conditioning
1 Office
7920
0.9
Nonresidential
Envelope TBD
Interior Lighting TBD
Exterior Lighting TBD
Efficiency Option must be specified (see Project screen)


Chalfoun Spring 2016 IECC 2012.cck - COMcheck 4.0.2.5
Code: 2012 IECC
File Edit View Options Code Help
Project
Envelope
Interior Lighting
Exterior Lighting
Mechanical
Requirements
Location
State Arizona
City Tucson
Climate zone: 2b
Project Type
New Construction
Addition
Alterations
Compliance Options
Efficiency Options
High Performance HVAC
Help...
Project Details (optional)
Edit Project Details...
This information will appear on the compliance certificate.
Title/Site/Permit
HED Office Building
4444 E. Boradway Blvd.
Tucson, AZ 85711
Permit Date: 1.21.2016
Owner/Agent
Nader Chalfoun
Designer/Contractor
Notes
ARC 461e/561e Spring 2016
Building Envelope Area Types
Interior Lighting Method and Areas
Exterior Lighting Areas
Building Area Method (apply building envelope area types to interior lighting)
Area Category (Space-By-Space) Method

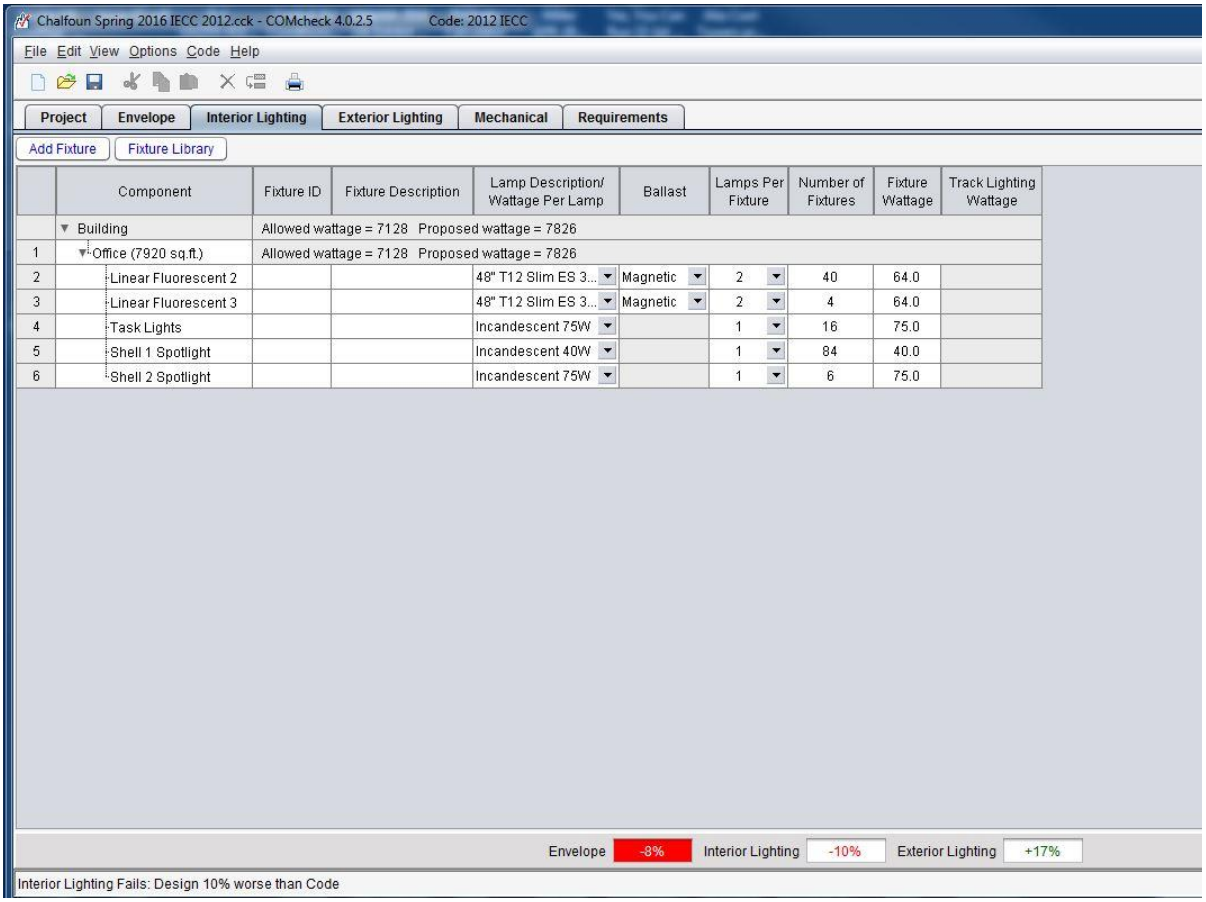

Untitled.cck - COMcheck 4.0.2.5 Code: 2012 IECC
File Edit View Options Code Help
Project
Envelope
Interior Lighting
Exterior Lighting
Mechanical
Requirements
Location
State Arizona
City Tucson
Climate zone: 2b
Project Type
New Construction
Addition
Alterations
Compliance Options
Efficiency Options
Unspecified
Help...
Project Details (optional)
Edit Project Details...
This information will appear on the compliance certificate.
Title/Site/Permit
HED Office Building
4444 E. Boradway Blvd.
Tucson, AZ 85711
Permit Date: 1.21.2016
Owner/Agent
Nader Chalfoun
Designer/Contractor
Notes
ARC 461e/561e Spring 2016
Building Envelope Area Types
Interior Lighting Method and Areas
Exterior Lighting Areas
Exterior Lighting Zone:
Neighborhood business district
Add
Delete
Duplicate
Help...
Exterior Lighting Area
Area Description
Quantity
Units
W/Unit
Tradable
1 Main entry 4 ft of doo... 20 Yes
2 Other door (not main entry) 2 ft of doo... 20 Yes
Envelope TBD
Interior Lighting TBD
Exterior Lighting TBD
Efficiency Option must be specified (see Project screen)


Chalfoun Spring 2016 IECC 2012.cck - COMcheck 4.0.2.5 Code: 2012 IECC
File Edit View Options Code Help
Project
Envelope
Interior Lighting
Exterior Lighting
Mechanical
Requirements
Roof
Skylight
Exterior Wall
Window
Door
Basement
Floor
Component
Assembly
Building Area Type
Orientation
Fenestration Details
Construction Details
Gross Area
Cavity Insulation R-Value
Continuous Insulation R-Value
U-Factor
SHGC
Projection Factor
Comments/Description (Optional)
Building
1 Roof Shell 1 Insulation Entirely Above Deck 1 - Office (No... 3744 ft2 22.0 0.044
High Albedo Roof Requirement Details
The selected roof must comply with one of the following requirements or be declared exempt from these requirements. Select the appropriate option.
3-Year-Aged Solar Reflectance >= 0.55 and Thermal Emittance >= 0.75
0.55 Solar Reflectance
0.75 Thermal Emittance
3-Year-Aged Solar Reflectance Index >= 64.0
Initial Year Solar Reflectance >= 0.70 and Thermal Emittance >= 0.75
Initial Year Solar Reflectance Index >= 82.0
Exemption Applies
Help...
OK
Cancel





	Component	Assembly	Building Area Type	Orientation	Fenestration Details	Construction Details	Gross Area		Cavity Insulation R-Value	Continuous Insulation R-Value	U-Factor	SHGC	Projection Factor	Comments/Description (Optional)
	Building													
1	Roof Shell 1	Insulation Entirely Above Deck: High Albedo Roof Required	1 - Office (No...				3744	ft2		22.0	0.044			
2	Roof Shell 2	Insulation Entirely Above Deck: High Albedo Roof Required	1 - Office (No...				416	ft2		22.0	0.044			
3	Skylight 1	Metal Frame:Plastic, With Curb			Product ID: NA		16	ft2			1.900	0.39		
4	South Wall Shell 1&2	Steel-Framed, 24" o.c.	1 - Office (No...	South			2016	ft2	13.0	4.0	0.075			Gyp + Stucco on 1/2" fo...
5	Shell 1	Metal Frame:Operable			Product ID: NA		400	ft2			1.110	0.40	0.00	
6	Shell 2 Upper	Metal Frame:Fixed			Product ID: NA		439	ft2			0.690	0.25	0.00	Tinted Fixed
7	Shell 2 Lower	Metal Frame:Fixed			Product ID: NA		64	ft2			0.690	0.25	0.00	Tinted Fixed
8	Sheel 2 Lower Door	Metal Frame:Operable			Product ID: NA		112	ft2			0.690	0.25	0.00	Tinted Operable
9	West Wall Shell 1	Steel-Framed, 24" o.c.	1 - Office (No...	West			960	ft2	13.0	4.0	0.075			
10	West windows	Metal Frame:Operable			Product ID: NA		240	ft2			1.110	0.40	0.00	
11	West Wall Shell 2	Steel-Framed, 24" o.c.	1 - Office (No...	West			258	ft2	13.0	4.0	0.075			
12	North Wall Shell 1	Steel-Framed, 24" o.c.	1 - Office (No...	North			1680	ft2	13.0	4.0	0.075			
13	North Windows	Metal Frame:Operable			Product ID: NA		720	ft2			1.110	0.40	0.00	
14	Back Door	Glass (> 50% glazing):Metal Frame, Entrance Door			Product ID: NA		64	ft2			0.690	0.25	0.00	Dbl Glass
15	North Wall Shell 2	Steel-Framed, 24" o.c.	1 - Office (No...	North			96	ft2	13.0	4.0	0.075			
16	East Wall Shell 1	Steel-Framed, 24" o.c.	1 - Office (No...	East			960	ft2	13.0	4.0	0.075			
17	East Windows	Metal Frame:Operable			Product ID: NA		240	ft2			1.110	0.40	0.00	
18	East Wall Shell 2	Steel-Framed, 24" o.c.	1 - Office (No...	East			258	ft2	13.0	4.0	0.075			
19	Floor 1	Slab-On-Grade:Unheated	1 - Office (No...			Insulation: None	276	ft						



Chalfoun Spring 2016 IECC 2012.cck - COMcheck 4.0.2.5 Code: 2012 IECC

File Edit View Options Code Help

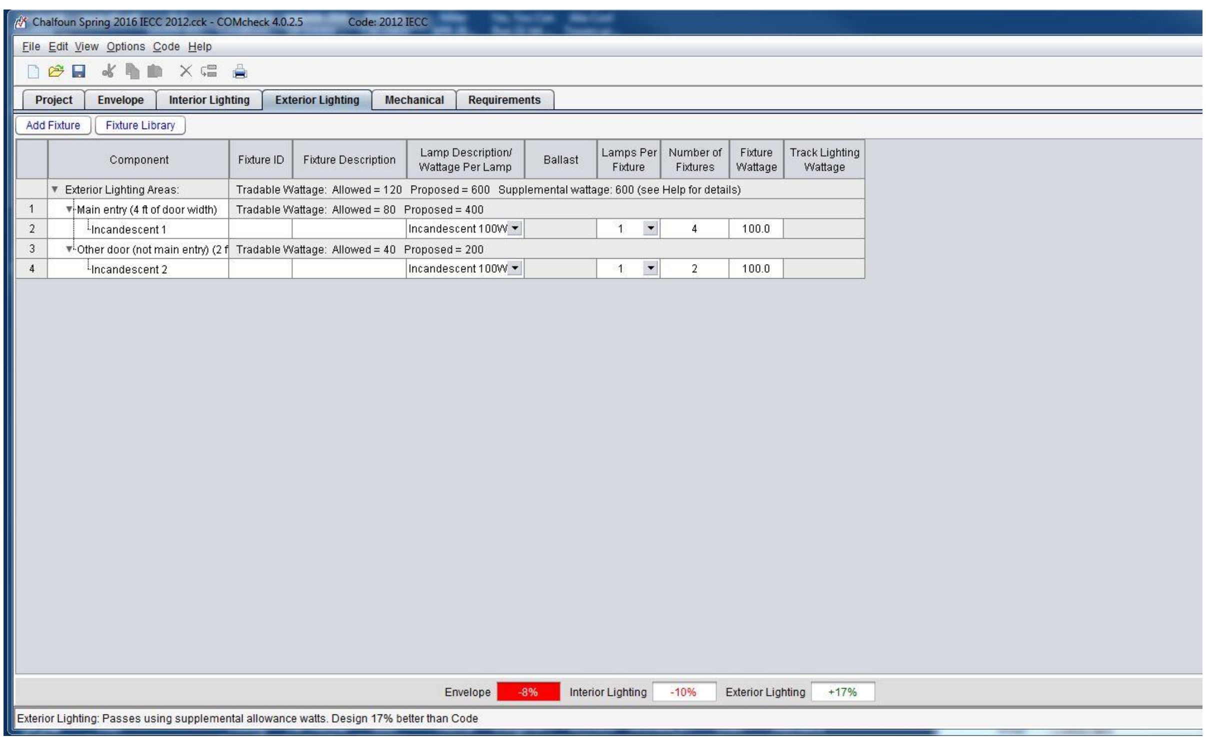
Project | Envelope | Interior Lighting | Exterior Lighting | Mechanical | Requirements

Add Fixture | Fixture Library

	Component	Fixture ID	Fixture Description	Lamp Description/ Wattage Per Lamp	Ballast	Lamps Per Fixture	Number of Fixtures	Fixture Wattage	Track Lighting Wattage
	Building	Allowed wattage = 7128 Proposed wattage = 7826							
1	Office (7920 sq.ft.)	Allowed wattage = 7128 Proposed wattage = 7826							
2	Linear Fluorescent 2			48" T12 Slim ES 3...	Magnetic	2	40	64.0	
3	Linear Fluorescent 3			48" T12 Slim ES 3...	Magnetic	2	4	64.0	
4	Task Lights			Incandescent 75W		1	16	75.0	
5	Shell 1 Spotlight			Incandescent 40W		1	84	40.0	
6	Shell 2 Spotlight			Incandescent 75W		1	6	75.0	

Envelope -8% Interior Lighting -10% Exterior Lighting +17%

Interior Lighting Fails: Design 10% worse than Code



Chalfoun Spring 2016 IECC 2012.cck - COMcheck 4.0.2.5 Code: 2012 IECC

File Edit View Options Code Help

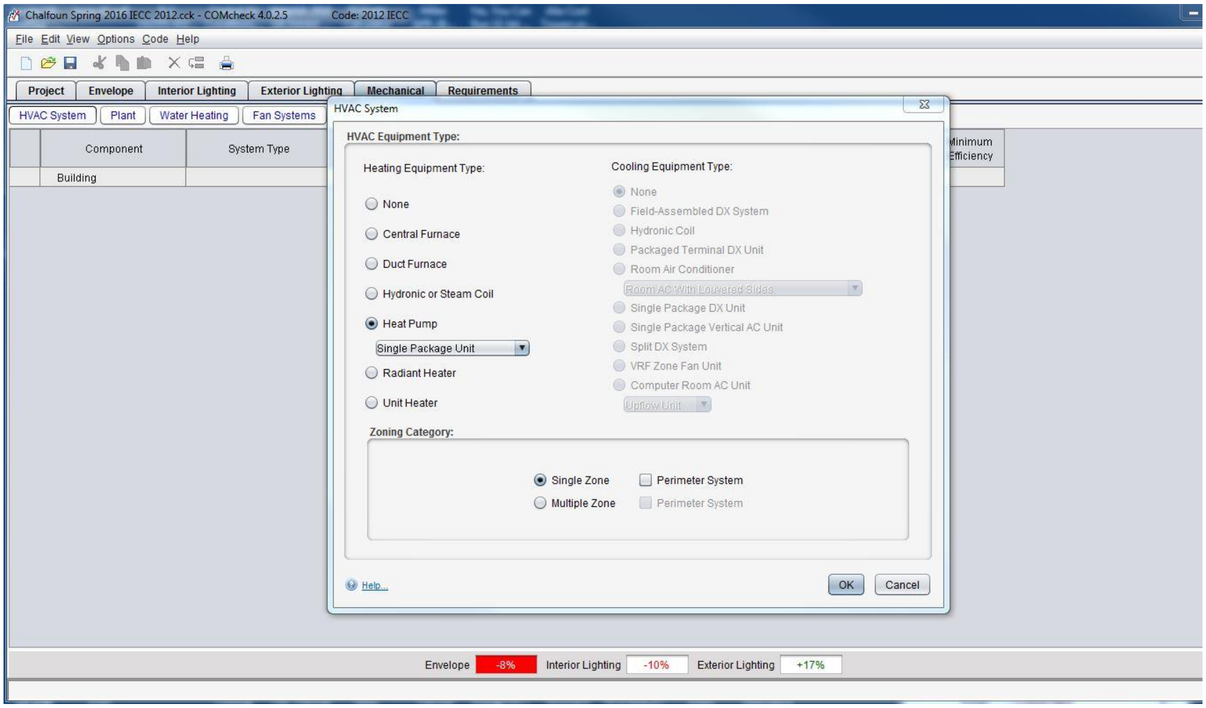
Project | Envelope | Interior Lighting | Exterior Lighting | Mechanical | Requirements

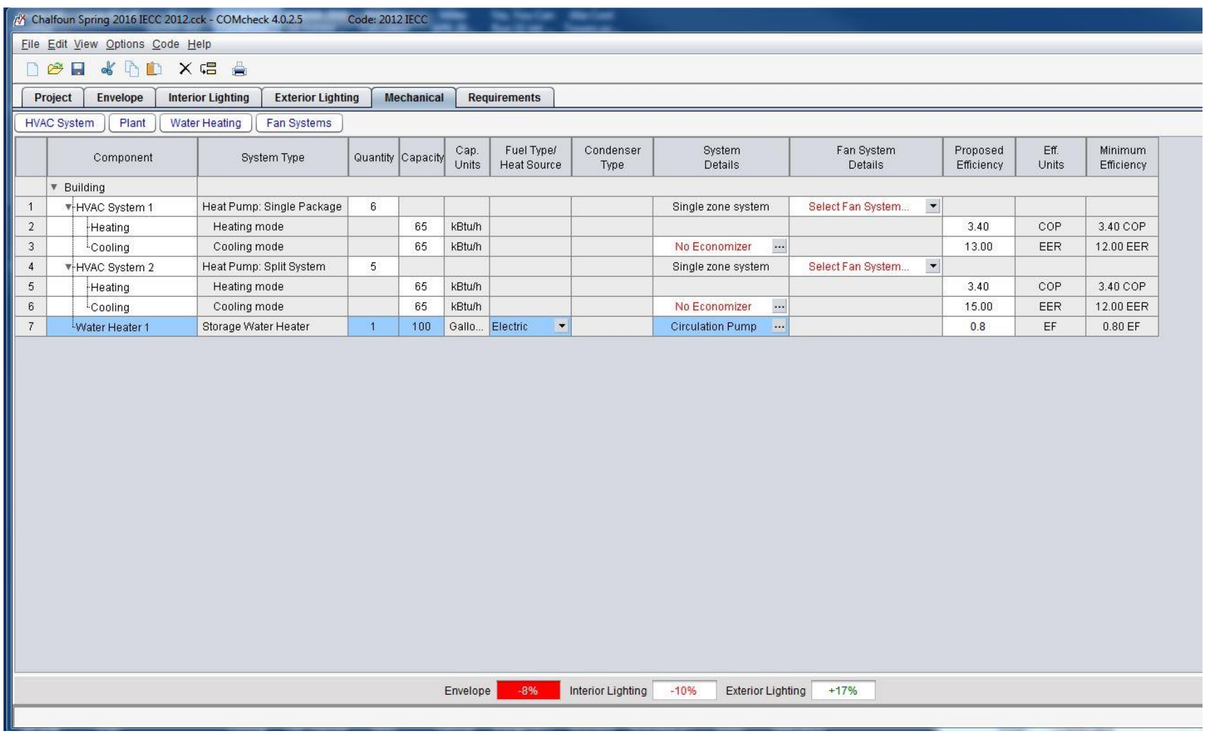
Add Fixture | Fixture Library

	Component	Fixture ID	Fixture Description	Lamp Description/ Wattage Per Lamp	Ballast	Lamps Per Fixture	Number of Fixtures	Fixture Wattage	Track Lighting Wattage
	Exterior Lighting Areas:	Tradable Wattage: Allowed = 120 Proposed = 600 Supplemental wattage: 600 (see Help for details)							
1	Main entry (4 ft of door width)	Tradable Wattage: Allowed = 80 Proposed = 400							
2	Incandescent 1			Incandescent 100W		1	4	100.0	
3	Other door (not main entry) (2 f	Tradable Wattage: Allowed = 40 Proposed = 200							
4	Incandescent 2			Incandescent 100W		1	2	100.0	

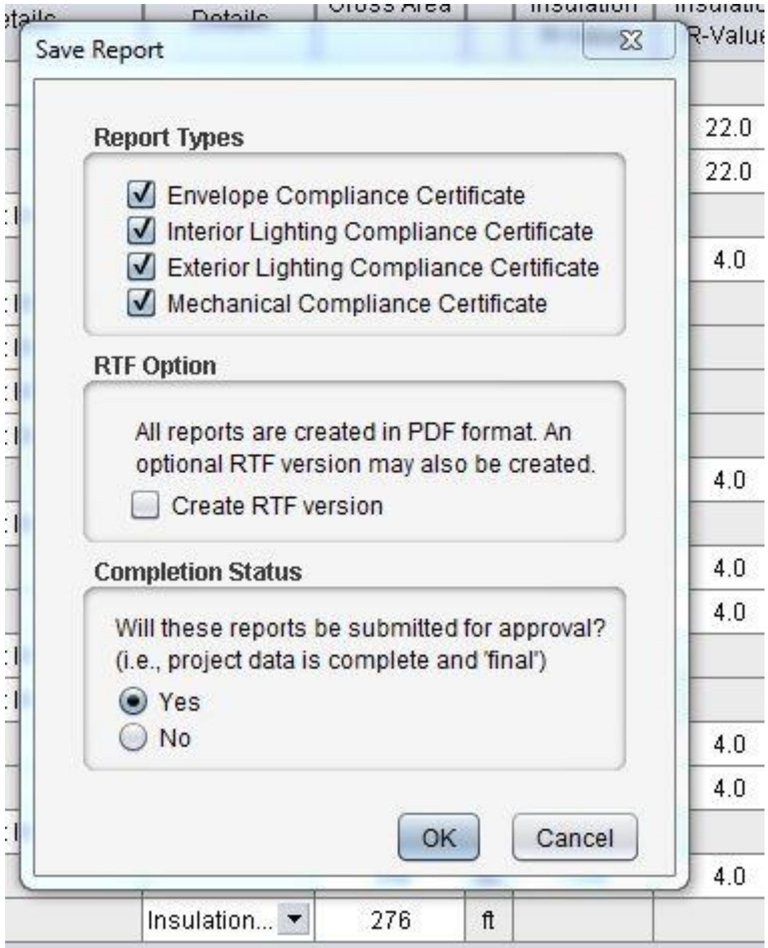
Envelope -8% Interior Lighting -10% Exterior Lighting +17%

Exterior Lighting: Passes using supplemental allowance watts. Design 17% better than Code





	Component	System Type	Quantity	Capacity	Cap. Units	Fuel Type/ Heat Source	Condenser Type	System Details	Fan System Details	Proposed Efficiency	Eff. Units	Minimum Efficiency
	Building											
1	HVAC System 1	Heat Pump: Single Package	6					Single zone system	Select Fan System...			
2	Heating	Heating mode		65	kBtu/h					3.40	COP	3.40 COP
3	Cooling	Cooling mode		65	kBtu/h			No Economizer		13.00	EER	12.00 EER
4	HVAC System 2	Heat Pump: Split System	5					Single zone system	Select Fan System...			
5	Heating	Heating mode		65	kBtu/h					3.40	COP	3.40 COP
6	Cooling	Cooling mode		65	kBtu/h			No Economizer		15.00	EER	12.00 EER
7	Water Heater 1	Storage Water Heater	1	100	Gallo...	Electric		Circulation Pump		0.8	EF	0.80 EF


Save Report
Report Types
Envelope Compliance Certificate
Interior Lighting Compliance Certificate
Exterior Lighting Compliance Certificate
Mechanical Compliance Certificate
RTF Option
All reports are created in PDF format. An optional RTF version may also be created.
Create RTF version
Completion Status
Will these reports be submitted for approval? (i.e., project data is complete and 'final')
Yes
No
OK
Cancel
R-Value
22.0
22.0
4.0
4.0
4.0
4.0
4.0
4.0
4.0
Insulation...
276
ft