

**Development of a Residential Code-compliant  
Web-based Energy Efficiency Calculator  
for Texas**

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## ABSTRACT

Since 2001, Texas has been proactive in initiating clean air and energy efficiency-in buildings policies. The Texas Emissions Reduction Plan legislation of 2001 mandated statewide adoption of energy codes; created a 5% annual energy savings goal for public facilities in affected counties through 2007, and provided approximately \$150 million in cash incentives for clean diesel emissions grants and energy research. Texas, as part of the TERP, also proposed calculating creditable Nitrogen Oxides emissions reduction credits for energy efficiency and renewable energy through the State Implementation Plan under the Federal Clean Air Act.

Residential energy codes create more energy-efficient homes and thus reduce emissions from savings in electricity generation and the burning of on-site natural gas. Since 2001, Texas energy code programs have partially transformed the housing market in Dallas/Fort Worth and Houston with 30,000 Energy Star homes (approximately 27%) in 2006, which have reduced emissions from building energy-efficient homes, and created new manufacturing jobs for energy-efficient equipment and windows. However, several obstacles remain to realizing a total market transformation: the market value of energy efficiency is not uniformly assigned, and there is a lack of consumer awareness to achieve market transformation. Therefore, certain old construction practices remain entrenched. To overcome some of these obstacles, the International Code Compliance Calculator (IC3)

was created. The objectives of IC3 are to: 1) increase the number of homes built in Texas with a target energy performance better than the 2000/2001 IECC baseline<sup>1</sup>; 2) increase the number of builders and building officials familiar with high performance home building options, technologies and quality assurance requirements; 3) increase the number of builders constructing and marketing high-performance homes; and 4) quantify NOx emissions reduction from the energy efficiency measures recorded and verified for each house constructed with IC3<sup>2</sup>. This paper presents information on the design and operation of the IC3 system .

## BACKGROUND

Since 2001, Texas has been proactive in initiating clean air through energy-efficiency-in-buildings policies. The Texas Emissions Reduction Plan (TERP) legislation (SB 5, 77th Leg., 2001) mandated statewide adoption of energy codes; created a 5% annual energy savings goal for public facilities in affected counties through 2007; and provided approximately \$150 million in cash incentives for clean diesel emissions grants and energy

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<sup>1</sup> As of mid-2008, Texas state wide minimum energy code was set to IECC 2000 with the 2001 amendments.

<sup>2</sup> Using eGrid

research. Texas, as part of the TERP, also proposed calculating creditable NOx emissions reduction credits for energy efficiency and renewable energy through the State Implementation Plan under the Federal Clean Air Act.

Starting in 2003, the Energy Systems Laboratory (ESL) at Texas A&M University (TAMU) has been developing the tools, processes, models and techniques to facilitate the above goals through improved home construction. The series of eCalc<sup>3</sup> web based calculators have been visible examples of this work. First, the eCalc system compared pre-code, code and user entered homes; commercial and multifamily buildings; and various municipal and renewable systems. In May 2007, the ESL published the International Code Compliant Calculator (IC3) which was an extremely easy and simple model for entering a new home and thus generating a certificate for above code performance. In August of 2008, the ESL published v3.2 of IC3<sup>4</sup> followed by v1.0 of the Austin specific version of IC3 called TCV<sup>5</sup>.

## METHODOLOGY

Given issues with the use of other code compliant software in Texas, the ESL upgraded its' existing eCalc software, already accepted by EPA and TCEQ for establishing a credible methodology for NOx emissions reductions from above-code construction. The design objectives for the upgrade were:

1. Easier to use than the earlier eCalc
2. Provide results more rapidly
3. Store projects under a user's account
4. Supported as a production web application (versus a University research project)
5. Share as much technology as possible with the Austin TCV product

To accomplish these objectives, new versions of the calculator were created with input from building code officials to provide

performance based simulations for both the given plans and the code equivalent version of those plans. In IC3, the DOE-2 simulation program<sup>6</sup> is used to predict expected energy performance by running two sets of 8760 hourly simulations and to compare the results. Calculated Nitrogen Oxides (NOx), Sulfur Dioxides (SOx), and Carbon Dioxide (CO2) emissions reductions from the above-code energy efficiency are also calculated for the homes that pass code compliance using the US eGrid emission database<sup>7</sup>.

## Workflow Overview

The workflow of both systems is extremely simple. Existing users simply log in and either enter a new home (called a **project**) or select an existing project for further edition. If they have not yet signed up, the user may create an account by filling in their email address and their password. If the current project is at or above code, then the user will receive a certificate (as an Adobe PDF file) suitable for printing, saving or emailing. If the home is below code, then the system will show the user where they may have missed an input or warn the user that the home is below code. Over time the "intelligence" of the software will be improved and suggestions will be provided to the user based on the most common reasons a project fails.

There is currently no inspection mechanism; hence, ESL is working with various governmental entities to define a realistic process for verification of homes being built as entered so they may be counted towards emission reduction goals with minimal discounting.

## Software Architecture

The IC3 Software consists of many logical packages explained as three layers as follows:

- Web Software
- Database
- Calculation Engine

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<sup>3</sup> eCalc 2005

<sup>4</sup> IC3 2007

<sup>5</sup> TCV 2008

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<sup>6</sup> LBNL, DO2.

<sup>7</sup> EPA 2002.

Each of these layers is further divided as described below. An overview of this architecture is provided in Figure 1 IC3 Architecture. The fully assembled software is deployed to two locations on the Test Tier and two on the Production Tier as described in Figure 2 IC3 Deployment..

### **Web Software**

The application is written using a foundation of Microsoft .NET v2.0<sup>8</sup> running on Microsoft IIS v6.0<sup>9</sup> hosted on a single HP server. Layered on top of the .NET software is a variety of open-sourced frameworks and libraries organized into three groups, including: views, business/domain rules and energy code rules. The system has been tested using a small cluster of web servers, thus allowing for larger computing loads. Simulated stress testing indicates that the system should be able to handle over 50 concurrent users<sup>10</sup>.

**Views:** This is the part of the program that “runs” in a browser. These are built dynamically using HTML and CSS technology, along with JavaScript where necessary. The Views provides placeholders for the actual controls (i.e., fields, buttons, and menus) to live, and applies a “skin” to them so they appear homogeneous with the rest of the site. The software currently supports Microsoft Internet Explorer (IE), versions 5 and 6, and Mozilla FireFox<sup>11</sup>, versions 2.2 and 3.0. Initial testing indicates that IE version 8 and Google’s Chrome browser work with only minimal visual differences.

**Business/Domain Rules:** This portion of the web system is written in Microsoft C#<sup>12</sup> on top of an open source framework. Together, the values are entered from the View and checked to see if values are within range, properly formatted (i.e., insulation values must be numeric, not letters), translated and then recorded to both the User’s values and the Code Compliant version of the User’s values into the database for the CalcEngines to later process.<sup>13</sup> Printing of the certificate for homes that pass is also handled at the WebServer. The certificate is created as an Adobe Acrobat™ file for easy storing, printing, and emailing. Emissions reduction are calculated by taking the electrical savings, using an historical power allocation per county<sup>14</sup> then allocated through EPA’s eGRID<sup>15</sup> emissions database to determine emissions by county for pounds of SOx, NOx, and CO2 per Kilowatt hour of savings. Note that natural gas savings are converted into NOx emissions using the EPA’s emissions factors.<sup>16</sup> Future versions of the calculators could support having this layer moved from the web server to a dedicated business machine, however, this level of complexity is not currently justified.

### **Database**

IC3 is data driven, which is to say the development effort is focused on creating “engines” that are as generic as possible and are “fueled” by data. The data is split between

<sup>8</sup> <http://www.microsoft.com/net/>

<sup>9</sup> <http://www.microsoft.com/WindowsServer2003/iis/default.msp>

<sup>10</sup> The system’s capacity was based on the following conservative values: 160,000 new homes in Texas in 2006, a maximum of 2064 working hours in the year, and five minutes per house, giving 6.5 concurrent users. Since Texas are currently building fewer houses, and builders will probably have houses entered at all times of the day and night, and it only takes 2 minutes to enter a house, there is plenty of capacity.

<sup>11</sup> <http://en-us.www.mozilla.com/en-US/>

<sup>12</sup> <http://msdn2.microsoft.com/en-us/vcsharp/default.aspx>

<sup>13</sup> See the discussion on polling that follows.

<sup>14</sup> The Texas Public Utility Commission published information on how each ERCOT County’s power was allocated according to the Power Control Authorities servicing each County in Texas. This information is used by the ESL in its Annual reports to the TCEQ.

<sup>15</sup> <http://www.epa.gov/cleanenergy/egrid/index.htm>

<sup>16</sup> EPA AP42 Project, published in 2003, [www.epa.gov/ttn/chief/ap42/ap42supp.html](http://www.epa.gov/ttn/chief/ap42/ap42supp.html). NOTE: the software uses a specially prepared version of eGrid for annual and Ozone Season Day calculations for the year 2007.

reference values, the actual projects, user data and simulation data.

**Reference Values:** These are values stored for use by the User Interface and the Calc Engines (see Section 3.3.3) that are not usually “hard coded” into the software. Rather, they tend to “persist” either in XML files (if they only need to be loaded once and kept in memory) or in the central SQL Server database (if they are numerous and require a lookup for each project, such as the eGRID data used to calculate emissions reductions).

**House (Project) Data:** This is the data kept for each and every house/duplex/multi-family home. They are called “Projects” by the IC3 software. User information is also stored in the database. The Project data is updated as the simulations are run so they carry calculated values such as their estimated energy values, and emissions. The application protects a builder’s data from all other builders.

**Simulation (Job) Data:** This data is specific to the running of the Calc Engine (see Calculation Engine). They are derived from the Project Data and put into a specific format for the CalcEngines to retrieve process and update. As versions of IC3 require running multiple simulations to arrive at an estimated energy usage, there is a need to store the data during the simulation runs. Storing the data in this way also allows for the system to “Scale Out” by adding CalcEngines when the load requires them. This data is not stored for very long periods of time.

### **Calculation Engine**

The Calculation Engine (CE) software lives on the CalcServer computers. The CE itself is comprised of several components that perform special functions to move data from the Jobs Database, to the simulation, and then post the results back to the Project Database.

**Poller:** Each CalcServer runs a query against its target Job database as often as once per second. The timing is controlled by a value in a configuration file hosted on the hosting CalcServer. The system was designed to accommodate additional users and, thus, simulation runs by simply adding CalcServers

and their CE’s; it can then be said that the system is “self balancing” and “scales out.” When a Job is found (based on the Status field in the Jobs Database), the Poller retrieves the Job data and transfers it to the Simulation Interface.

**Simulation Interface:** This component of the CalcEngine processes the Job Data and prepares it for use by the legacy simulation. It writes out the values into files “consumed” by the custom scripts that are then “fed” into the DOE-2 legacy simulation program. This component is also responsible for retrieving the output of the simulation and passes it back to the Project Database.

**The Simulation:** The legacy simulation used for the thermal analysis is the DOE-2.1e program from the Lawrence Berkeley National Laboratory.<sup>17</sup> DOE-2 is controlled by a custom input file called Building Description Language (BDL). The ESL faculty, staff and graduate students have invested several years in the creation and testing of scripts that are used to simulate buildings of different types. Presently, the scripts take the specific Project variables through a specially formatted parameter file. At this time various business and energy code rules are also found in this layer, future versions will see those rules moved out to Business Layer of the system

## **QUALITY ASSURANCE**

Software Quality Assurance (SQA) includes both review and testing. The three TERP Groups (Modeling, Software Engineering, and Energy Building Codes) follow a process for adding new features to the system that starts with a request for a new feature, developing the specifications for that feature, design, review during development, and then testing of the assembled system that includes that feature.

### **Simulation**

The Modelers perform their own SQA, which is loosely based on the processes of the SE Group. These include peer code reviews, which design and execute both White box and Black box tests, and provide test sets for regression

<sup>17</sup> LBNL 1993a; 1993b

tests used by the Modelers and the SE Group. They also compare our results to other publically available systems to ensure that the simulations are reasonable.

### **Software**

The ESL TERP Groups have an extensive set of activities to maximize the quality of the deployed system. Using the design materials as a starting point, a Test Plan is created and populated with Test Sets. Some of these Test Sets are written by the programmers, i.e. White Box and Unit Tests, and others by the Software Quality Assurance (SQA) person, i.e. Black Box. Many of the tests are run overnight as part of the Continuous Integration process that compiles tests and automatically deploys parts of the system.

Additional tests are run by the SQA group against the fully integrated system using software tools to verify correction operation as well as load capacity. Some of these tests are intended to confirm that the simulation scripts work the same on the assembled web program as they do on desktops of the modelers where the DOE-2 program is used directly. Manual (human) tests are also run. Additional testing occurs with the Modeling and Energy Building Code Groups, as well as by Stakeholders, who run their own tests on the candidate system before it is put into production. If a defect is found, there is an established procedure (and tool) for reporting, confirming, fixing and confirming the fix with a full audit trail.

### **Other Quality Measures**

ESL executed the original eCalc project under the guidance of an EPA approved Quality Assurance Project Plan (QAPP). Going forward, the ESL continues to be guided by the practices found in the QAPP.

ESL is part of the Texas Engineering Experiment Station, a Texas State Agency. As such, ESL is subject to audits by the Agency and State for IT compliance in such areas as security, change management, systems development, and disaster recovery.

## **SUMMARY**

The ESL TERP Groups have delivered three major versions of the IC3 software family in two years. As indicated, ESL is looking at the best ways to fulfill the legislative mandates and

opportunities presented by the Texas Legislature, as well as applying research results to improve the lives and prosperity of Texans and Americans.

## **ACKNOWLEDGMENTS**

This project would not have been possible without significant participation from Mr. Ed Dryden at the City of Arlington, Mr. John Umpress and Mr. Richard Morgan at Austin Energy; Ms. Sherrie Hughes, ESL staff; Mr. Matt Moss, Ms. Megan Bednarz, Mr. Sean Choate, Ms. Heeyon Cho, Mr. Sean Taylor, Mr. Vardhaman Bora, Mr. Craig Schraeder, Mr. Lance Ballard, and Ms. Mini Malhotra, ESL students.

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LBNL, DOE2, DOE-2.1e Software, Lawrence  
Berkeley National Laboratory, US Department of  
Energy, Build 119.

TERP, Texas Emissions Reduction Plan  
legislation (SB 5, 77th Leg., 2001)

### FIGURES

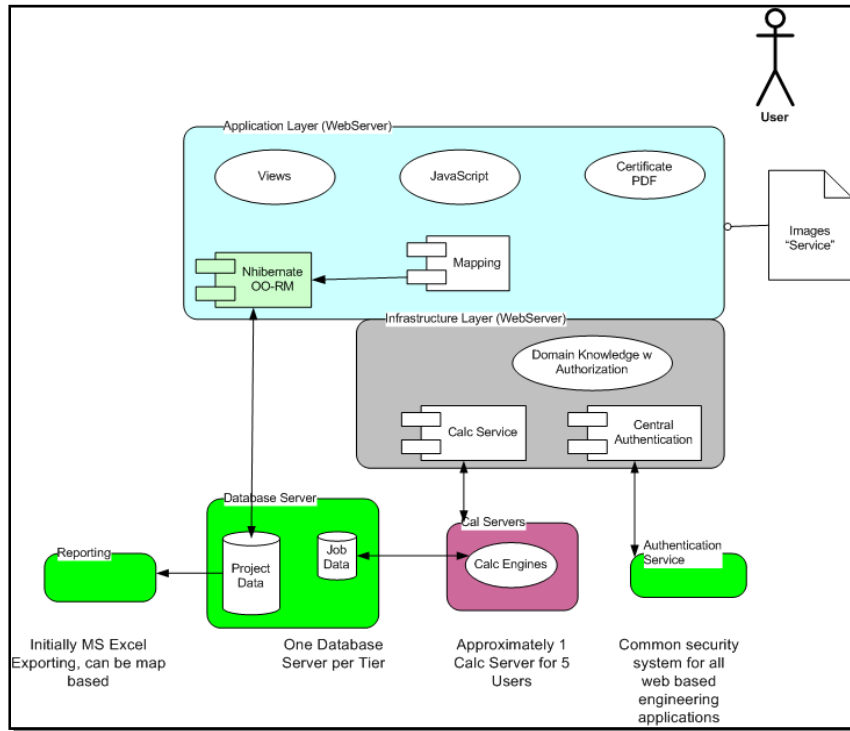


Figure 1 IC3 Architecture

This is a very high-level overview of the major parts of the web-based software.

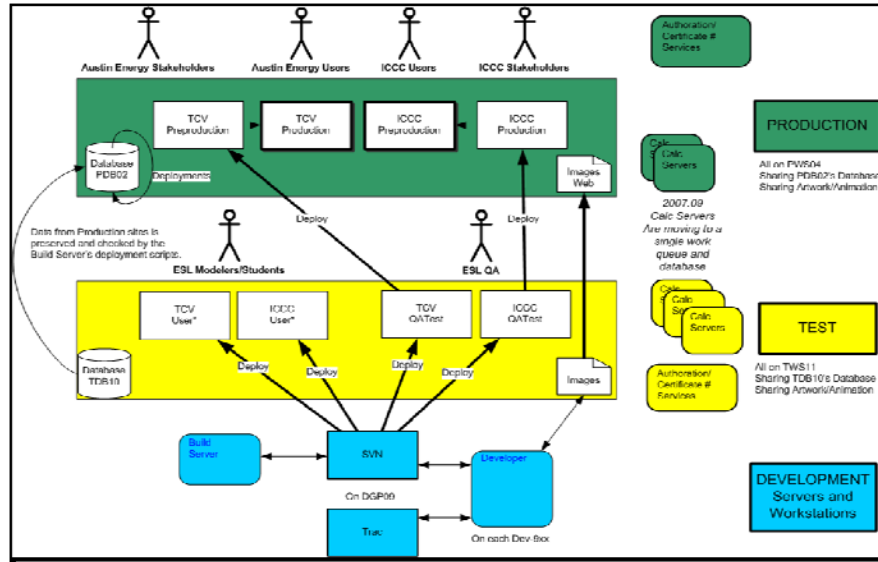


Figure 2 IC3 Deployment.

This diagram illustrates the three tiers used by the ESL in Developing, Testing, and then publishing IC3.

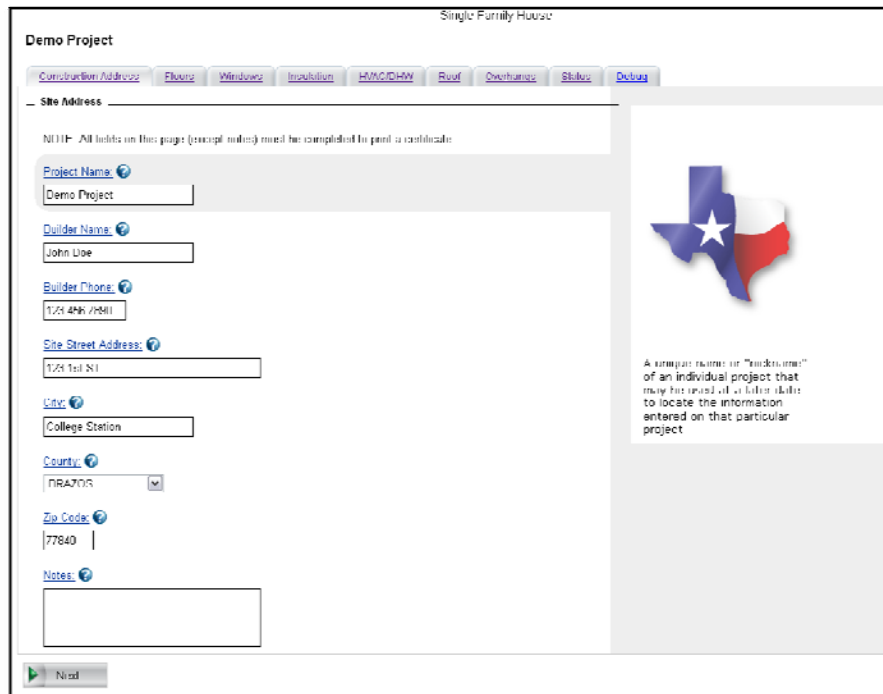


Figure 3 IC3 Address Tab

The Builder enters the information on the house (Project) they wish to have rated. The "Project Name" field is unique to each Builder's account and is specifically for their reference.

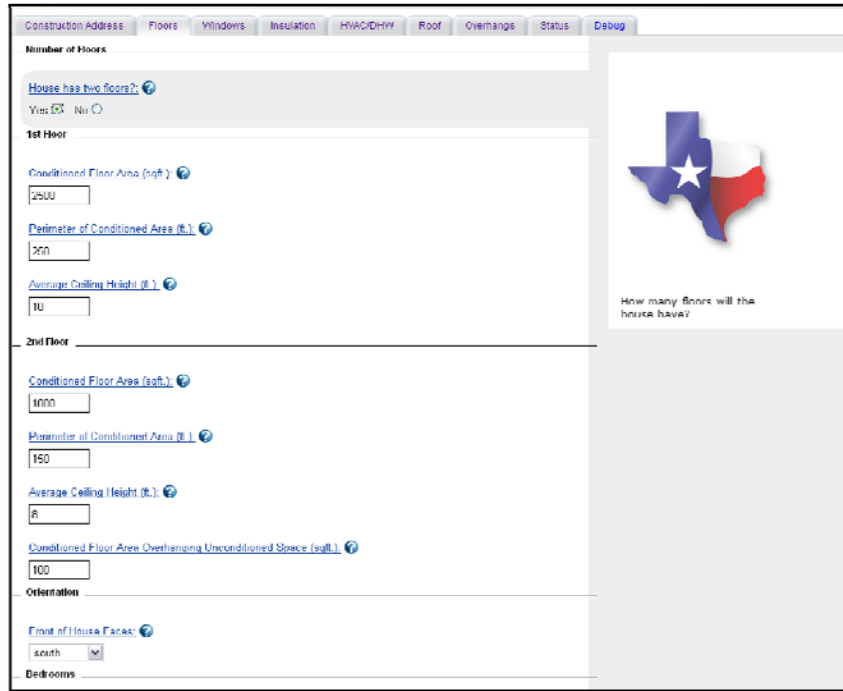


Figure 4 IC3 Floor Tab.

This tab starts the process of entering a house (Project). The system supports houses with one or two floors and allows for different measures for each of the floors, and allows a user to specify any overhang of the second floor over the first. The system will trap geometries that cannot be simulated.



Figure 5 IC3 Window Tab.

The Window tab allows for the building level entry of glazing information, as well as each elevation's windows.



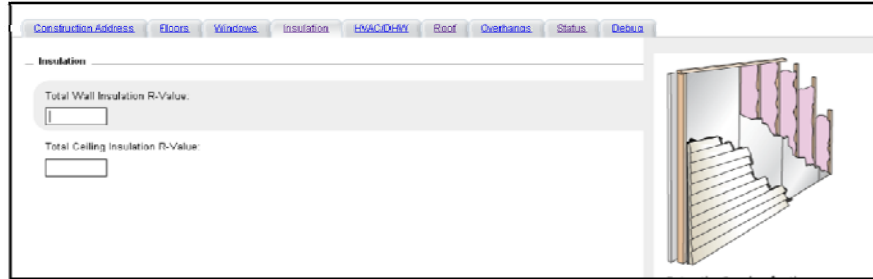


Figure 6 IC3 Insulation Tab

Ceiling and wall insulation: a new field for external sheathing insulation is being evaluated.

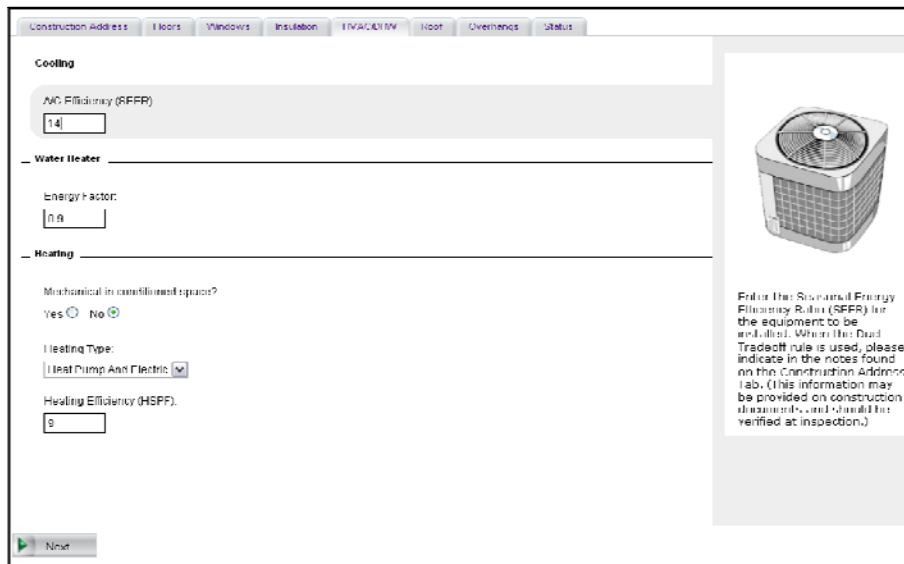


Figure 7 IC3 Climate Control Tab.

Here the Builder is able to enter the details of the home's mechanical systems. As IC3 is a performance calculator, the positive impact of putting the Mechanicals in Conditioned Space is given due credit. The water heater can have a large impact on the performance of the home.

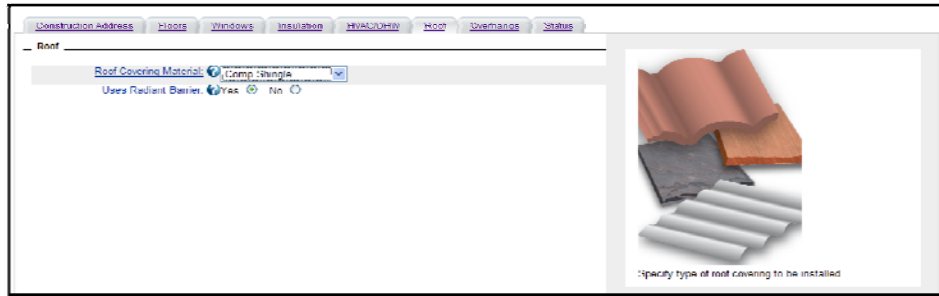


Figure 8 IC3 Roof Tab

These questions allow the system to capture and model the impact of roof construction. In middle and northern climate zones, Radiant Barriers have a modest impact due to the increased heating energy required in the winter.



Figure 9 IC3 Horizontal Projection Tab.

The software calculates the shading provided by overhangs on glazing, but in more northern climates, too much shading can reduce the net positive impact due to increased heating energy in the winter.

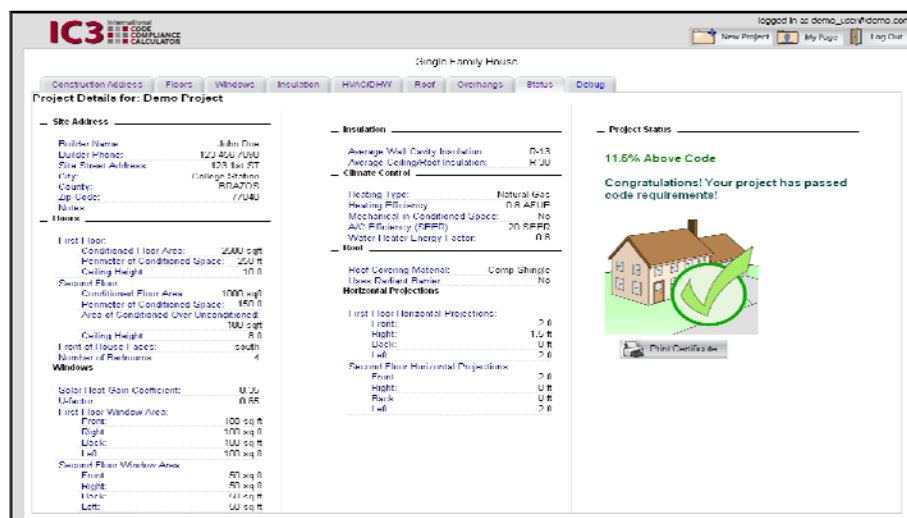


Figure 10 IC3 Project Status Tab.

This screen provides a recap to the builder of all of the prior sections. Errors are noted and allow for one click to return to the tab needing attention. Several common errors are specifically trapped, and with feedback from the users to ESL, the system will provide additional guidance for the more common failure modes in the future.

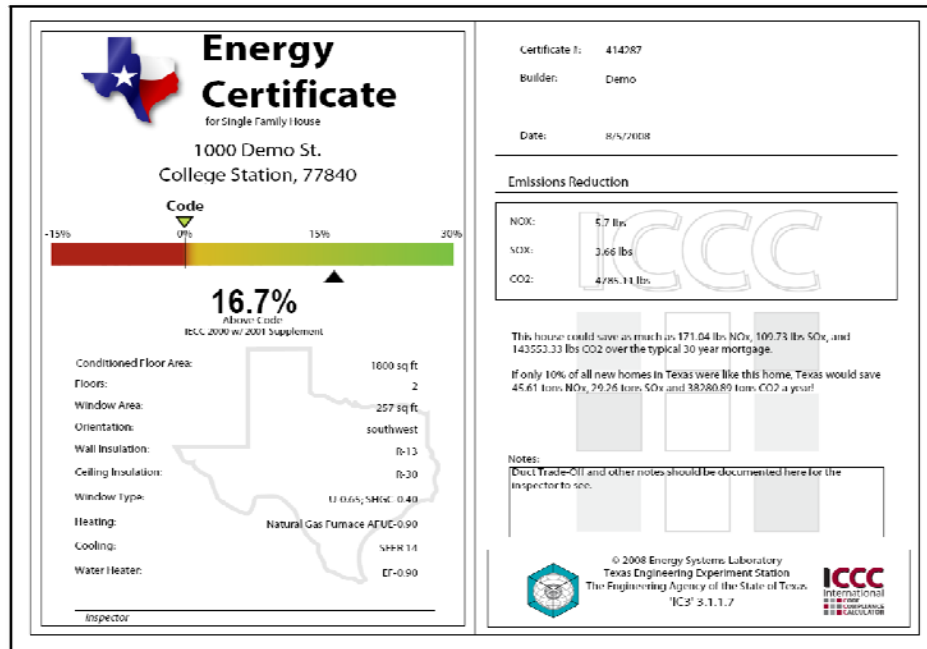


Figure 11 IC3 Energy Compliance Certificate

This report is generated by IC3 if the house meets or exceeds Code. It is presented to the Builder as a PDF file and can be saved, printed, or e-mailed for the code review process.