Development of a Residential Code-compliant Calculator for the Texas Climate Vision Project

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1 - ABSTRACT

The United States Environmental Protection Agency (EPA) has designated four areas in Texas as having unacceptable ozone levels in excess of the National Ambient Air Quality Standard (NAAQS) limits, leading to a designation as non-attainment areas. One of those areas is Austin, a City already known for its environmental zeal. Austin owns its municipal power provider, Austin Energy (AE). Together, they have embarked on many programs to reduce greenhouse gases while maintaining service levels and providing the best return on capital. Of the stationary emissions, a large percentage is sourced to buildings that have driven Austin to adopt "above code" standards for new buildings. Austin, with assistance from the Energy Systems Laboratory (ESL), extended the IECC 2006 to further strengthen building codes. Funding from the US Department of Energy (DOE) and the Texas State Energy Conservation Office (SECO) has provided an opportunity for Austin Energy to team with ESL to implement a two-year project called the "Texas Climate Vision" (TCV). The mission of TCV is to realize 20%-40% above code homes using a combination of better codes, improved processes, inspection, and information technology. This paper provides an overview of the permitting process of a single-family house and how the web-based software collects, calculates and certifies above-code compliance for each home, while aggregating data and providing value to builders, inspectors and Austin Energy.

2 - BACKGROUND

The TCV Project is intended to serve as a pilot program to demonstrate the feasibility of 20% to 40% increase in the energy efficiency of new residential buildings when compared to the 2006 IECC by providing technical assistance, training, advanced modeling and information technology. The existing Texas Energy Partnership created by the State Energy Conservation Office (SECO), will be extended by the ESL creating new teaming arrangements with the City of Austin and with the Texas Home Energy Raters Organization (TxHERO) to provide the services and tools to builders and inspectors in the Austin market. One of the key benefits from the energy savings is NOx emissions reduction, which can reduce dangerous ozone concentrations in those areas of the state that are not in compliance with the NAAQS.

Since 2001, Texas has been proactive in initiating clean air and energy efficiency-in-buildings policies. The Texas Emissions Reduction Plan (TERP) legislation (SB 5, 77TH Leg., 2001), mandates statewide adoption of energy codes, creates a 5% annual energy savings goal for public facilities in affected counties through 2007 and provides approximately $150 million in cash incentives for clean diesel emissions grants and energy research. Texas was the first state in the nation to create emissions reduction credits for energy efficiency and renewable energy through the State Implementation Plan under the Federal Clean Air Act.

Residential energy standards create more energy-efficient homes and thus reduce emissions from electricity generation. Texas programs have partially transformed the housing market in Dallas/Fort Worth and Houston with 30,000 Energy Star homes (approximately 27 %) in 2006, greatly 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, old construction practices remain entrenched.

The objectives of TCV are to: 1) increase the number of homes built in Texas with target energy performance at least 20% better than the 2006 IECC baseline; 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; 4) increase the market penetration of proper HVAC sizing and home energy performance testing; and 5) quantify emissions reduction from energy efficiency. The ESL has also proposed to transfer the Austin model to other areas in Texas, including: Dallas, Houston, and San Antonio.

3 - METHODOLOGY

Starting in early 2008, Austin Energy will require the majority of new single-family homes to run pre- and post-construction simulations in order to:

1. Confirm code compliance (IECC 2006 w Austin Energy amendments),
2. Quantify above code projected savings, and
3. Quantify the emissions reductions relative to 2000 IECC as modified by the 2001 Supplement.

To accomplish this, a web-based software system[1] (TCVS) was developed to assist in the plan review and adherence to inspection standards by checking values and running both pre- and post-construction simulations using the DOE-2 simulation program[2] to predict expected

[1] Derived from ESL's eCalc and e^{2}Calc software systems, "ecalc.tamu.edu".

[2] Department of Energy, Lawrence Berkley National Laboratory, DOE-2 simulation.

energy performance. Estimated emissions reduction from the savings that result over and above compliance to the 2000 IECC are calculated and reported to both the Texas Commission on Environmental Quality (TCEQ) and the U.S.E.P.A.

3.1 Austin Codes Overview

Since 1982, the City of Austin and Austin Energy have been operating a variety of energy-efficiency programs. These programs have been successful in providing energy-efficient homes and buildings for the citizens and businesses of Austin and in reducing demand on Austin Energy's generation assets. Data from the Texas Public Utility Commission show that the average annual electric usage for Austin Energy residential customers is lower than other major cities in central and south Texas.

In addition, under an agreement with the City of Austin Watershed Protection and Development Review Department (WPDR), Austin Energy Green Building (AEGB) has been responsible for developing new energy codes for the City since 1995. This code development process entails the review of national energy codes, in this case the International Energy Conservation Code of 2006, and developing local amendments which will help the City meet its policy goals and the needs of its citizens. These goals include energy-efficient housing and buildings that will reduce utility costs for citizens, reduce demand for new generation capacity for the electric utility, and reduce greenhouse gas emissions from fossil fuel power plants.

In August 2006, the Austin City Council directed that city staff create a Task Force to develop a plan to make all homes built in the city "Zero Energy Capable" by the year 2015. Members of the task force represented the local home builders association, HVAC contractors associations, American Institute of Architects, affordable housing providers, energy-efficiency advocates, and city staff. Over the course of 10 months, the task force reviewed, amended, and approved a package of local amendments to the 2006 IECC that was adopted as the City of Austin Energy Code on October 18, 2007, and will take effect on January 1, 2008. The task force also adopted a plan to fully achieve Zero Energy Capable Homes by 2015. The plan includes goals for further improving the energy code in code cycles 2009, 2012, and 2015 and the process by which the code changes will be reviewed, evaluated, and approved to be forwarded to the City Council for adoption. These improvements, when fully adopted, will make the typical home built in Austin 65% more efficient than current code. "Zero Energy Capable" was defined by the task force as being 65% more efficient that the energy code in effect in November 2006.

The local residential code amendments adopted by the City of Austin include:

- Requirement for building thermal envelope testing;
- Requirement for installation of a radiant barrier;
- Requirement for testing for duct system leakage;
- Requirement for submittal of HVAC sizing documentation;
- Requirement for air balancing and static pressure testing of HVAC system; and

- Requirement that 25% of indoor lighting be high-efficacy lighting.

These code changes are estimated to reduce electric consumption in the typical 2,300 square foot home built in Austin by 2515 kWh per year.

3.2 Workflow Overview

Verifying the energy efficiency of a new home is captured in three steps by the TCVS: 1) A builder's input of building specifications (i.e. the Plans), 2) Assignment of a Third Party Inspector (TPI), and 3) The TPI's confirmation of "as built" values and measures (Figure 13). The Builder's input results in an As Designed Estimated Energy Report (Energy Report) which shows the "percentage above code" for the given plans. This Energy Report is provided to the Builder as an Adobe Acrobat™ file (i.e., a PDF file) when the house meets or exceeds IECC 2006 with Austin Energy amendments. The printed Energy Report is processed along with the paper Plans in the existing City of Austin work flow (Figure 14). When the home is ready for inspection, the Builder selects an approved TPI from within the web software. The Inspector is notified with an email and a copy of the Energy Report in PDF form.

Finally, the TPI inspects the house to record performance measures such as Duct Blaster, Blower Door, as well as "as built" values such as the number of pilot lights, water heater size, the installed HVAC's SEER and tonnage. When all of the inspection values have been entered, they are checked for meeting or exceeding the Austin amended IECC 2006 standards. If the house passes, a Certificate of Estimated Energy Compliance is presented as a PDF. This is then printed and provided to the Builder and the City for mounting in the electrical panel and for presentation for a City of Austin Certificate of Occupancy (Figure 13).The system was designed by an interdisciplinary team of inspectors, artists, and programmers to ensure that the system was as easy to use as possible. A walkthrough of the system is provided in *BUILDER* WALKTHROUGH, below.

3.3 Software Architecture

The TCV Software (TCVS) consists of many layers that have been organized into three packages:

Web Software	Database	Calculation Engine

Each of these is further divided as described below. An overview of this architecture is provided in Figure 16. The fully assembled software is deployed to two locations on the Test Tier and two on the Production tier as described in the Figure 17.

3.1.3 Web Software

The application is written using a foundation of Microsoft .NET v2.0[3] running on Microsoft IIS v6.0[4] 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.

[3] http://www.microsoft.com/net/

[4] http://www.microsoft.com/WindowsServer2003/iis/default.mspx

Views. This is the part of the program that "runs" in your browser. Portions of this are very much like a basic website. It is built using HTML and CSS technology, along with Javascript where necessary. This view 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.

Business/Domain Rules. This portion of the web system is written in Microsoft C#[5] 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 textual), 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.[6] Printing of the certificate (or "Top 10 List" for *houses* that fail) 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[7] then allocated through EPA's eGRID[8] emissions database to determine emissions by county for pounds of SOx, NOx, and CO2 per Kilowatt hour of savings. Natural gas savings are converted into NOx emissions using the EPA's emissions factors.[9] The email functionality is also kept at this level, allowing both the ENERGY CERTIFICATE (see Figure 12 – Certificate) and ENERGY REPORT to be emailed automatically if a Builder has entered email addresses for concerned parties.

Separation of Concerns – Energy Code "Rules." During development of the first release (i.e., Single Family), the ESL determined a method to organize the software components such that a municipalities' rules and the rules specific to a particular version of IECC should be coded separately to improve the ability of the system to accommodate different jurisdiction's requirements more accurately, robustly and quickly.

3.2.3 Database

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

Reference Values. These are values stored for use by the UI 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). Most of the values set by the ESL as a result of compliance with the IECC (as

[5] http://msdn2.microsoft.com/en-us/vcsharp/default.aspx

[6] See the discussion on polling that follows.

[7] The Texas Public Utility Commission published information on how each ERCOT County's power was allocated according to the Power Control Authorities servicing that County. This information is used by the ESL in their Annual reports to the TCEQ.

[8] http://www.epa.gov/cleanenergy/egrid/index.htm

[9] EPA AP42 Project, published in 2003, www.epa.gov/ttn/chief/ap42/ap42supp.html.

amended by Austin) are usually found in the XML files.

House (Project) Data. These are the data kept for each and every house/duplex/multi-family home. They are called “Projects” by the TCVS 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, emissions, inspection results, and status. The application protects a Builder’s Data from all other Builders and only allows the assigned inspector to have access to the information. Austin Energy has access to all data, which is consistent with the current workflow and the public nature of the data.

Simulation (Job) Data. This data are specific to the running of the Calc Engine (see Section 3.3.3). They are derived from the Project Data and put into a specific format for the CalcEngines to retrieve process and update. As versions of e^2Calc 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. These data are not stored for very long periods of time.

3.3.3 Calculation Engine (CalcEngine)

The CalcEngine software lives on the CalcServers computers. The CalcEngine 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 CalcEngines; hence, it is 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 Berkley National Laboratory.[10] DOE-2 is controlled by a custom input file called Building Description Language (BDL). The ESL staff and graduate students have invested 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.

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[10] LBNL 1993a; 1993b

4 - Quality Assurance

The Software Quality Assurance (SQA) includes both review and testing. The ESL's Modeling and Software Engineering Groups present to each other (and the Code Group[11]) the intended programming and testing approaches for new Calculator functionality early in the development cycle. The two groups have an established process to coordinate the development of the user interface, simulation interface, scripts, code rules and domain rules among each other and our external stakeholders.

4.1 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 tests used by the Modelers and the SE Group.

4.2 Software

The Software Engineering Group has 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 Quality Assurance (QA) 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.

[11] The Code Group is responsible for bringing ESL's research to the Codes Community through committee participation, consulting and training.

Additional tests are run by the QA 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 Code Groups, as well as Stakeholders, who run their own tests on the complete 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.

5 - SUMMARY

The currently funded project is aimed at an integrated approach to significantly improve Austin residential building performance. The integrated use of the software tool for both energy estimation and workflow is one unique aspect of the project. The project is on track toward accomplishing the stated objectives. The ESL has also proposed to transfer the Austin model to other areas in Texas, including Dallas, Houston, and San Antonio.

6 - ACKNOWLEDGMENTS

Funding for this work was provided from the US Department of Energy (DOE) and the Texas State Energy Conservation Office (SECO). This project would not have been possible without significant participation from Mr. John Umpress at Austin Energy; Ms. Sherrie Hughes and Ms. Angie Shafer of the ESL staff; Ms. Megan Bednarz, Mr. Matt Moss, Ms. Heeyon Cho, Mr. Sean Taylor and Ms. Mini Malhotra, ESL

students; and Mr. Felix Lopez, P.E., the project manager with SECO.

7 - REFERENCES

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IECC 2000. International Energy Conservation Code. International Code Congress, Falls Church, VA, Second printing, January 2001.

IECC 2001. 2001 Supplement to the International Codes. International Code Congress, Falls Church, VA, Second printing, March 2001.

IECC 2001. 2006 Supplement to the International Codes. International Code Congress, Falls Church, VA, Second printing, November 2006.

LBNL, 1993a. DOE-2.1e BDL Summary. Lawrence Berkeley National Laboratory LBNL Report No. 349346.

LBNL, 1993b. DOE-2.1e Supplement. Lawrence Berkeley National Laboratory LBNL Report No. 349347.

8 - BUILDER WALKTHROUGH

This walkthrough assumes that the builder has created an account, it has been approved, and they have logged into the system. Note that when a builder clicks any of the "?" icons or the blue underlined text, a specific image/animation appears along with supporting help.

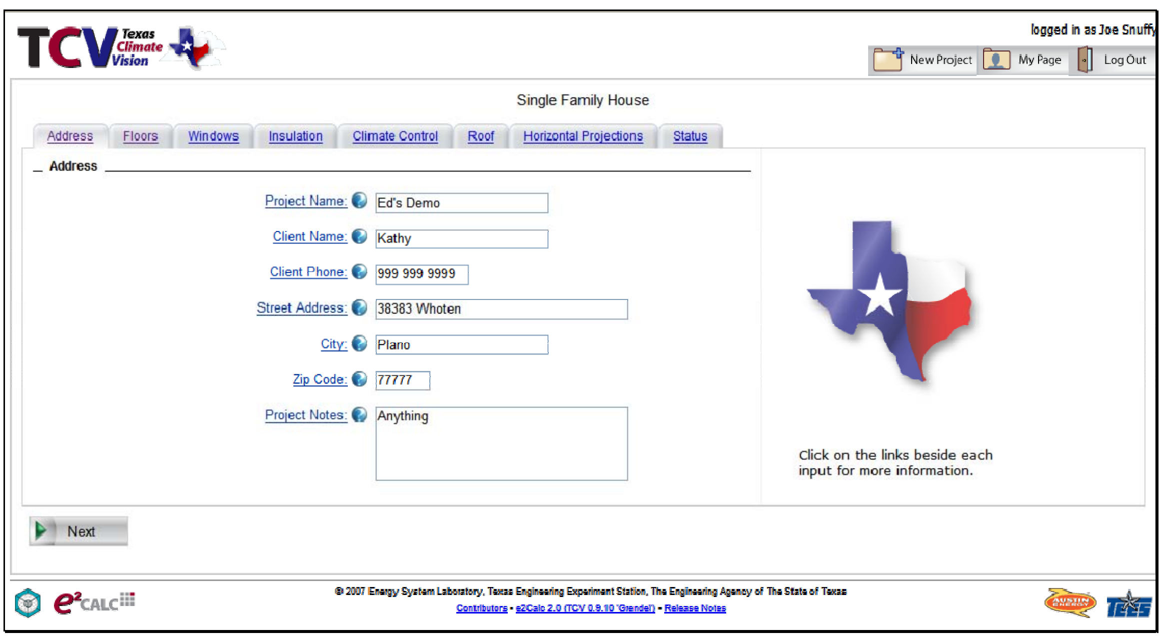


Figure 1 – Address

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.

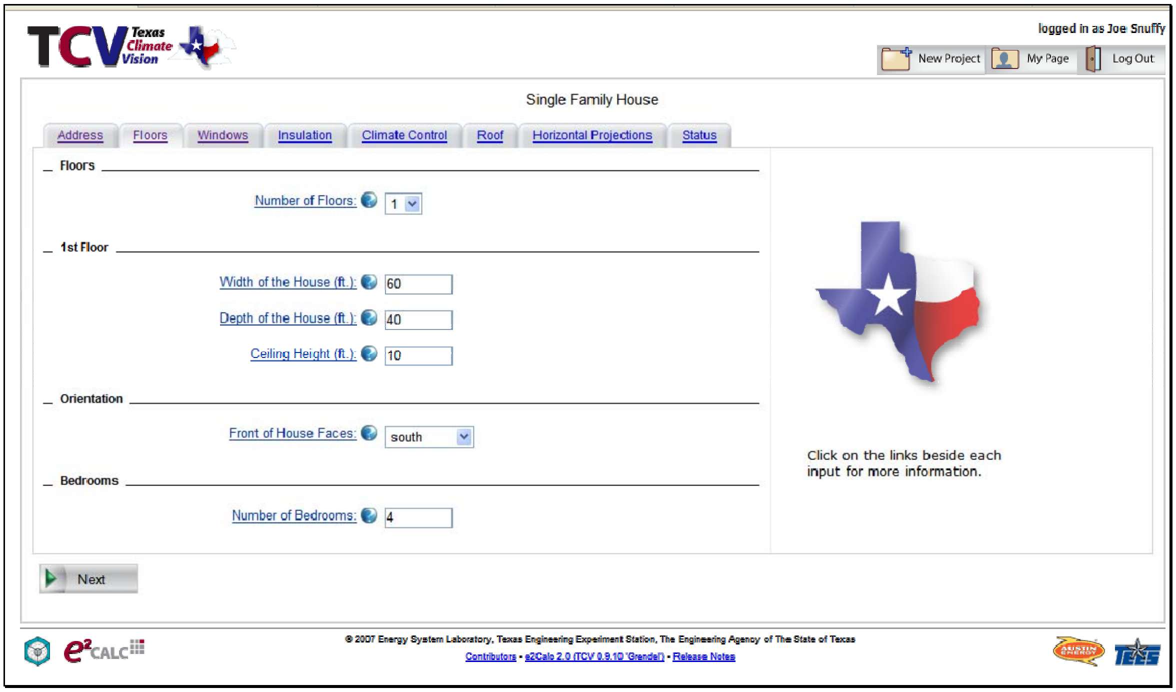


Figure 2 – Floors

This tab provides for the entry of the house "Squared Up" geometry. The system supports houses with one or two floors and allows for different measures for each of the floors. The number of bedrooms is needed to help calculate internal loads as per IECC 2006.

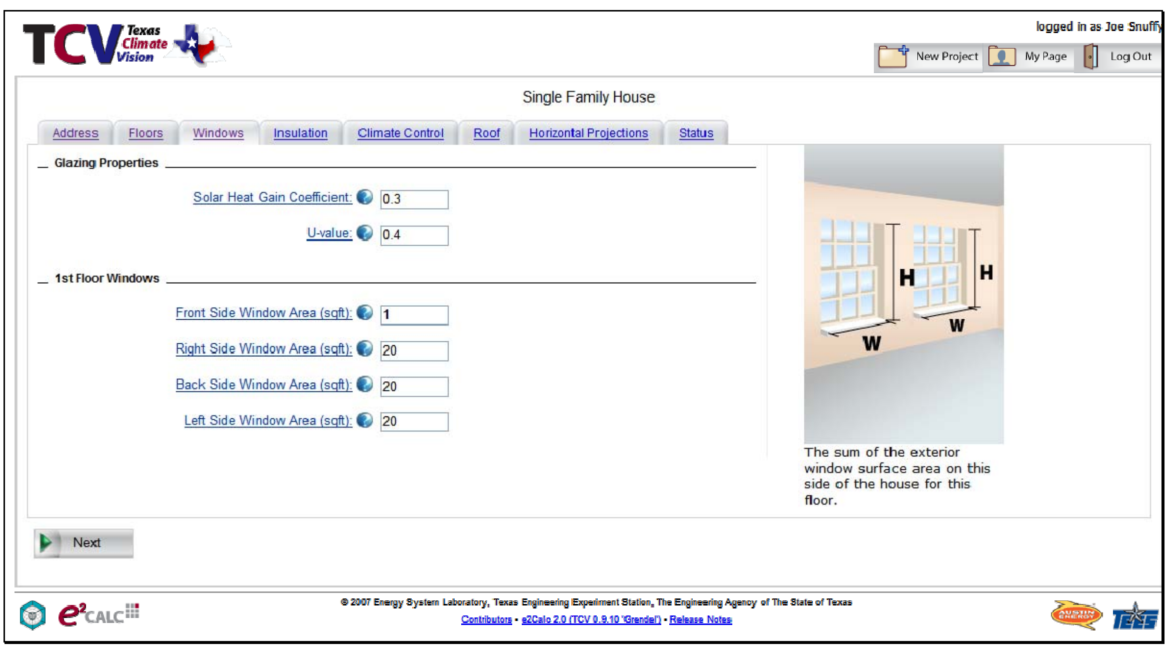


Figure 3 – Windows

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

Figure 4 – Insulation

TCVS allows for multiple insulation values to be entered and used to produce a weighted average. This example illustrates that the system can accommodate multiple insulation types.

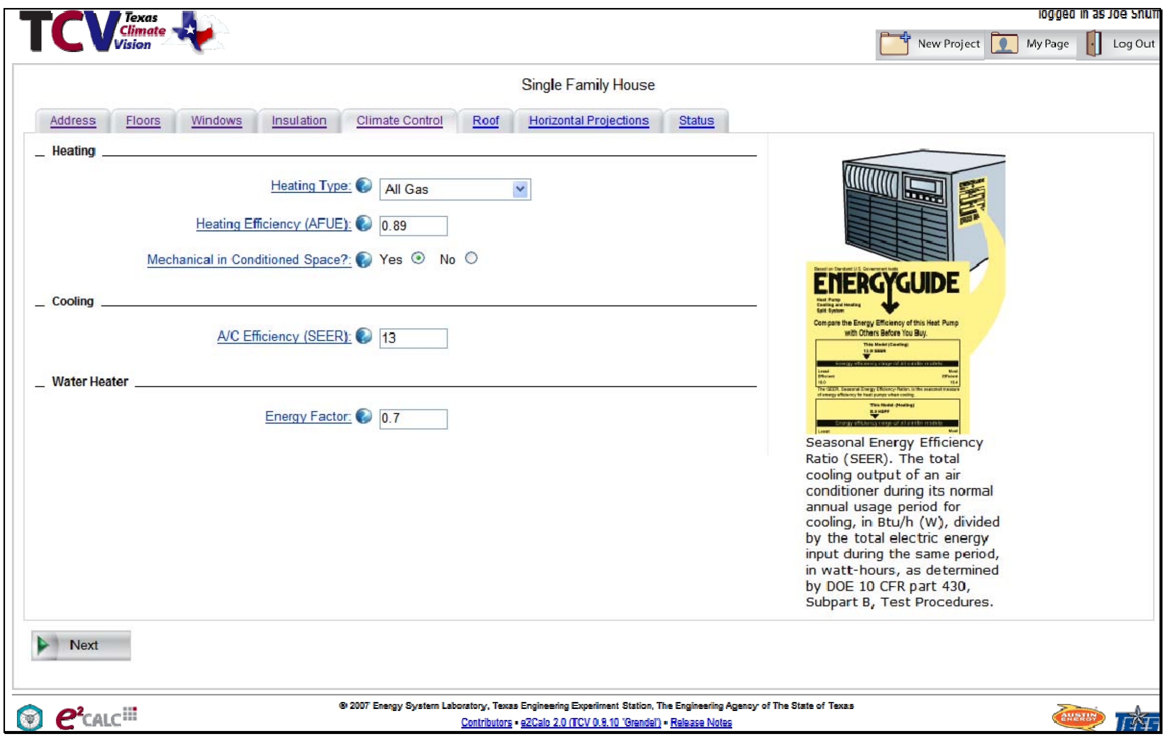


Figure 5 - Climate Control

Here the Builder is able to enter the details of the home's systems. As TCVS is a performance calculator, the positive impact of putting the Mechanicals in Conditioned Space is given due credit.

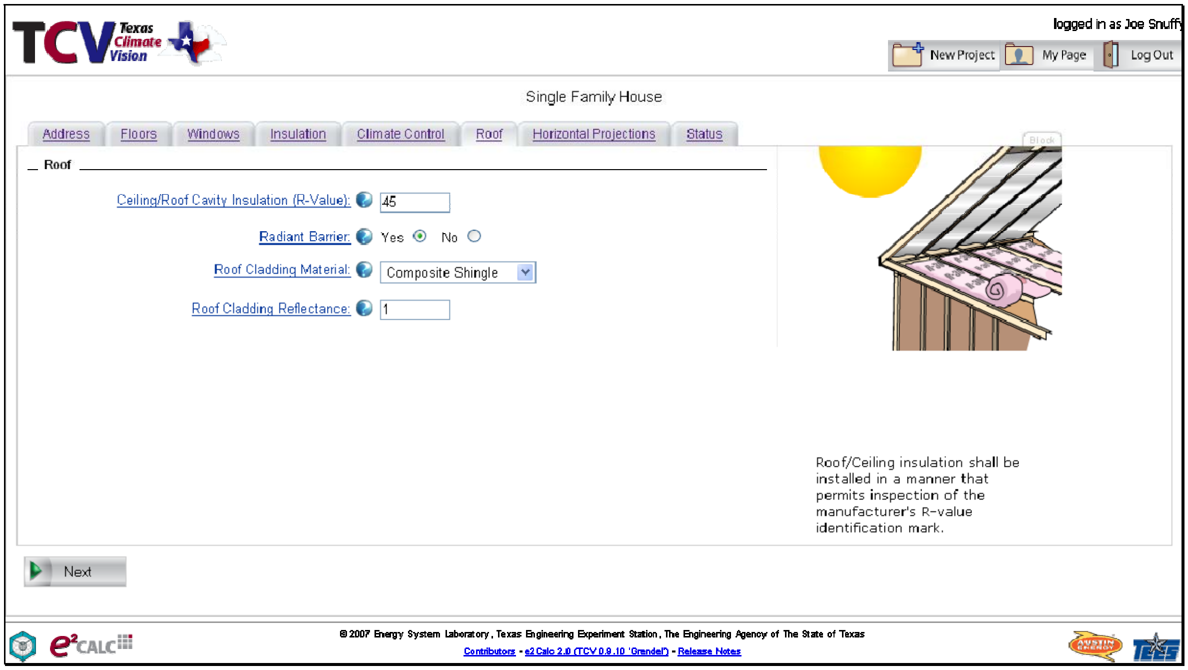


Figure 6 – Roof

Austin has realized the importance of Radiant Barriers and other roofing solutions. These questions allow the system to capture and model the impact of roofing construction.

Figure 7 – Horizontal Projections

Keeping the summer sun off the windows is an easy way to lower the cooling load on a house, the TCVS allows for shading to be specified and the benefits credited.

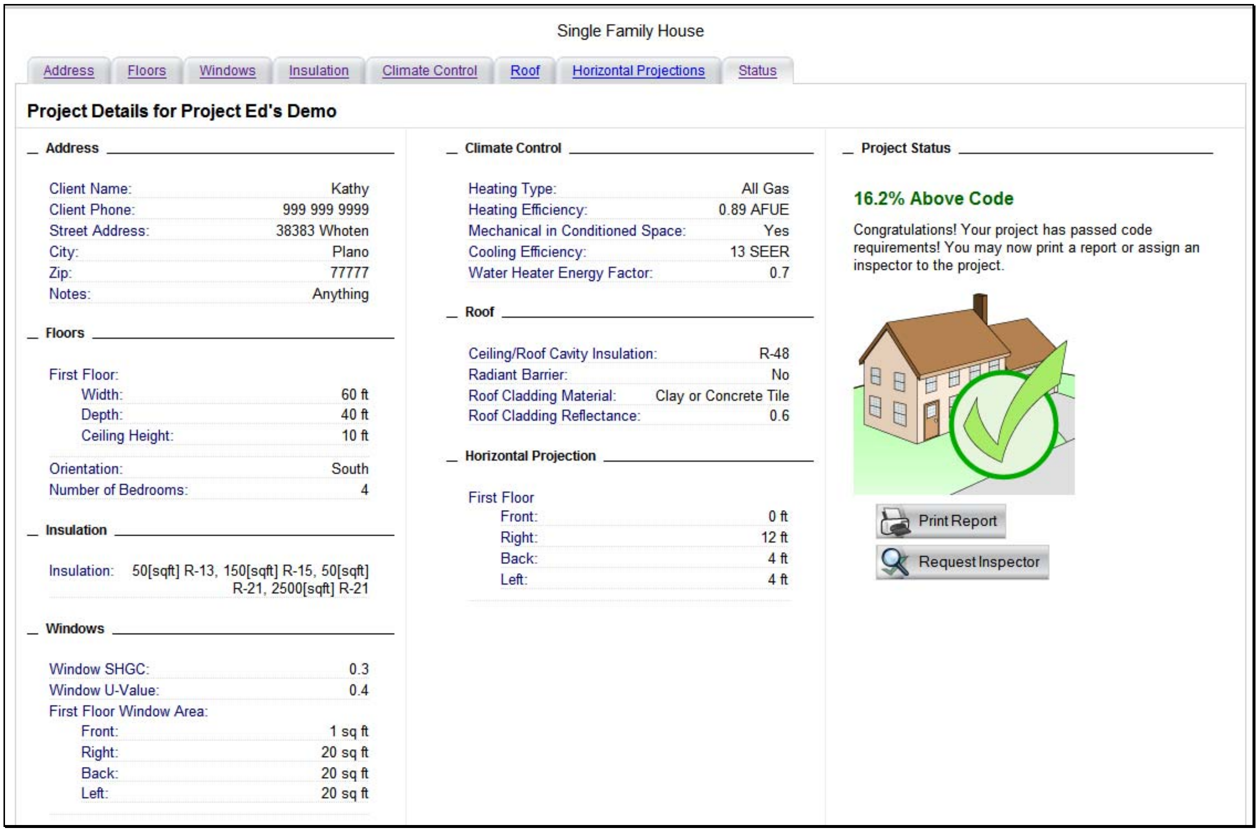
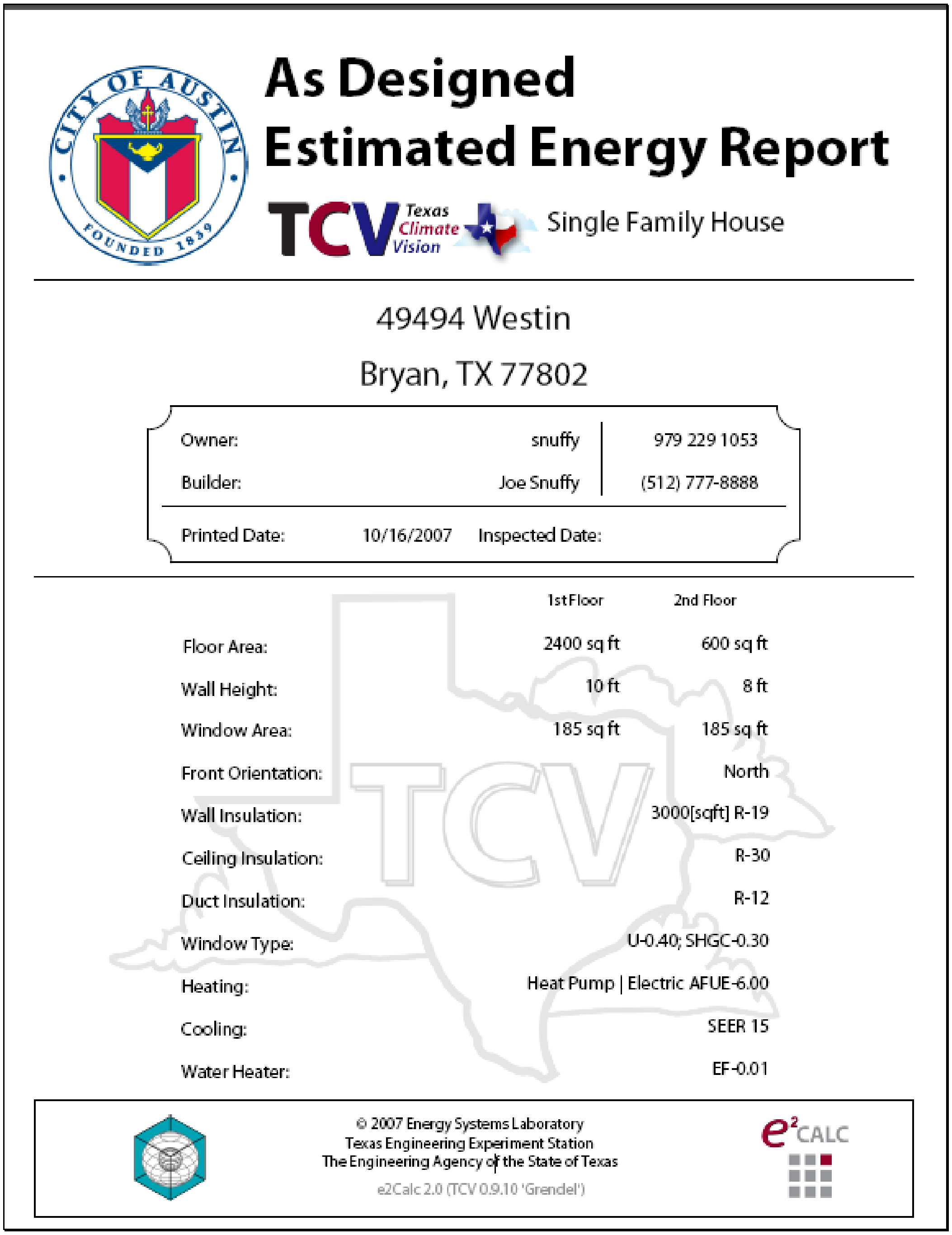


Figure 8 – Status

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. Another click will then confirm that the house meets Austin's 2006 code and allows for printing of the Energy Report (below) and the assignment of a third party inspector.



As Designed Estimated Energy Report

TCV Texas Climate Vision — Single Family House

49494 Westin

Bryan, TX 77802

Owner:	snuffy	979 229 1053	
Builder:	Joe Snuffy	(512) 777-8888	
Printed Date:	10/16/2007	Inspected Date:	

	1st Floor	2nd Floor
Floor Area:	2400 sq ft	600 sq ft
Wall Height:	10 ft	8 ft
Window Area:	185 sq ft	185 sq ft
Front Orientation:		North
Wall Insulation:		3000[sqft] R-19
Ceiling Insulation:		R-30
Duct Insulation:		R-12
Window Type:		U-0.40; SHGC-0.30
Heating:		Heat Pump | Electric AFUE-6.00
Cooling:		SEER 15
Water Heater:		EF-0.01

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Texas Engineering Experiment Station
The Engineering Agency of the State of Texas
e2Calc 2.0 (TCV 0.9.10 'Grendel')

Figure 9 - Estimated Energy Report

This report is generated by TCVS if the house passes Austin's Code. It is presented to the Builder as a PDF file and can be saved, printed, or e-mailed to Austin for the code review process. If the house does not pass, a "Top 10" list is produced as a guide to the most common reasons a house fails. Contact information is also provided if the Builder needs further assistance from the City of Austin.

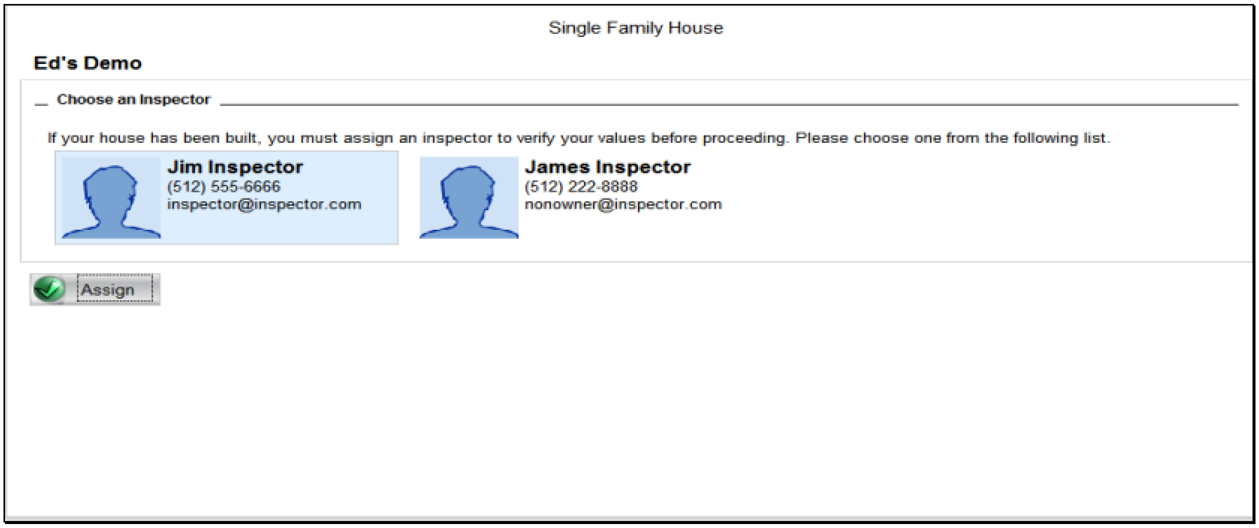

Figure 10 - Assign Inspector

This screen allows the Builder to request the TPI inspection by sending an email form the system to the Inspector with the request for the specific project. The Energy Report will be attached to the email. Note that only *approved* TPI's are in the system and eligible to receive requests to inspect homes.

9 - INSPECTOR WALKTHROUGH

These screens illustrate how the Third Party Inspector (TPI) uses the system to confirm the measured performance of the house and then allow for the Certificate to be printed.

Figure 11 - Inspector's Input

This single screen captures the remaining values necessary for the TPI to certify a house passes the Austin Energy Code. It requires certain performance tests to be run, as well as capturing some “as built” details necessary to make the simulation’s estimated energy usage as accurate as possible.

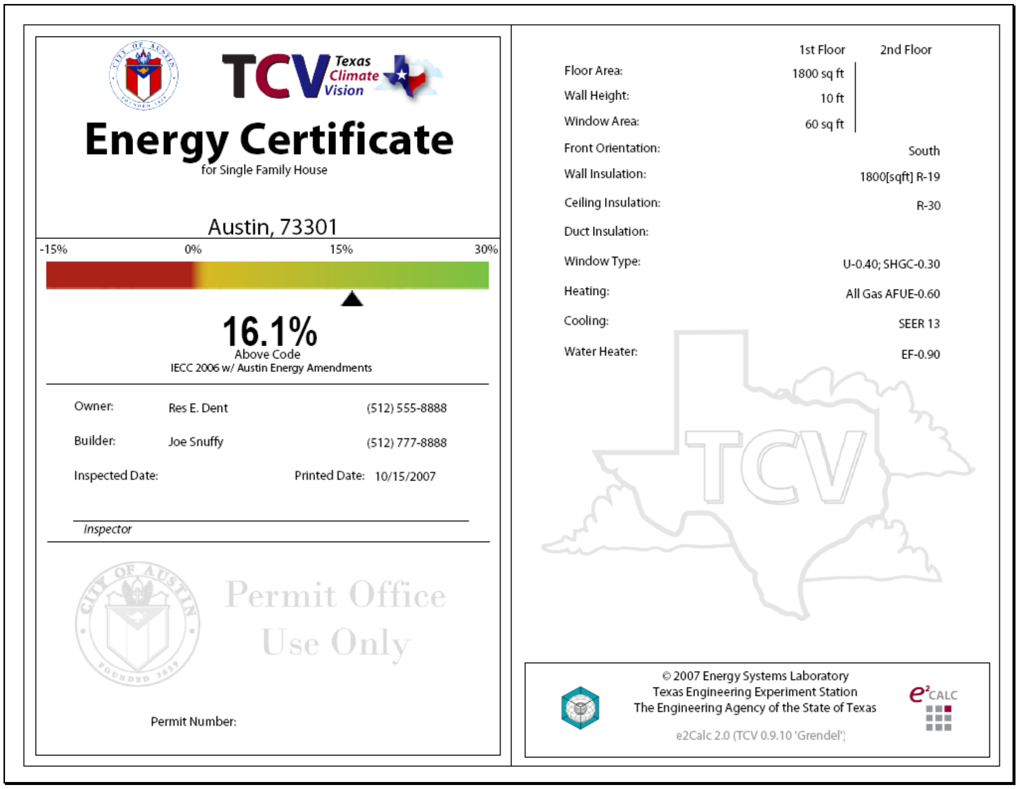

Figure 12 – Certificate

If the house passes, a certificate is produced.

10 - MODELS

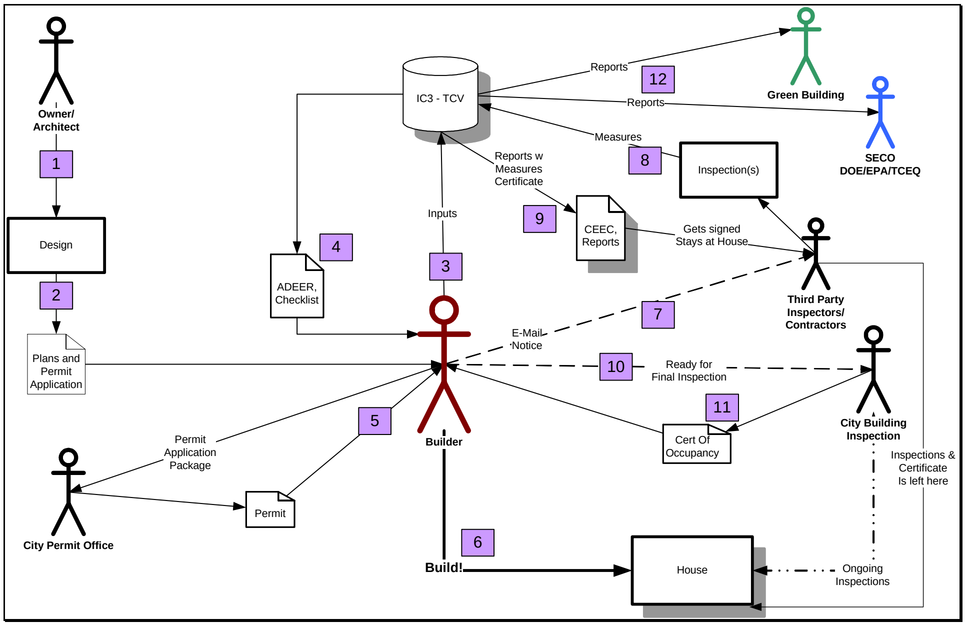

Figure 13 - Overview of TCV Process

The numbers indicate sequence in the TCV process, not just the TCV Software!

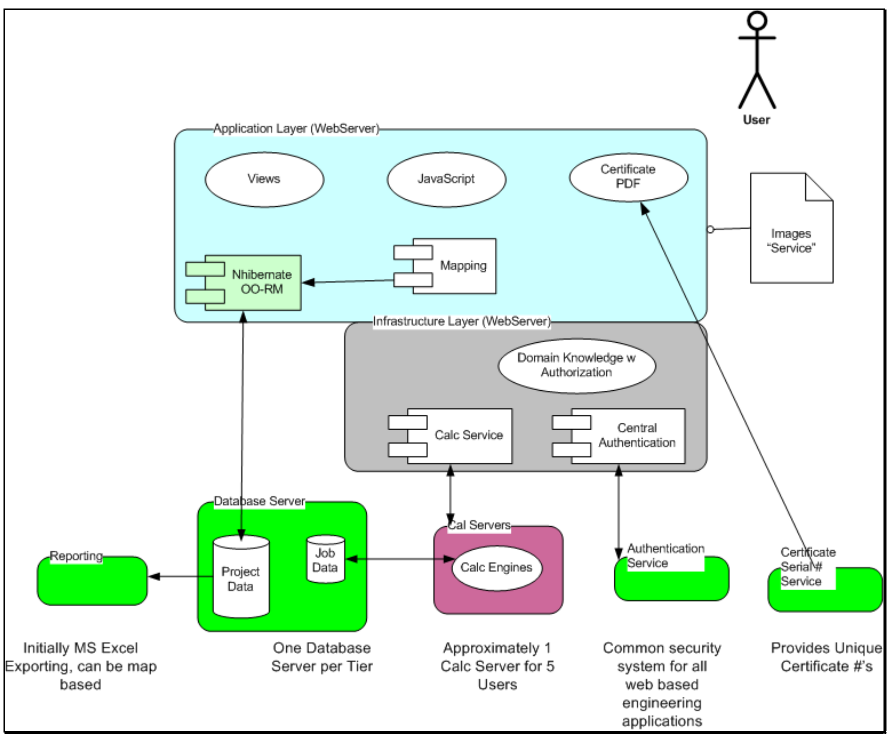

Figure 14 - e2Calc Architecture

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

An overview of the many layers of software

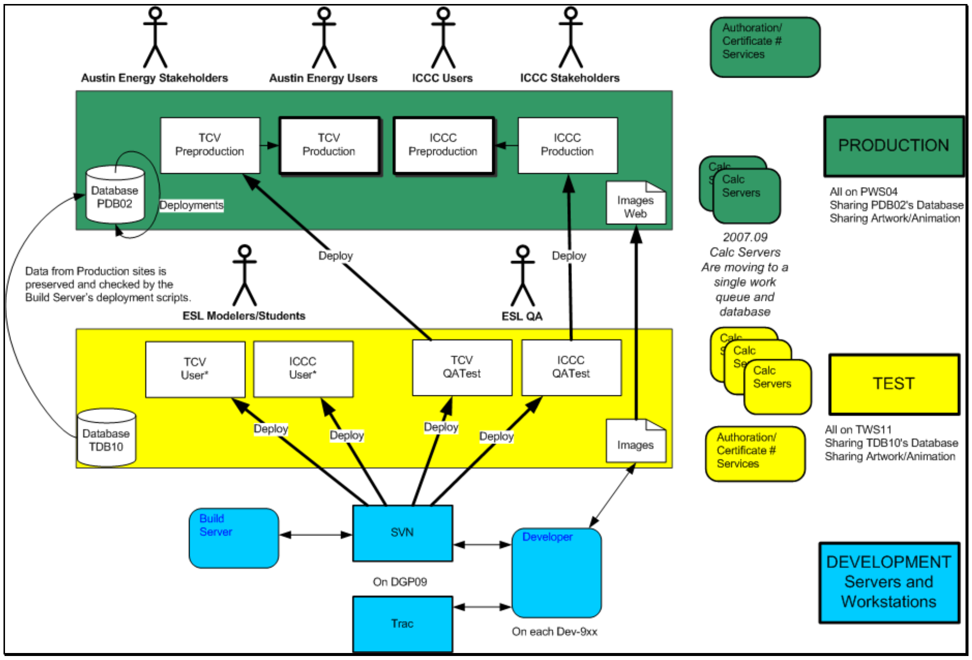

Figure 15- Deployment

This diagram illustrates the three tiers used by the SE Group in Developing, Testing, and then producing the Calculators (includes the “sister” IC3 software).