CLIMATE DESIGN RESOURCES – 2ND GENERATION TOOLS

TECHNICAL REPORT

Prepared For:
Idaho Power Company

Authors:
Jacob Dunn
Lauren Hemley
Kevin Van Den Wymelenberg

Date
February 5, 2013

Report No.
120540-01

This page left intentionally blank.

Prepared By:
University of Idaho, Integrated Design Lab | Boise
306 S 6th St. Boise ID 83702 USA
www.uidaho.edu/idl

IDL Director:
Kevin Van Den Wymelenberg

Authors:
Jacob Dunn
Lauren Hemley
Kevin Van Den Wymelenberg

Prepared For:
Idaho Power Company

Contract Number:
JBK 962

DISCLAIMER

This report was prepared as the result of work sponsored by Idaho Power Company. It does not necessarily represent the views of Idaho Power Company or its employees. Idaho Power Company, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by Idaho Power Company nor has Idaho Power Company passed upon the accuracy or adequacy of the information in this report.

Please cite this report as follows: Dunn, J., Hemley, L., Van Den Wymelenber, K. 2012. *Climate Design Resources – 2nd Generation Tools;* Technical Report 120540-01, Integrated Design Lab, University of Idaho, Boise, ID.

This page left intentionally blank.

1. CONTENTS

2. Introduction

This proposal builds upon the work conducted for Idaho Power in 2010-2011 subtask 1.1 Climate Design Resources. The previous scope of work included developing passive design assistance calculators, comparison studies to simulation, and case study applications, all of which culminated with a training event and tool publication on the IDL website. This project continued the development of additional passive design strategy calculators and also included a training event to help disseminate the tools and research to the market. Additional tools developed include a balance point calculator, a passive design analysis tool, and an earth tube design tool.

2.1. Research Objectives

Both the 1st and 2nd generation Climate Design Resources projects aimed to provide the design community with spreadsheet-style calculation tools that analyze the feasibility and capacity of various passive design strategies. The tools addressed the need for a varying level of analysis and toolset across the different phases of the design process. The spreadsheets provide an ample format for linked and robust calculations that are quick and easy to use during conceptual phases of design. The tools are meant to open up the dialogue between architects and engineers through the provision of robust analysis for critical design parameters that increase understanding of building loads and annual energy usage.

Additionally, by utilizing more simplified tools early in the design process, passive design strategies have a better chance of making it through to the final building construction. Increasing the accessibility and usability of analysis tools has a large role to play in this process. These tools are designed to provide quick feedback loops that make direct correlation between design and performance apparent through instantaneous outputs in an intuitive spreadsheet input format. These outputs and conclusions can also help inform decisions to move forward with more detailed analysis such as building simulation or more robust calculations by a professional engineer. Overall, the spreadsheet calculators serve as another tool in the repertoire of the designer when reaching for energy efficiency goals and high performance buildings.

2.2. 2nd Generation Improvements

The second generation of tools is similar in format to the first generation toolset, but features some critical improvements in both structure and process:

- While the first generation tools required the completion of the “Heat Gain Worksheet” before moving on to the passive design strategies, the second generation spreadsheets can be used independently of any other spreadsheet. Whatever support calculation needs to be completed (balance point calculation, heat gain calculation, or annual heating fuel calculation), it is conveniently incorporated directly within each tool to facilitate analysis without having to stop and complete a different spreadsheet before proceeding.

- The spreadsheets use conditional formatting extensively to automatically adapt the spreadsheets depending on what other worksheets have been completed. The introductory page now contains additional inputs that describe the general parameters of the project and ask which previous tools have been completed. Depending on the answer, the rest of the spreadsheet will automatically adjust using if-then conditional formatting to gray out, hide, highlight steps and cells, etc. For instance, if you are working within the "Earth Tube Calculations" tools and have already completed the "Passive Solar Calculations" spreadsheet, than the inputs will reference cells already calculated in completed spreadsheets while automatically graying out any redundant inputs.
- Similarly to how the spreadsheets adapt depending on previous tools completed, the 2nd generation tools also change according to commercial and residential-specific analysis. Depending on the project type, different equations and calculations are used to determine internal loads, calculation procedures, etc. One input on the front page of each spreadsheet specifies the type of project, which controls how the rest of the tool is accordingly automatically updated.
- The 2nd generation of tools utilizes hourly TMY3 data for calculations specific to the three different reference cities in Idaho Power's service territory. Using such a detailed level of weather data provides a robust climate-specific analysis while opening the door to more advanced calculations for balance point, passive solar capacity, etc.
- References are hyperlinked within the document for easy navigation between tabs.
- The tools make a concerted effort to provide simple diagnostics, flagging, and design tips depending upon output and results. One of the goals of the 2nd generation toolset included providing more specific design support depending on the input parameters of the project. For instance, if the realized savings for the passive solar calculations are lower than expected given the design parameters of the system, suggestions automatically appear that highlight design options for savings optimization.

3. Statement of Work Specific Task Progress

3.1. Create spreadsheet calculation and analysis tools for the three of following strategies: a1 – balance point calculator, a2 – heat loss calculator, a3 – passive solar heating calculator, a4 – earth tube calculator.

The UI-IDL completed the development of all spreadsheet calculators specified in this task. However, the toolset combined "a2 – heat loss calculator" into both the "a3 – passive solar heating calculator" and "a4 – earth tube calculator." Each tool contains an introductory tab where the user learns about the tool and some of the general design considerations that affect the design strategy in question. This page also contains the instructions of how to use the spreadsheet, a step-by-step overview of the specific tool, and some general building parameter inputs that determine how the rest of the spreadsheet is formatted. The next set of tabs contains detailed step-by-step instructions on how to proceed through the analysis. There was a conscious choice made at the beginning of the tool development process to structure the process to be as informative as possible. Thus, users are lead through the specification process while being exposed to as much of the calculation methodology as possible. This is in direct contrast to the opposite alternative, which entails more of a "black box" approach where all inputs are on a single sheet and calculations are handled in the background. The tools still contain calculation-specific tabs that describe some of the more computationally-intensive calculations, but a balance is sought that still gives the user a clear understanding of how the calculations progress throughout the spreadsheet. Finally, a "weather data" tab contains all of the TMY3 data specific to the reference city and a "references" tab that contains tables and charts that are referred to throughout the step-by-step procedures. As mentioned previously, these references are hyperlinked throughout the document to make navigation across tabs easier and more streamlined.

The following sections outline the description included on the cover page of each tool, their step-by-step process, and their salient outputs.

3.1.1. Balance Point Calculator

General description: Balance point is defined as the outside temperature at which the indoor heat gains balance building heat loss to maintain a desired indoor temperature. If the balance point of a building is 50 degrees Fahrenheit, then the building will require cooling when the outdoor air is above the temperature and vice versa when below. The balance point can help us predict fuel consumption, understand the heating and cooling needs of a building in its climate, and give us an idea of how different zones of a building might affect each other in thermal exchanges. The balance point calculated in this spreadsheet will be used in subsequent design strategy calculators to determine how much natural ventilation is possible, how much energy passive solar will save, etc.

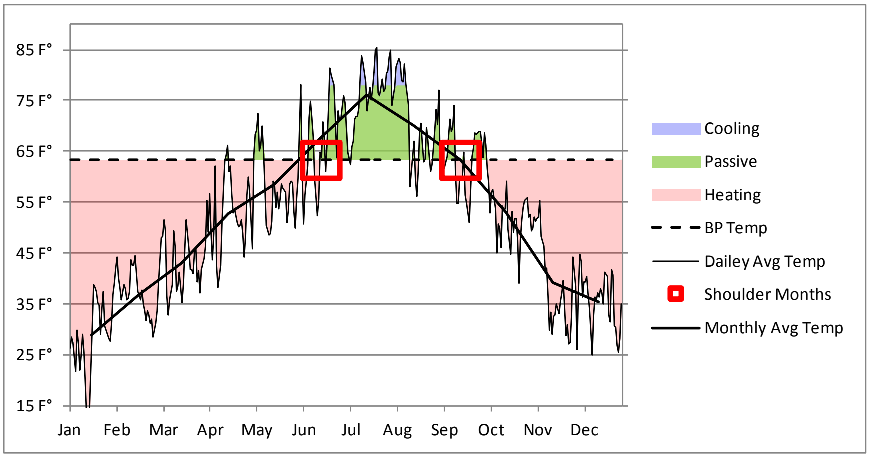
Inputs:

- Step 1 – Defines the indoor seasonal setpoint for the balance point calculation
- Step 2 – Determines internal heat gain contribution from occupants
- Step 3 – Determines internal heat gain contributions from lights
- Step 4 - Determines internal heat gain contribution from equipment
- Step 5 – Determines heat gains from southern glazing (inputs can be copied from "Heat Gain Calculator" spreadsheet)
- Step 6 – Provides a heat gain summary on internal + solar loads.
- Step 7 – Calculate heat loss from envelope (inputs can be copied from "Passive Solar Calculations" or "Earth Tube Calculations)
- Step 8 – Calculate heat loss from ventilation (inputs can be copied from "Passive Solar Calculations" or "Earth Tube Calculations)

Outputs:

- Balance point in degrees Fahrenheit.
- Yearly temperature graph with modes of operation color-coding (Figure 1)

Figure 1 – Daily Balance Point Temperatures Output Example



- Quantification of hours when natural ventilation is possible, broken down into the entire year, the shoulder seasons, and also during all hours or just occupied conditions.

3.1.2. Passive Solar

General Description: Passive solar design is perhaps one of the oldest and most popular passive strategies utilized in contemporary practice today. Significant reductions in annual heating energy are possible in our heating-dominated Idaho climates. However, the balance of design parameters within these systems requires much forethought to truly optimize both heating performance without sacrificing cooling performance in a project. While there are many types of passive solar systems, i.e. trombe wall, sunspace, roof pond, etc., this spreadsheet tool focuses on direct gain systems coupled with thermal mass. Critical design parameters explored through this tool include: load reduction measures, thermal mass amount and distribution, and glazing parameters and area.

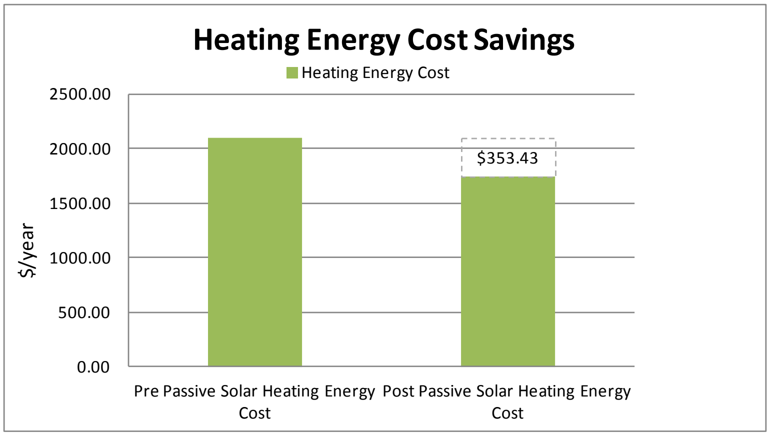
Inputs:

- Step 1 – Calculates Annual Heating Energy, if you have already filled out the Earth Tube or Balance Point spreadsheets, their outputs can be copied into this step.
- Step 2 – Defines the thermal mass system parameters.
- Step 3 – This step checks the load reduction effectiveness of the envelope and ventilation design to determine if higher performance is needed before proceeding with passive solar considerations.
- Step 4 - Finds the load collector ratio (LCR) based upon the area of southern glass and the load reduction effectiveness.

Outputs:

- Shows heating energy savings fraction compared to the annual heating energy calculated from step 1. This metric is shown as total kbtu savings, percentage savings, EUI savings, and utility cost savings

Figure 2 – Heating Energy Cost Savings Output Example



- Provides diagnostic that show suggestions on how to optimize energy savings. Suggestions range from built in diagnostics that analyze load reduction effectiveness to suggestions on thermal mass system design (Figure 2

3.1.2.1. Comparison Study

The UI-IDL compared the results from the annual fuel heating calculations to both actual utility data on a real project, simulation results from Energy Plus, and other similar energy consumption calculators from other resources. The comparisons intended to determine the accuracy of the simplified calculations. Figure 3 shows the 2nd generation toolset's annual heating calculation results (CDR Spreadsheet), disaggregated into ventilation and heating EUI, compared against the Department of Energy (DOE) simulation results for their small office building prototype using EnergyPlus simulation software. The tool's calculations were conducted with two different balance points (55 and 65 degrees Fahrenheit) to show a range of results given the variation of this specific parameter. The results show that when using a balance point of 55 degrees Fahrenheit, the tools is very close (3.2% difference) to the simulated results. However, energy consumption was proven to be very sensitive to balance point temperature, given that the 65 degree Fahrenheit balance point almost doubled the tool's calculated energy consumption. The calculated balance point from the toolset produced a 60 degree Fahrenheit balance point and lies somewhere in the middle of the two calculated results. More refined inputs to the balance point spreadsheet serve as the most critical input parameters where accuracy is concerned.

Figure 2 – Simulation Comparison Sutdy

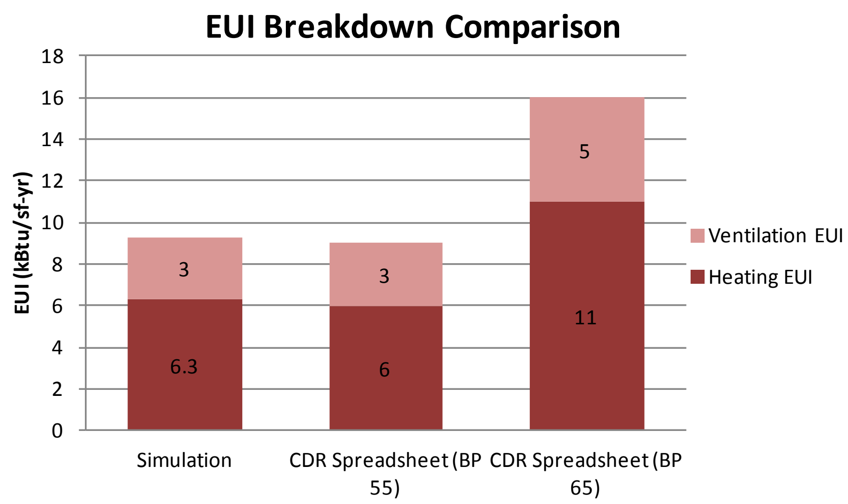
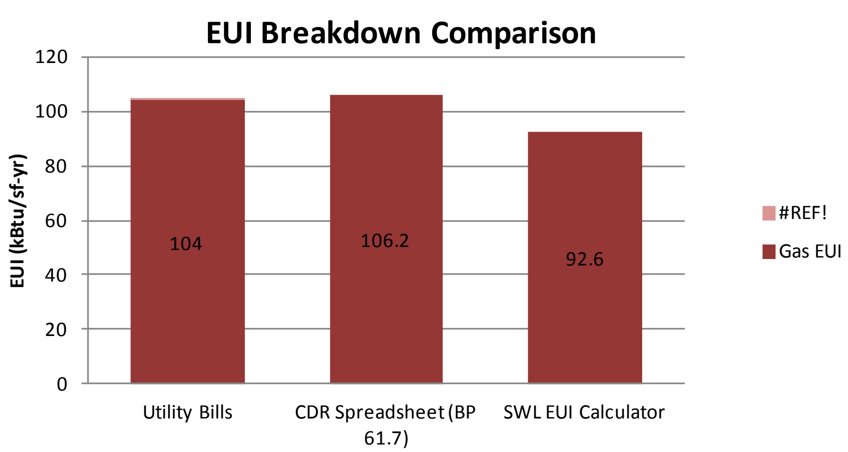


Figure 3 displays the results from a similar study that compared various calculation results from a 30,000 square foot office building in Missoula, Montana. The comparison looked at the project's utility bills, the tool's annual fuel heating calculations (CDR Spreadsheet), and the heating EUI calculated from a simplified ASHRAE "bin method" procedure. In general, the tool's calculations were very close (2% difference) to the actual utility bills for the project. The third set of results from the ASHRAE bin method was close enough to provide confidence in the relative accuracy of the tool's calculation methodology. Given the results, the annual heating EUI calculations are reasonably accurate for predicting baseline heating fuel usage for simple HVAC systems, but still should only be used for comparative analysis between different passive design iterations within the tool.

Figure 3 –Case Study Comparison



3.1.3. Earth Tube

General Description: Earth tubes are earth-to-air heat exchangers that capitalize on the moderate temperatures below ground to help reduce the heating and cooling loads of a building. They can be used to provide cooling in residential and commercial applications, or be used to pre-treat outdoor air for the ventilation requirements of commercial buildings. As air moves through a pipe, it transfers heat or couth to the surrounding tube material and soil before connecting into an HVAC system or being delivered directly to a space. The amount of heat transfer is contingent on the following critical design parameters: temperature difference between the ground and air, soil conductivity, pipe material, pipe diameter, tube length, and air velocity through the system. This spreadsheet calculator will help guide you through testing the effect of these parameters on heating and cooling performance.

System Design Considerations (unique to the Earth Tube calculations due to the complexity of design issues): Earth tubes consist of an air intake, a direct outlet to the interior or connection into an HVAC system, piping runs, and a small fan that moves air through the tube. Earth tubes can be made of multiple materials such as concrete, non-toxic plastics such as drain piping, and different types of metals—all of which have different conductivity and thermal resistance values. The intake of the system is usually elevated above the ground to avoid water infiltration, while the outlet depends on the system application. For residential strategies, the earth tube is usually directly connected to the inside of the space through one or multiple diffusers. Since outdoor ventilation is not required, the system is usually only used for cooling applications and closed off during the winter. For commercial applications, the earth tube can be connected to the larger HVAC system of the building to deliver pre-treated ventilation air before entering the heating and cooling elements of the system.

In terms of duct run design, multiple layout options are available. In a study on earth tubes conducted by the DOE, system designs can have tubes in parallel terminating in a header, radial designs which collect in a central sump, or even single tubes are acceptable. This design parameter must be balanced with duct length and diameter to get a desired heating or cooling capacity.

Inputs:

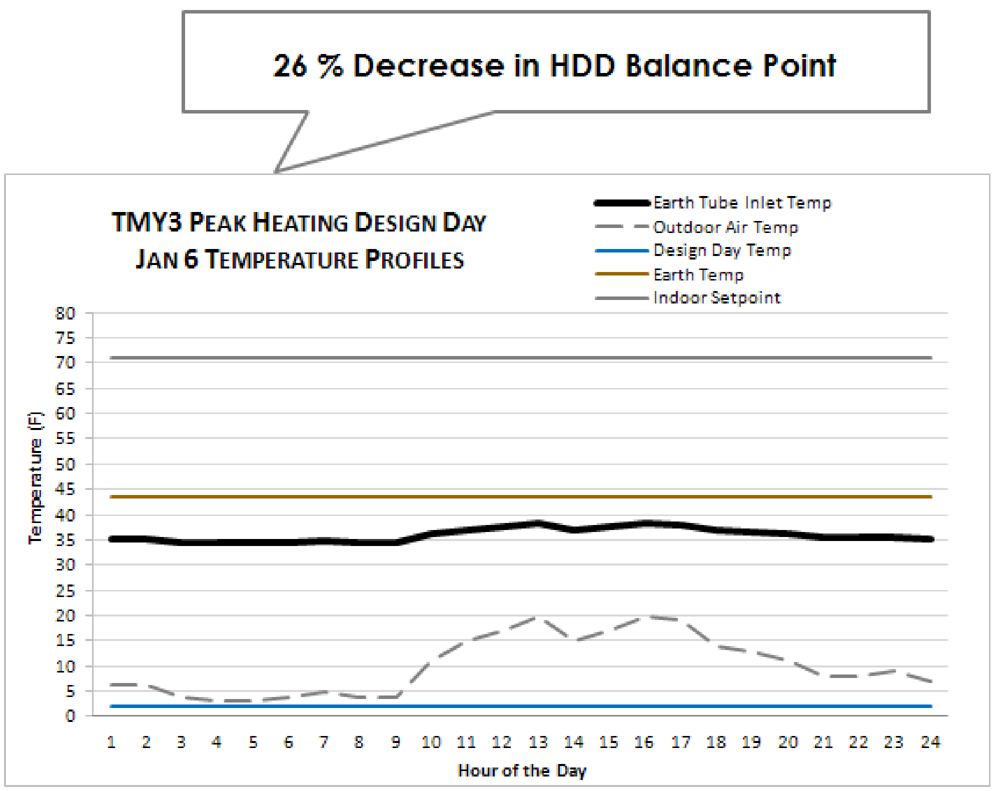
- Step 1 – Calculate Step 2 - Determine heat gains from the internal loads of the project. This calculation will be used to determine peak heat gain and will be compared against the performance of the earth tube later in the spreadsheet.
- Step 3 - Shows a summary of all the heat gains.
- Step 4 – Residential Only - If this is residential project, Step 4 will calculate the peak cooling capacity of the earth tube and show its contribution over the peak cooling design day. Additional fan energy required for the system will also be calculated.
- Step 4 Commercial Only - If this is commercial project, Step 4 will calculates the annual heating energy of the project and will be compared against the annual heating performance of the earth tube later in the spreadsheet.

- Step 5 – Commercial Only - This step calculates the heating performance of the earth tube based upon a number of critical design parameters. Once performance is established, annual heating energy and cost savings are calculated.
- Step 6 – Commercial Only - Once heating energy and cost savings are calculated, peak cooling load reductions are automatically generated from the earth tube design specified in Step 5. However, the user has the opportunity to modify design parameters to optimize for cooling in this step.

Outputs:

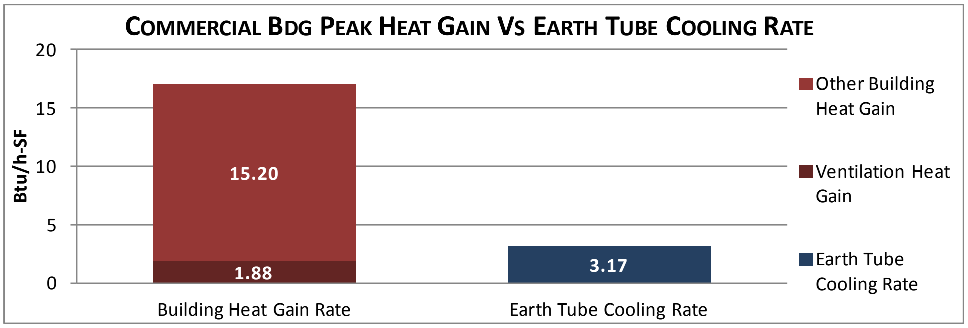
- For commercial only - annual heating energy savings, output as total kBtu, percentage savings, EUI savings, utility cost savings. Heating consumption is disaggregated into an envelope and ventilation component.
- For commercial only – winter design day temperature profile line graph with outside air temperature, design day temperature, and earth tube outlet temperature graphed (Figure 3)

Figure 3 – Winter Design Day Temperature Profile Chart Example



- For both commercial and residential – peak cooling load reduction shows and percentage reduction of total heat gain and offset ventilation heat gain. (Figure 4)

Figure 3 – Peak Cooling Load Reduction Example Chart



- For both commercial and residential – increase fan energy penalty in terms of both kwh and utility cost.

3.2. Integrate relevant weather data and charts that pertain to each strategy directly within the spreadsheets for three different cities in the Idaho Power Service territory.

The 2nd generation toolset integrates a myriad of different weather data directly within the spreadsheets. Keeping consistent with the 1st generation toolset, tool packages specific to three different reference cities were created for Boise, Idaho; Twin Falls, Idaho; and McCall, Idaho. Data ranges from design day temperatures to 8,760 hours of detailed weather data from TMY3 files downloaded from the Energy Plus website. Additionally, the tools incorporate custom performance curves for each type of passive solar thermal mass system (nine in total for direct gain setup) based on the three different reference city's heating and cooling degree day split. Adding this level of weather data, especially the inclusion of the TMY3 data, required significantly more complicated and sophisticated excel spreadsheet techniques. The tools avoided using macro-enabled spreadsheets to keep the usability and development process as simple as possible.

3.3. Integrate relevant TMY data in first generation of Climate Design Resources Tools

While the research team made significant process on incorporating TMY3 data into the 2nd generation of tools, the team did not have the time or budget to execute this particular specific task. The team learned a great deal about how to include these types of extensive weather datasets into excel-linked equations and will be more adept at revisiting the tools in later scopes and projects. It is important to note that the research team was able to create three sophisticated excel calculation spreadsheets that are more extensive when compared to the four 1st generation spreadsheets developed. However, these three tools were developed on a significantly smaller budget and timeframe.

4. DELIVERABLES PROGRESS

4.1. Package Three of the tools mentioned in "Specific Task a" and post to the IDL website along with previous tools created for the 2010-2011 SOW.

Both of the UI-IDL Climate Design Resources 1st and 2nd generation toolsets are available to download from the UI-IDL website as of December 20th, 2012 (http://idlboise.com/design-tool/ui-idl-climate-design-resources-1st-2nd-generation-toolsets). The webpage includes a description of the project, a brief discussion on the evolution of the toolsets, the goals of the research, and reference citiy-specific toolset downloads. The webpage packages the two generations of spreadsheets together as one download to provide a comprehensive set of analysis tools per reference city. Finally, the webpage also contains a link to both the 1st and 2nd generation Climate Design Resources reports.

4.2. Written Report to IPC describing the usage and application of the new set of tools

Included herein.

4.3. Develop and deliver a half-day training event at the Integrated Design Lab to showcase the new tools.

The UI-IDL attempted to schedule a training event on the 7th of December, but failed to garner enough RSVPs to justify the training. Due to the holiday season and the wealth of other free education content offered by the UI-IDL in December, low attendance was not necessarily un-characteristic. Consequently, the UI-IDL rescheduled the training for January 25th, 2013. Time will be billed for the training this using the remaining 2012 budget and delivered next year.

The UI-IDL designed the training to run 3.5 hours from 8.30am-12.00 noon as an interactive workshop where participants conduct a passive design analysis of the DOE medium office reference building. During the workshop, participants would use the 2nd generation toolset and pre-designated input parameters provided by the UI-IDL to complete the spreadsheets and answer a set of questions before watching a demonstration by lab staff on each of the different tools. To ensure proper support and attendance for the workshop, the following advertising venues will be targeted:

- UI-IDL Sustainable Events Calendar
- UI-IDL January Newsletter
- USGBC Newsletter and Calendar
- IURDC Calendar
- ASHRAE Idaho Newsletter and Calendar
- AIA Idaho Newsletter and Calendar
- The UI-IDL will target various personal contacts within architecture and engineering firms
- The UI-IDL will specifically target attendees of the first Climate Design Resources workshop
- Boise Revits Users Group Newsletter
- Building a Greener Idaho Radio Boise advertisement
- UI-IDL Facebook page
- Small flyers will be created and handed out during UI-IDL events

5. Conclusion

The 2nd generation toolset provides additional value to the 1st generation of tools and furthers their mission to both improve and move passive systems analysis earlier in the design process. The new tools move beyond load analysis and enter the realm of calculated annual energy and cost savings for heating. The structural excel changes provide some much needed functionality and interface improvements to the spreadsheets. Workflow is quicker and more streamlined with the new conditional formatting improvements, spreadsheet-to-spreadsheet referencing, and adaptive spreadsheet behavior.

The seven total spreadsheets now provide many useful outputs which range from peak cooling load reduction, to heating energy/cost savings, to the quantification of natural ventilation hours for various design strategies. As the toolset continues to grow, it has the potential to form an even more comprehensive conceptual design phase analysis of the passive design strategies available to architects and engineers within the Idaho Power service territory. Potential future improvements include:

- Adding TMY3 data to the 1st generation toolset to report annual and hourly load impacts of night flush and natural ventilation design strategies.
- Developing a cooling fuel calculator, similar to the heating fuel calculator of the 2nd generation toolset, that uses specific balance point calculations and TMY3 data to determine annual cooling energy and cost. This type of calculator could then be incorporated into both the 1st and 2nd generation toolsets to show both heating and cooling energy savings for the various passive design strategies.
- Additional tools for future development include: indirect evaporative cooling towers, wind catchers, phase change material calculator, labrynth tools, transpired solar collectors, and displacement ventilation analysis tools.

6. References

ASHRAE 90.1-2007. "Energy Standard for Buildings Except Low-Rise Residential Buildings". Atlanta, Georgia, 2007.

G.Z. Brown and Mark DeKay. "Sun, Wind & Light - Architectural Design Strategies." 2nd Edition. John Wiley & Sons. Copyright 2001

Lee, Strand. "Implementation of An Earth Tube System into EnergyPlus Program." University of Illinois at Urbana-Champaign, IL. 2006.

Muehleisen, T Ralph. "Simple Design Tools for Earht-Air Heat Exchangers." Decision and Information Sciences, Argonne National Lab, Argonne, IL, USA. IBPSA Conference Proceedings. 2011.

Reynolds, Stein. "Mechanical and Electrical Equipment for Buildings" Tenth Edition. Canada. John Wiley & Sons. Copyright 2006