A Free User-Friendly Design Tool that Shows How To Reduce Cooling Energy in Buildings

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ABSTRACT

HEED (Home Energy Efficient Design) shows architects, builders, and homeowners how to design or remodel their buildings to reduce or even eliminate air conditioning loads. It is intended for use at the very beginning of the design process, when most of the critical decisions effecting energy consumption are made.

This paper goes step-by-step through a typical building remodeling design using HEED. It shows graphically the differences in performance between various passive cooling alternatives including things like window shading, thermal mass, ventilation, improved envelope, and optimized shape and orientation, etc. Among the features users especially appreciate is the simple way they can draw in floor plans and how they can drag and drop windows onto each facade. HEED shows them bar charts comparing the difference in heating and cooling energy costs for up to nine different designs. The objective is to facilitate a simple, non-technical, smooth flowing, decision-making experience.

Once the user defines four facts about their project (total floor area, number of stories, location, and building type), HEED's built-in expert system automatically designs two buildings, the first is a Basecase building that meets California's Title 24, and the second is an even more Energy Efficient version that is usually about 30% better.

This new free design tool can use climate data for over 600 stations around the world. HEED is available at no cost via the internet (www.aud.ucla.edu/heed).

1. INTRODUCTON

Simple "Rules of Thumb" about how to reduce the cooling energy in a building often include strategies like shading the windows, using light colored walls and roof, adding a smart whole-house fan, improving weather-stripping, and increasing insulation. But which design option is best and what are the actual savings of each of these and do any of them have negative unintended impacts on other aspects of building performance such as heating costs or lighting costs.

2. THE DESIGN PROCESS

HEED starts by asking four facts about the home (location, total floor area, number of stories, and building type). With this information it automatically designs Scheme 1, a home that meets the California Energy Code (Title 24). Then it designs Scheme 2 that is More Energy Efficient. Together these two act as benchmarks to help users evaluate their own evolving designs and revisions. Note that individual components, like walls or windows need not need to meet Title 24 prescriptive standards, as long as the new home's overall energy consumption is less than Scheme 1, the Code Compliant version.

2.1 Climate Data

Weather data for all 16 of California's Climate Zones are included in HEED, however EPW climate data for over 600 stations from around the world can also be loaded directly from the EnergyPlus web site (see the link in the HEED web page)[1]. In this example climate Data for Athens, Greece, was loaded automatically.

California's Energy Code has different requirements for buildings in each of the state's 16 climate zones. In order for non-California locations to use the California Energy Code, HEED automatically finds the best match between non-California climates and one of California's 16 climate zones. In this case Athens seems most similar to Climate Zone 9.

HEED also contains the electricity and gas rates for California's five largest utilities. These rates can be modified if desired, but for this example, because Climate Zone 9 is served by Southern California Edison and Southern California Gas, their rates were used.

2.2 Creating Your Own Home

The problem of how to remodel and improve the energy performance of a traditional Greek hill-side house will be used for this example, assuming 4-stories, 2000 sq.ft (200 sq.m.), and masonry construction. Once HEED created the two basecase homes, the user can copy one of them (usually Scheme 2, Energy Efficient) into Scheme 3 and start to create their own home.

2.3 Drawing in the Floorplan

HEED lets users quickly draw in their home's floorplan, by filling squares in a checkerboard, then clicking on the Up or Down button to fill in the other floors (Figure 1). Note that floor plans can have a different footprint on each floor level. Garages, neighbors, paving, or embankments can be added at any floor level, either attached or free standing. A 3-D image of the home can be clicked and rotated to establish its exact compass heading.

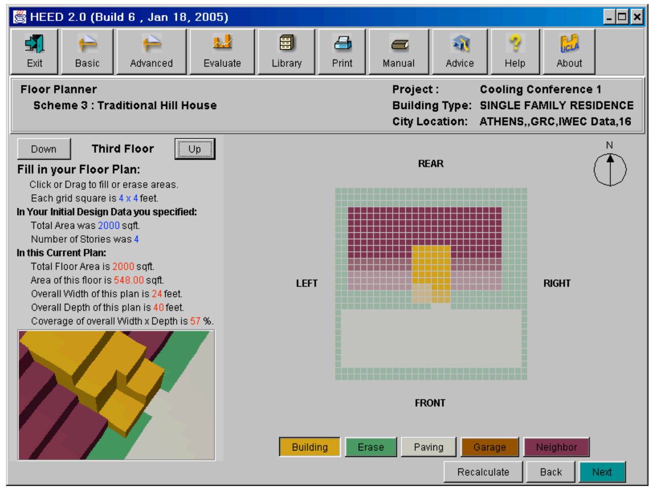

Figure 1: Floor Planner: HEED allows users to draw in their floor plan by selecting the "FloorPlanner" icon, then click and drag on the checkerboard to fill in squares on a four-foot module (roughly 1 m.sq.).

2.4 Placing Windows of the Elevation:

Users can then design their windows and drag them to the correct location on each elevation on the Window Layout screen (Figure 2).

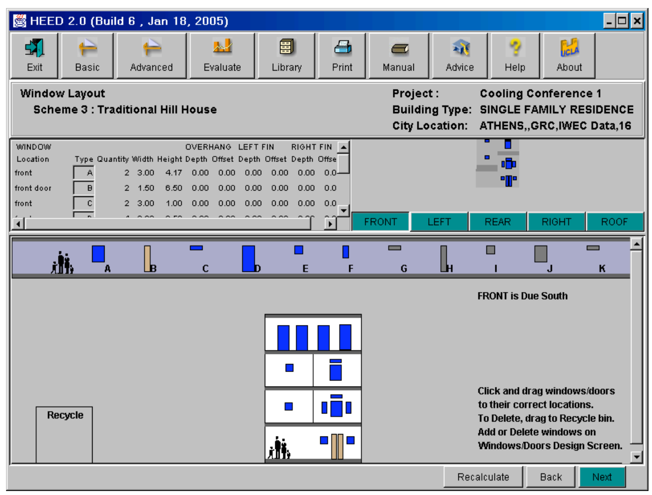

Figure 2: Window Layout: The user can click and drag windows from the catalog bar into the correct location to accurately compose each elevation, in this case the 4-story South elevation. Any of the green buttons can be clicked to show each of the other elevations or the roof. .

2.5 Defining Building Construction:

Users can easily describe their home's construction by choosing from a dozen different lists of building components such as Floors, Roof, Insulation, etc (Figure 3). In this example for Walls, the user clicked on the bottom line which reads “Solid 8” Masonry Wall, Uninsulated…” (or about 20 cm thick).

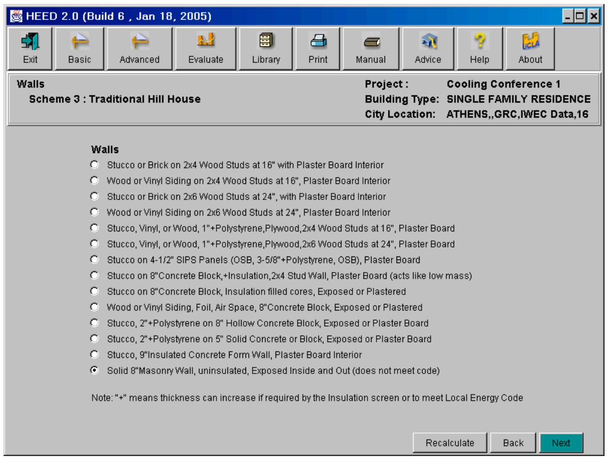

Figure 3: All aspects of building design and construction like Ventilation, Heating and Cooling Systems, Operable Shading, and Appliances can be defined by selecting from lists like this one.

2.6 Testing Other Design Alternatives:

To run through a series of “what if” possibilities the user only needs to copy the As-Built design (Scheme 3), and then make any re-design or remodeling change desired. Most of these changes can be easily made by selecting from lists of various types of building construction. Advanced users can input detailed numerical descriptions of any conceivable assembly or component using almost two dozen different Advanced Design screens.

3. BEST COOLING STRATEGIES:

While users are designing all the different options, the Energy Cost Bar Chart shows the comparison of the Annual Costs for Electricity, Gas, and Total for each scheme (Figure 4). In this case the schemes 4 to 9 are listed from poorest to best cooling effectiveness, compared to Scheme 3, the Traditional Hill House As-Built. Cooling is represented as Air Conditioning, which is the upper (darker) bar in Electricity Costs.

The Cost Effectiveness of each of these schemes is also calculated (Table 1). In this case Total Annual Energy Costs were used and the savings of each scheme are compared to Scheme 3, The Traditional Hill House As-Built. The cost of making these remodeling improvements were estimated for either DIY (do it yourself) or Contracted projects. Dividing these initial costs into the annual savings gives the Years to Pay Back.

3.1 Scheme 4 Insulated Ceiling

Surprisingly this has the least effect on cooling, because other factors (walls, windows, infiltration) have much larger impacts. Note however this it makes the greatest reduction to heating costs, leading to the greatest reduction in total annual costs of any other single change.

3.2 Scheme 5, Weather-stripping

This also has a relatively minor impact on cooling costs, but it has the second greatest impact on heating costs, and it is the least expensive of all the proposed changes, and thus is the most cost effective with a 1.1 year payback as a DIY project. This illustrates the importance of not looking at the cooling costs in isolation, but rather evaluating the total building energy performance.

3.3 Scheme 6, Operable Window Louvers

Throughout much of the Mediterranean, slatted louvers are closed over the open window in mid-day to provide a breeze and at the same time shade the interior from direct radiation. Here it shows that while the cost of cooling electricity is reduced significantly (top bar), the cost of even very dim electric lighting is almost doubled (second from bottom bar), which in turn adds more loads on the air conditioner. Because of the high labor costs to manufacture and install all these louvers, this is the most expensive remodeling alternative and thus the least cost effective option.

3.4 Scheme 7, White Walls and Roof

Traditional Greek homes are often white-washed every spring. HEED shows it as one of the most effective cooling strategies. Unfortunately, this also blocks solar heat gain in the winter which gives it the worst heating costs of all the options. In spite of this, it still saves money on an annual basis, and as a Do It Yourself (DIY) project has only a 4.7 year payback.

3.5 Scheme 8, Large Whole-House Fan

A smart whole-house fan flushes heat out of the building whenever it is cooler outside than indoors. In high-mass buildings like this, the night 'coolth' is stored up for use during mid-day when the fan is off. Here it is one of the best cooling strategies, and even as contracted work it will have a reasonable 8.2 year payback.

3.6 Scheme 8: Combine Schemes 3,4,5,6,7,8

Finally when all these strategies are combined into Scheme 9, the Total Yearly energy cost is reduced by about 27%, which has a 5.8 year payback as a Do It Yourself project. This means that if the homeowner included all these in a major remodeling project they would be cost effective. If the homeowner contracted this work out, only the Weather-stripping and the Whole-House Fan would be cost effective. However for aesthetic reasons other projects such as installing operable shutters or painting the building white might also be included.

4. EFFECT OF CLIMATE ON COOLING PERFORMANCE

This study proves dramatically that the way a home is designed or remodeled can make a significant difference in the amount of heating and cooling energy it uses.

However, producing significant improvements in the cooling performance of this traditional home was more difficult in Athens' climate than would have been expected in California's dryer climates. All the usual 'sure fire' cooling strategies that are successful in California, are somewhat less successful in Athens.

Compared to the typical California climate, the climate of Athens is very different in important ways. For example. it appears that Athens is more humid in summer because the day-night temperature swings are much flatter, which means that the effectiveness of the night venting using a whole-house fan is only modestly successful (Scheme 8). Athens' more overcast summer sky conditions means that window shading with operable louvers is one of the least effective strategies tested (Scheme 6). Athens has much cooler winters with less clear sky solar gain, as shown by the fact that in all schemes the Heating costs are always greater than the Air Conditioning portion of the Electricity costs.

In a related paper[2], HEED was used to evaluate the relative effectiveness of three different passive cooling strategies in each of California's 16 different climate zones. These three cooling strategies are Operable External Shades, Operable Internal Shades, or a Whole-House Fan. Using the high-mass More Energy Efficient home (Scheme 2) that HEED designed for each climate, adding Operable Shades always produces a significant reduction in cooling energy. However adding a Whole-House fan produces even better performance, to the point of eliminating the need to install an air conditioner in 10 of California's 16 climate zones. The results of this study shows unequivocally that the way a building is designed can significantly reduce the amount of cooling energy it uses.

5. THE HOME IMPROVEMENT TREND

In the United States the Home Improvement Research Institute[3] estimates that over $300 billion is spent annually on all forms of home improvements and repairs. This is more than the amount spent on new home construction. In other countries these numbers presumably are comparable. Thus, if free user-friendly tools like HEED can help even a tiny fraction of homeowners decide to invest their own funds in energy efficiency improvements, the potential global annual energy savings could be immense

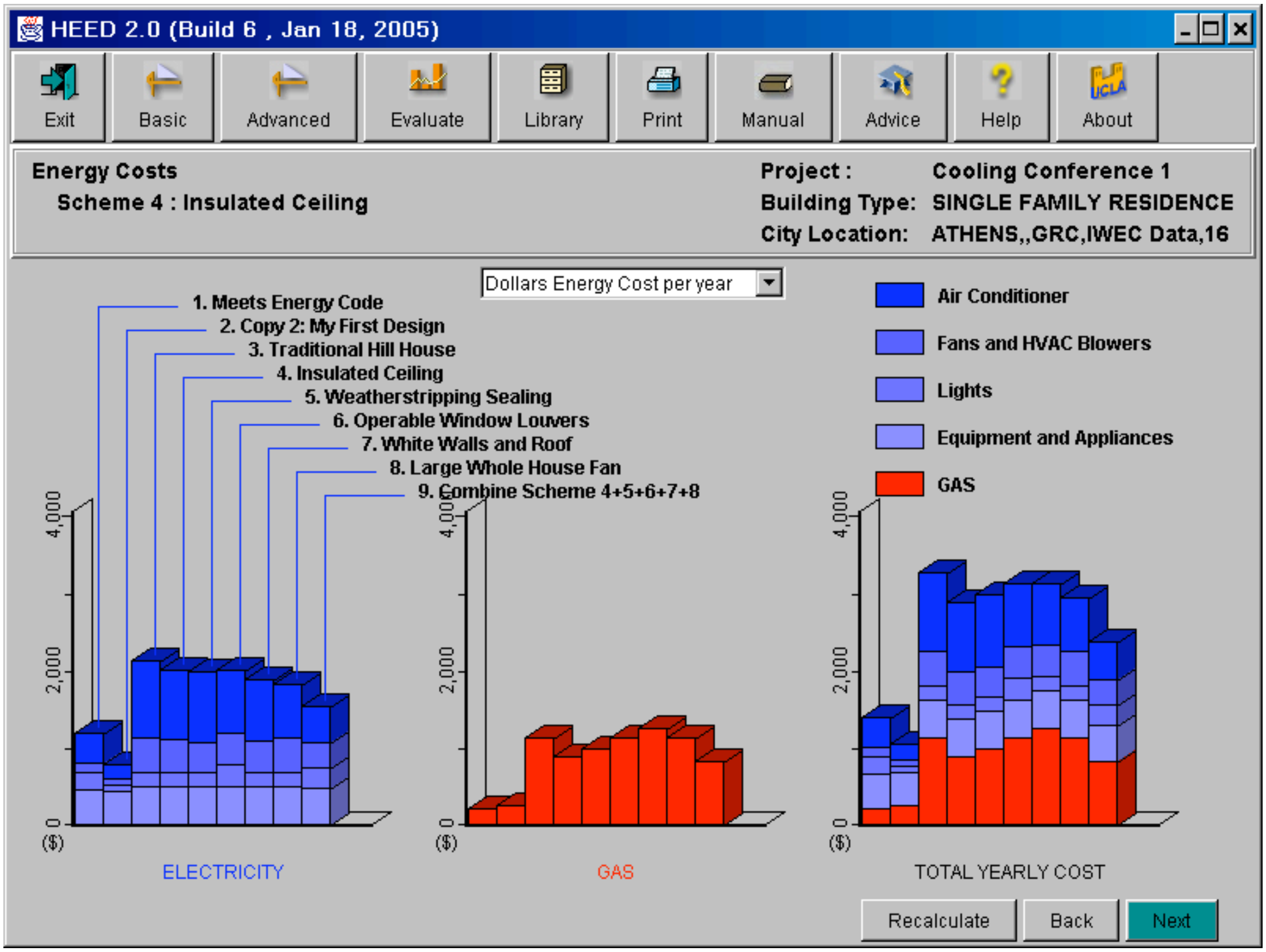

Figure 4: Energy Costs for all schemes are shown comparatively. Air Conditioning is the top (darkest) portion of the Electricity bars. Schemes 3 to 9 are organized in order of increasing cooling effectiveness. Notice that some good cooling strategies produce worse heating energy consumption.

Table 1: Cost Effectiveness

	Options Tested	Total Annual Energy Costs	Savings Compared to Scheme 3	Estimated Costs of Improvements		Years to Pay Back Annual Energy Savings	
				DIY	Contracted	DIY	Contracted
3	Traditional Hill House As Built	$3245	-				
4	Copy 3: Insulated Ceiling	$2860	$385 (12%)	$1000	$7000	2.6	18.0
5	Copy 3: Weather-stripping Sealing	$2966	$279 (9%)	$300	$2500	1.1	9.0
6	Copy 3: Operable Window Louvers	$3121	$124 (4%)	$2700	$7200	21.8	58.0
7	Copy 3: White Walls and Roof	$3118	$127 (4%)	$600	$4000	4.7	31.5
8	Copy 3: Large Whole-House Fan	$2940	$305 (9%)	$600	$2500	2.0	8.2
9	Combine Schemes 3+4+5+6+7+8	$2353	$892 (27%)	$5200	$23200	5.8	26.0

The cost of DIY (Do It Yourself) or Contracted remodeling options can be estimated by visiting the local Home Improvement Store or by calling local contractors for bids. Notice that four of the DIY schemes have paybacks of less that 4.7 years which would be very attractive investments in any economy. If the work is to be Contracted, only the Weather-stripping and Large Whole-House Fan are marginally cost effective. For reference, investing this same amount of money at 8% interest would have a 9 year payback, which means that 7 of these 12 options are at least equal to an investment with this kind of return.

6. OTHER FEATURES IN HEED

In this paper only a few of the many feature of HEED have been presented. Here are a few others:

6.1 Metric HEED:
It is hoped to demonstrate the metric version of heed at this conference, at which point it will also be available of HEED's web site.

6.2 Validation:
HEED is extremely fast especially given that it calculates the heat balance for all 8760 hours of the year, and integrates building loads and system performance with thermostat comfort deadbands to produce a true energy calculation. HEED is driven by a sophisticated hourly heat balance algorithm. HEED has been validated using ASHRAE's Bestest procedure.[4] Recently HEED's ability to accurately predict indoor air temperatures has been validated using a set of full-height test cells.[5]

6.3 Indoor Air Temperatures:
HEED calculates the indoor air temperature for each hour, which can be plotted for any 12-day period. This is useful for checking the comfort of peak indoor air temperatures if the air conditioner is eliminated.

6.4 Context Based Help:
If users have questions about anything on any screen, they only need to click on the "Help" icon. This context-specific information will explain all the terms and options on that screen. In addition, the "Advice" icon in HEED has been expanded by adding access to related web sites. For any other questions, UCLA staffs an email User Support Hot-Line.

6.5 Spanish Language Version:
HEED is one of the few Energy Efficiency software programs that is also available in Spanish.

CONCLUSIONS:

HEED is a simple, easy-to-use, free, design tool that can quickly calculate the energy savings of home design and remodeling alternatives.

ACKNOWLEDGEMENTS:

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[1] A file in the download folder called READ-USA.TXT explains how to load EPW weather data directly from the. EnergyPlus web site for over 600 locations throughout the world.

[2] "Comparing Passive Cooling Strategies in 16 Different Climate Zones", Murray Milne, et.al., Proceedings of the 2005 Solar World Conference, the American Solar Energy Society, Orlando, 2005 (Note, this material was originally intended for inclusion in this paper, but space limitations prevented it. Both these papers will be available, along with many others, in the bibliography section of www.aud.ucla.edu/energy/design/tools)

[3] Home Improvement Research Institute (HIRI), www.hiri.org

[4] HEED produces valid heating and cooling results for 28 different test buildings using ASHRAE's "Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs", ANSI/ASHRAE Standard 140-2001, (see "BestTest Validation" on HEED web site)

[5] "Automatic Sun Shades, An Experimental Study", Pablo LaRoche and Murray Milne, Proceedings of ASES 2004, American Solar Energy Society