

Effectiveness of energy rating systems in evaluating Solar Decathlon homes

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Introduction

What is the U.S. Department of Energy Solar Decathlon?

- A competition managed by NREL. Every two years, approximately 20 teams compete to build the most energy-efficient solar home.
- The custom homes use unique systems and designs that are uncommon in standard homes.

What are energy rating systems?

- Tools used by homebuilders and homeowners to measure home energy efficiency.

Research Questions:

- Are energy rating systems appropriately designed to evaluate Solar Decathlon homes, and do the ratings accurately reflect energy performance?
- What recommendations can be made to energy rating system designers to accommodate future progress in home energy efficiency?

Energy rating systems:

- U.S. Department of Energy Home Energy Score (HEScore)
 - 1-10 scoring system based on asset energy use
 - Simple design of data input fields
- RESNET Home Energy Rating System (HERS Index)
 - Score of 100 = new home built to code, score of 0 = net-zero home
 - Based on total site energy consumption
 - Design of data input fields is more complex
- USGBC LEED for Homes Certification
 - 4 different levels of certification
 - Based on points earned from LEED credits
 - Uses a holistic approach considering building performance, site selection, the construction process, and regional priorities.

Process

Home Selection:

- Eight homes from the Solar Decathlon 2013 that used a variety of building materials, construction designs and HVAC systems were selected:

Participating Universities	Team Name	Abbreviation
Norwich University	Norwich	NU
University of Nevada Las Vegas	Las Vegas	UNLV
Southern California Institute of Architecture and California Institute of Technology	SCI-Arc/Caltech	SCICAL
University of North Carolina at Charlotte	North Carolina	UNCC
Middlebury College	Middlebury College	MIDD
Queen's University, Carleton University, and Algonquin College	Team Ontario	ONT
Czech Technical University	Czech Republic	CTU
Vienna University of Technology	Team Austria	VUT

Energy Rating System Selection: HEScore, HERS Index, and LEED

- These rating systems were chosen because they have been extensively used/studied, have sufficient documentation, award a numerical score, and represent a variety of calculation approaches and input designs.

Score Calculation:

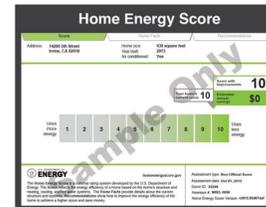
- Initial examination of homes with LEED indicated further analysis would not be beneficial for this study.
- HEScores and HERS Indexes (with and without effects of photovoltaics) were calculated for each home.
- Scores were calculated using the Home Energy Scoring Tool website (HEScore) and REM/Rate v14.6.1 (HERS Index)
- Solar Decathlon project manuals, construction drawings, manufacturer's websites, product specification sheets and rating system documentation were used to determine housing characteristics.

Outcomes

Evaluation of the Design of Rating System Inputs

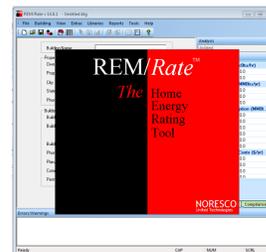
HEScore

- The simple design of the HEScore data input fields caused the following home characteristics to be modeled inaccurately:
 - Thermal insulation
 - HVAC system components
 - Passive systems
 - Construction materials

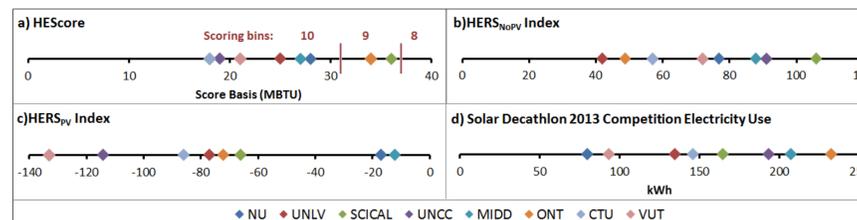


HERS Index

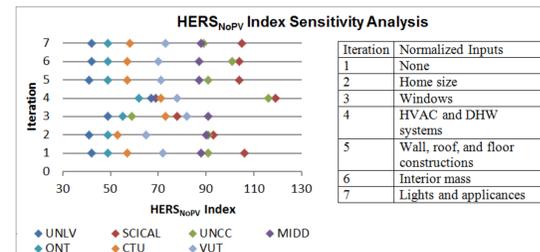
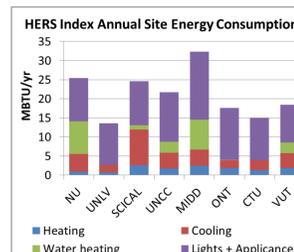
- REM/Rate required more comprehensive housing information than the HEScore website.
- User-defined inputs allowed for greater accuracy in defining unique home characteristics. Problems were encountered when modeling:
 - Hydronic distribution systems
 - Heat pumps
 - Drywall



Home Energy Rating System Results



- All homes received a HEScore of 9 or 10 indicating high energy performance.
- HERSPV Indexes were an average of 144.9 points lower than the HERSNoPV Indexes for the studied homes.
- HERSPV Indexes ranged from -133 to -12, indicating net-zero or better energy performance for each home.
- SCI-Arc/Caltech, North Carolina, and Middlebury homes received HERSNoPV Indexes of 106, 91, and 88 respectively, suggesting that their energy performance is similar to a standard new home built to minimum code requirements.
- Las Vegas and Ontario homes received HERSNoPV Indexes of 42 and 49 respectively, indicating high energy-efficiency.
- Some homes performed consistently with different rating systems (Austria and SCI-Arc/Caltech) while others did not (Norwich and Ontario).



- According to HERS estimates, lights and appliances accounted for 44.4 – 80.2% of total site energy use while heating and cooling only accounted for 19.9 – 48.3%.
- A sensitivity analysis suggested the HERSNoPV Index is most sensitive to HVAC, DHW, window and home size inputs.

Analysis of Home Characteristics

HVAC and DHW systems and percent use in Solar Decathlon 2013 homes

System	Percent Use
Solar thermal collector	65%
Radiant hydronic system	45%
Energy or heat recovery ventilator	80%
Heat Pump for heating/cooling	100%
Heat pump water heater	15%
Tankless water heater	25%
Electric storage/solar booster water heater	45%
Hybrid heat pump/conventional electric water heater	30%

Insulation techniques and percent use in Solar Decathlon 2013 homes

Insulation Technique	Walls	Floors	Roof
Single stud insulated cavity	50%	80%	70%
Double stud insulated cavity	10%	5%	0%
Concrete Layer	5%	15%	0%
Structurally Insulated Panel	35%	15%	30%
Vacuum Insulated Panel	5%	5%	5%
Continuous Insulation (rigid or spray foam)	20%	15%	50%
Green Roof	NA	NA	10%

- High use of heat pumps, energy or heat recovery systems, and solar thermal collectors among Solar Decathlon 2013 homes
- Although single stud insulation cavities are common in standard homes, teams typically designed unusually thick walls resulting in high R-values.

Conclusions & Future Work

Design of Energy Rating Systems:

- Key home characteristics (thermal insulation, HVAC systems) were not defined accurately for the HEScore due to the simple data input design.
- Almost all home characteristics except the most unique HVAC systems were defined accurately for the HERS Index due to the more complex data input design.

Energy Rating System Scores:

- The high HEScores obtained by the studied homes suggest the rating system was not designed to assess very efficient homes.
- The sensitivity of the HEScore to DHW inputs may amplify existing modeling inaccuracies arising from the HEScore's inability to model solar thermal systems.
- All homes consistently scored well with the HEScore, but received HERS Indexes representing energy performance ranging from very efficient to slightly worse than a new home built to minimum code requirements.
- Some homes showed consistent energy performance with different rating systems, but other did not, perhaps due to inaccurate modeling and different calculation methods.

Solar Decathlon Homes:

- Solar Decathlon homes use HVAC systems, DHW systems, and thermal insulation techniques that are not necessarily typical in standard homes.

Possible Future Work:

- Perform on-site home evaluations and specific end use metering at future Solar Decathlon competitions to provide more reliable home data for later studies.
- Conduct a similar analysis of net-zero homes in the current housing market to provide further insight into applying energy rating systems to energy-efficient homes.

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