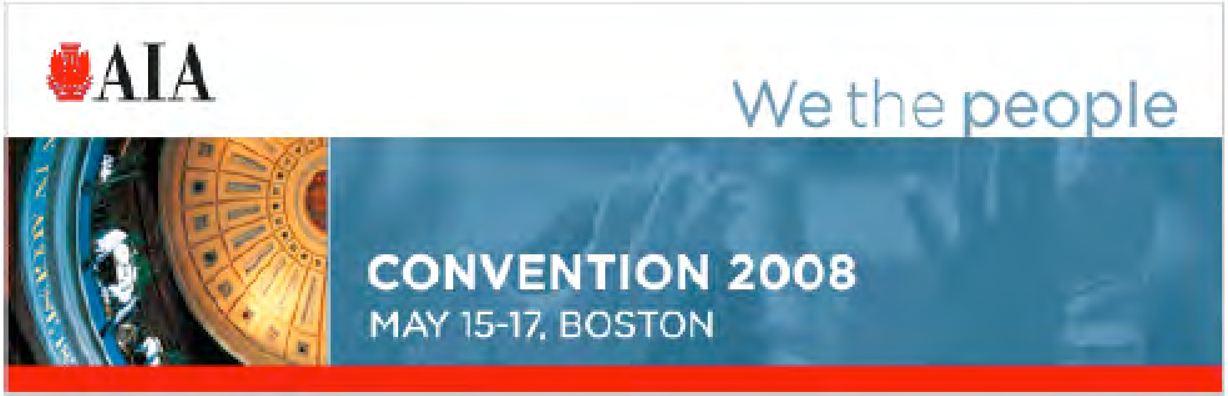

IP52 – Passive-Solar Building Design & Energy Analysis Through B.I.M.

Wednesday, May 14, 2008, 1:00-2:30 p.m.

1.5LUs

Learning Objectives

1. The participants will gain a better understanding of energy code requirements for residential buildings, as well as basic concepts and strategies for better energy performance through passive and active strategies.
2. The participants will understand how BIM is used to package building data and interface with other software tools.
3. The participants will understand how various schematic design tools for energy analysis and green / sustainable / passive solar design can be used to evaluate and enhance the energy performance of the building design using BIM in conjunction with energy-analysis tools.
4. The participants will understand how data can be packaged through BIM to compare with measured energy performance data in ways that help refine designs and analysis procedures to enhance future sustainable-design knowledge.

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Architecture, sustainable
and
passive-solar design

CAD and
graphic services

Sustainable
Architecture

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IP52 – Passive Solar Building Design & Energy Analysis Through B.I.M.

W. Brent Swain, AIA, NCARB

Wednesday, May 14, 2008, 1:15-2:45p.m.

presentation

AIA

WHERE WE LIVE | WHERE WE WORK | OUR PLACE IN THE WORLD | HOW WE COME TOGETHER | OUR PLACE ON THE LAND

CONVENTION 2008

We the people

IP52 – Passive-Solar Building Design & Energy Analysis Through B.I.M.

Wednesday, May 14, 2008 1:00-2:30 p.m.

Passive-Solar Building Design & Energy Analysis Through B.I.M.

W. Brent Swain, AIA
Sustainable Architecture
www.sustainablearch.us

Acknowledgements/Credits

Amy Newby, client

Greg Blunier, CAD Systems Specialist
Integrated Computer Resources Division
Klaus Companies
www.klausco.com
•ArchiCAD Geometric Description Language (GDL) scripting & calculation support

Bruce Chyka, HERS certified rater, EnergyStar partner
Performance Plus Homes
http://www.performanceplushomes.net/
•Home Energy Rating of the design using REMrate

Passive-Solar Building Design & Energy Analysis Through B.I.M.

Learning Objectives

- The participants will gain a better understanding of energy code requirements for residential buildings, as well as basic concepts and strategies for better energy performance through passive & active strategies.
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- The participants will understand how various schematic design tools for energy analysis and green, sustainable and passive solar design can be used to evaluate and enhance the energy performance of the building design using BIM in conjunction with energy-analysis tools.
- The participants will explore how data can be packaged through BIM to compare with alternative schemes or measured energy performance data in ways that help refine designs and analysis procedures to enhance future sustainable-design knowledge.

Context: U.S. Greenhouse Gas Emissions Budget

Union of Concerned Scientists: www.ucsusa.org/emissionstarget.html

▪*Potential Risks of 2ºC rise above pre-industrial levels:*
▪12- to 40-foot sea level rise
▪serious economic & life consequences

▪*U.N. Framework Convention on Climate Change* goal:
▪80% reduction in greenhouse gas emitting fossil fuel consumption from 2000-50 by industrialized nations

▪ U.S. GHG emissions budget: 265 GtCO2eq 2000-50
▪45GtC02eq has already been emitted in the U.S.
▪with a “business-as-usual trajectory: 97% consumed by 2030.
▪with 4% annual reductions starting in 2010, 80% consumed by 2030

Context: Peak Oil synopsis

(excerpts from documentary "A Crude Awakening," Gelpke / McCormack)

- Petroleum creation: twice in geologic history –
  - 150 million years ago and 90 million years ago.
  - "They aren't making any more dinosaurs."
- U.S. peak production: Dec. 1970
  - 10 yrs. later, 4X as many wells were being drilled, only 2/3 production
  - no new major discoveries expected
- World peak production estimates:
  - 2006, 2010, or 2037 depending on the source
  - The EIA 2037 estimate features a skewed-right peak (compared to a "bell" curve) followed by a sharper decline
- Accessible oil will be very scarce by the end of the century
  - major price adjustments with drastic economic consequences
  - (e.g. compare to a cup of coffee today @ $4.50 = $72/gallon)

Review: Passive Design Strategies

Passive Solar Design Handbook (Van Nostrand Reinhold, 1984)

Systems: DG,TW,WW,SS

Passive Cooling Strategies: natural ventilation, ventilation W/ high-mass cooling, solar shading, daylighting, evaporative cooling

Orientation: east-west long axis

Fenestration Concepts:

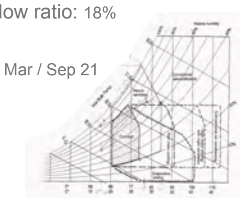
•IECC recommended wall-window ratio: 18%

•load windows on south face

•shade to window sill, equinox: Mar / Sep 21

Thermal Mass Concepts:

•mass-collector ratios: 3:1,6:1



Case Study Target Reductions: emissions, consumption

In light of the GHG emissions budget, and the oil supply scenario, this case study has the following objectives:

- Target Goal: achieve a consumption rate 20% of current residential levels using the EIA's RECS01 data for residential primary energy intensity (kBtu/s.f. floor area)
- Sources: primary energy = all consumption by end-users (site) excluding electricity, but including electric generation (source) consumption
- end uses: heating and cooling (future topics: lighting)
- Strategy: improve building envelope energy efficiency through conservation (R-values, fenestration scheme), passive solar heating, and passive cooling strategies

Case Study Objectives, Scope

Covered in this Case Study:

•energy code compliance (2006 IECC)

•building orientation / solar shading

•envelope performance (passive & conservation)

•fenestration schemes

•estimating: energy demand, consumption, cost

•life Cycle Costing, cost estimating

Future Topics:

•active HVAC system selection

•daylighting controls / sensor technologies

•monitoring of as-built performance

Case Study Methods & Tools

Direct Schematic Analysis:

•Green Building Studio plug-in for ArchiCAD, Revit

Iterative BIM direct data export to spreadsheets for:

•Code compliance analysis

•Passive-solar heating analysis

•Building Data sheet: for data input to external software tools

External Software Tools for Schematic Analysis

•REScheck (energy code compliance tool)

•Energy-10 (schematic passive solar / sustainable design tool)

Performance Simulation:

•eQUEST (DOE freeware for full performance simulation)

Home Energy Rating:

Performance Plus Homes (for quality-control purposes)

Life-Cycle Cost evaluation of Passive Solar Strategies:

•BLCC (DOE Building Life-Cycle Costing software)

Case Study Limitations, Future Topics

•Analyses in this Case Study are architectural only to facilitate design decision-making, not engineering. The Home Energy Rating Service analysis was performed by an independent agent.

•This Case Study was limited to the specific climatic conditions and technological considerations of the design problem. Results do not necessarily apply to other climates or design problems.

•The schematic design software tools were used for specific areas of specialty and for quality control, and had limited levels of control not designed for full performance simulation. A building data sheet is under development to facilitate performance simulation runs according to 2006 IECC section 404 for comparison between a "benchmark" version and a design in question.

•Active System selection depends heavily on life-cycle costing, which was beyond the scope of this Case Study.

•Spreadsheets are being developed to analyze the as-built performance once the home is constructed.

i.a. Case Study “Newby” Residence

Software Tools:

•Graphisoft: ArchiCAD (full BIM)
http://www.graphisoft.com/products/archicad/ac11/

•Green Building Studio (web-based direct plug-in)
http://www.greenbuildingstudio.com/About.aspx

•DOE: eQUEST (full performance simulation)
http://doe2.com/equest/

•SBIC: Energy-10 (schematic energy analysis)
http://www.sbicouncil.org/store/e10.php

•DOE: REScheck (energy code check)
http://www.energycodes.gov/rescheck/

•DOE: BLCC 5.3-07
http://www1.eere.energy.gov/femp/information/download_blcc.html

i. Case Study “Newby” Residence

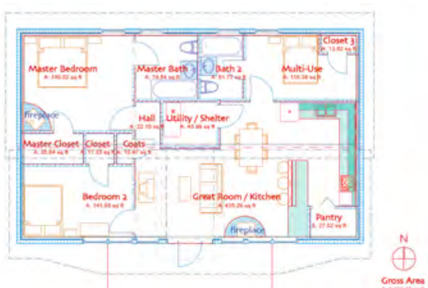
This study features energy analyses using BIM for the “Newby” home, a proposed 1178s.f. passive-solar home in Pratt, KS. The goal is to design the building envelope to achieve annual fossil-fuel consumption level of 80% of current residential energy intensity.

Case Study “Newby” Residence

Schematic Floor Plan

•1178s.f., 2-bed/2-bath + guest bedroom/den

•8:1 ratio int. thermal mass to solar collection (S-glass) area



Case Study “Newby” Residence > EE features

Passive Solar Heating / Cooling, EE Features:

<u>Orientation:</u>

•South-facing with long axis running East-West

<u>High Insulation Values:</u>

•10 1/4” SIP roofs, R-38

•6 1/2” SIP walls, R-33/34

•bermed earth with masonry knee walls, R-15, for additional interior thermal mass while minimizing heat loss

Case Study “Newby” Residence > EE features

<u>Passive-Solar Fenestration Scheme:</u>

•windows loaded on S-face, sheltering overhangs “tuned” to solar equinox

•clerestory windows for additional solar gain / daylight penetration

•Minimal (no) windows on east or west to limit summer gain

•barrel vaulted dormer with feature window added for additional solar gain (passive solar heating)

•Optional Sunspace at entrance beyond, to be evaluated for cost effectiveness in this case study using BLCC software.

Case Study “Newby” Residence > EE features

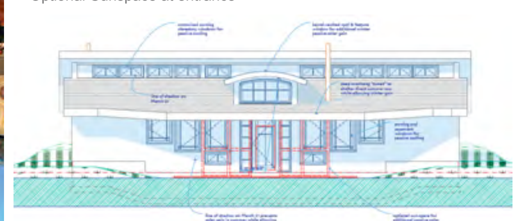
South Elevation:

•Maximum South-glass (collector) area

•Solar shading (see shadow line at solar equinox)

•Clerestory windows to light rear of home

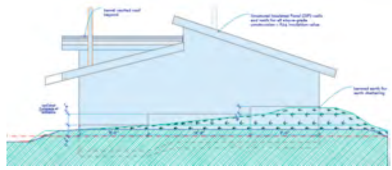
•Optional Sunspace at entrance



Case Study "Newby" Residence > EE features

East Elevation (West Elevation opph.):

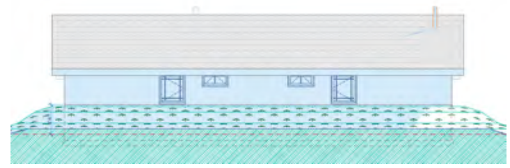
•Bermed earth with high-mass knee walls
•Optional sunspace beyond at entrance
•Clerestory for solar gain to rear of home
•Sheltering overhang at South



Case Study "Newby" Residence > EE features

North Elevation:

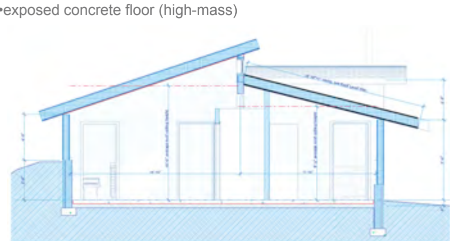
•Egress windows only
•Bermed earth to minimize heat loss (winter)



Case Study "Newby" Residence > EE features

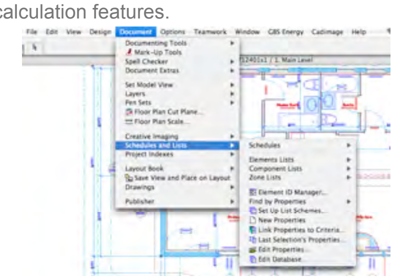
Building Section:

•Clerestory windows for solar gain to rear of home
•Bermed earth with high-mass knee walls
•exposed concrete floor (high-mass)



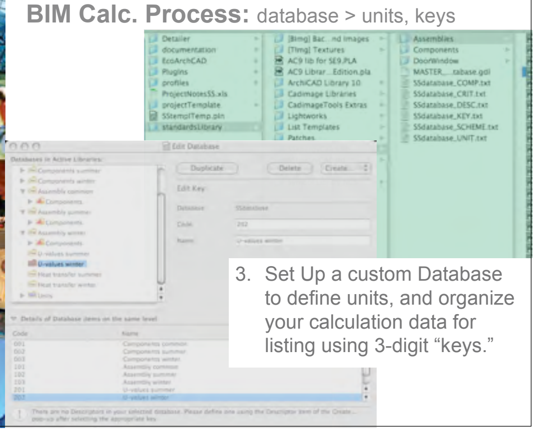
BIM Calc. Process: database > units, keys

1. Customize the pull-down menu to access ArchiCAD's calculation features.



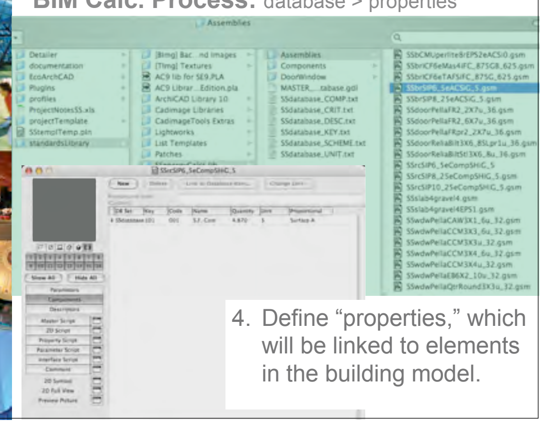
2. Create an independent "library" folder to store custom databases (see next slide).

BIM Calc. Process: database > units, keys



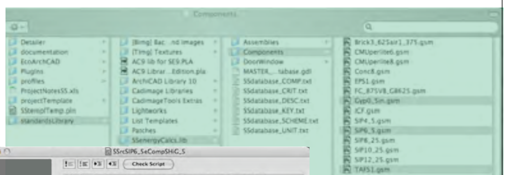
3. Set Up a custom Database to define units, and organize your calculation data for listing using 3-digit "keys."

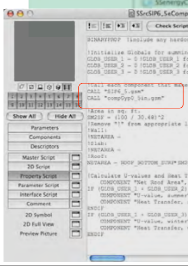
BIM Calc. Process: database > properties



4. Define "properties," which will be linked to elements in the building model.

BIM Calc. Process: database





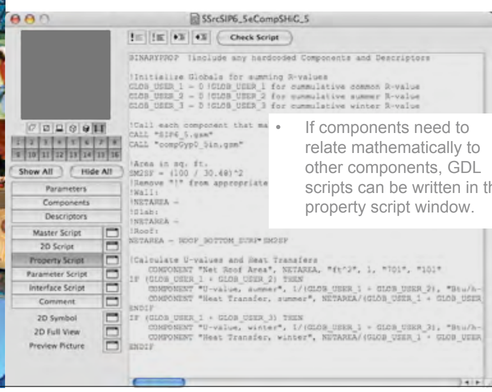
- Properties can be “nested” using ArchiCAD’s GDL by “calling” sub-properties in the property script window.
  – NOTE: Our CSI Assembly properties and sub-properties were labeled “assemblies” and “components” (even though “components” are ArchiCAD’s term for a property’s characteristics).

BIM Calc. Process: properties > components

5. Properties have “components” (characteristics) and “descriptors” (information) which are applied to the building elements when links are established. Define those components and descriptors, assigning database units and keys to them, along with custom 3-digit “codes” that determine the order in which the components will be listed.

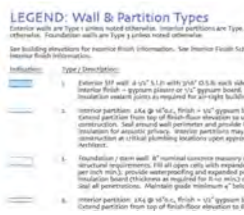
- Components can be created directly in the property’s components window, or,

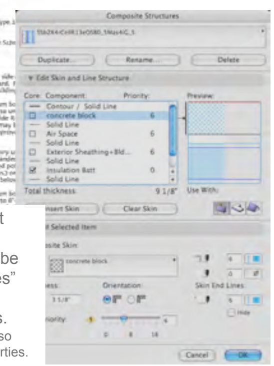
BIM Calc. Process: property script



- If components need to relate mathematically to other components, GDL scripts can be written in the property script window.

BIM Calc. Process: model > elements

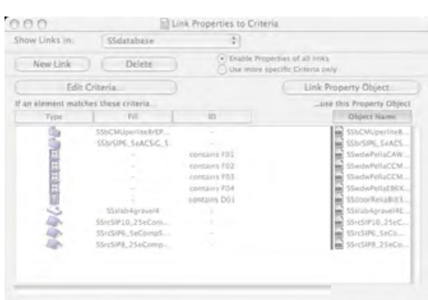




6. Model building elements that correspond to the database properties to which they will be linked – e.g. wall “composites” (assemblies, or types) that match “assembly” properties.
   Assign unique IDs to the elements so they can be linked to specific properties.

BIM Calc. Process: building model > links

7. Link the properties to elements in the building model either manually or “by criteria” using the “find and select” window.



BIM Calc. Process: list scheme, export

8. Create a “component list scheme,” which will list your linked property’s components based on the property-to-element links you have created, and organized by their keys and codes. You can manually include specific layers, objects, components, etc. and save alternate list schemes. Run the desired list scheme.
9. Save the list as a tabbed-text file, which can be inserted into a spreadsheet, which can have as many calculations as you wish referencing the raw data. Once the number of elements being listed is fixed, you can establish your spreadsheet references in your formulas and re-export the data as often as you like and view the results of design changes.

Results: BIM sample data

8	Ro2S	1	S.F. Cost	687.886	$
8	Ro2S	70	6 1/2-in. Structural Insulated Panel	24	h-ft^2-F/Btu
8	Ro2S	90	1/2-in. Gypsum	0.320	h-ft^2-F/Btu
16	Ro2S	101	R-value	24.32	h-ft^2-F/Btu
8	Ro2S	301	U-value, winter	0.041	Btu/h-ft^2-F
8	Ro2S	501	Heat Transfer, winter	5.6	Btu/h-F
8	Ro2S	701	Net Roof Area	135.51	ft^2
1	S01	1	S.F. Cost	5,733.00	$
1	S01	301	F2-value, winter	0.441	Btu/h-ft-F
1	S01	501	Heat Transfer, winter	61.4	Btu/h-F
1	S01	701	slab perimeter	139.17	ft
5	W01E	1	S.F. Cost	2,457.95	$
5	W01E	70	6 1/2-in. Structural Insulated Panel	24	h-ft^2-F/Btu
5	W01E	90	1/2-in. Gypsum	0.320	h-ft^2-F/Btu
10	W01E	101	R-value	24.32	h-ft^2-F/Btu
5	W01E	301	U-value, winter	0.041	Btu/h-ft^2-F
5	W01E	501	Heat Transfer, winter	8.7	Btu/h-F
5	W01E	701	Net Wall Area	211.53	ft^2

Results: IECC Compliance

BIM results:

IECC2006 T.402.1.1, Insulation & Fenestration Req'ts. by Component*

component	proposed	required	
Fenestration U	0.320	0.40	compliant
Skylight. U	NA	0.60	NA
Fenestration SHGC	NA	NR	NA
Ceiling R	39.3	38	compliant
Frame Wall R	24.3	13	compliant
Mass Wall R	15.6	5	compliant
Floor R	NA	19	compliant
Basement Wall R*	NA	10	compliant
Slab R	10.0	10	compliant
Slab insul. Depth	2.0	2	compliant

The building shell meets all insulation and fenestration requirements of IECC06 402.1.1

Results: IECC Compliance

BIM results:

As a deduct-alternate, since 10 1/4" roof SIPs aren't required for structural reasons, a U-factor alternative computation per IECC06 402.1.3 could be performed to investigate reducing the roof-ceiling panels to 8 1/4".

IECC2006 T.402.1.3, Equivalent U-factors

component	proposed UA	req'd. U	req'd. UA
Fenestration U	71.675	0.400	87.522
Skylight. U		0.600	
Ceiling U	31.320	0.030	36.627
Frame Wall U	33.215	0.082	66.237
Mass Wall U	20.635	0.141	65.250
Floor U		0.047	
Basement Wall U		0.059	
Crawlspace wall U		0.065	
	156.8	compliant	255.6

The results show the design is still energy code-compliant.

Results: summary data

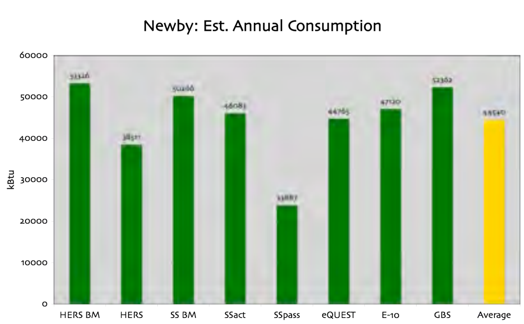
NEWBY	HERS BM	HERS	SS BM	SSact	SSpass
peak heat/cooling load (kW)		5.7	2.7	2.7	2.7
consumption Jun-Sep(kWh)	5015	3622	4727	4334	2246
consumption Oct-May (kWh)	10614	7665	10005	9172	4754
annual cons. est. (kWh)	15629	11287	14732	13506	7001
annual cons. est. (kBtu)	53326	38511	50266	46083	23887
utility cost Jun-Sep ($/kWh)	0.115	0.115	0.115	0.115	0.115
utility cost Oct-May ($/kWh)	0.107	0.107	0.107	0.107	0.107
annual energy cost est.	$1,710	$1,235	$1,612	$1,478	$766
avg. monthly consumption	$142	$103	$134	$123	$64
energy intensity (kBtu/ft^2)	45	33	43	39	20

values in red are estimated values calculated from the data (in black)

NEWBY (cont'd.)	eQUEST	E-10	GBS	Avg.	RECS01
peak heat/cooling load (kW)	4.5	2.6	3	3.4	
consumption Jun-Sep(kWh)	4210	4431	4924	4522	
consumption Oct-May (kWh)	8910	9379	10422	9570	
annual cons. est. (kWh)	13120	13810	15346	14092	
annual cons. est. (kBtu)	44765	47120	52362	48082	
utility cost Jun-Sep ($/kWh)	0.115	0.115	0.115	0.115	
utility cost Oct-May ($/kWh)	0.107	0.107	0.107	0.107	
annual energy cost est.	$1,435	$1,511	$1,679	$1,542	
avg. monthly consumption	$120	$126	$140	$128	
energy intensity (kBtu/ft^2)	38	40	44	41	81

values in red are estimated values calculated from the data (in black)

Results: Summary Data



Results: Summary Data

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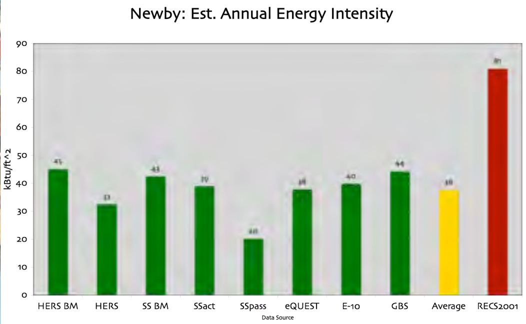
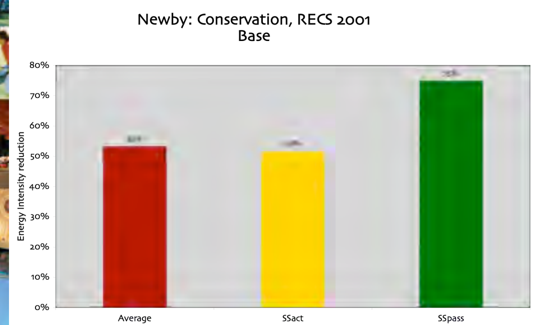


Results: Summary Data



Analysis: passive solar heating

LCR Passive Heating Analysis		
int. thermal mass area	1641	ft^2
Ap DGA3	189	ft^2
Mass:Ap ratio	9	
BLC	5494	Btu/DD
HL rate	4.7	Btu/DD-ft^2
LCR	29.1	Btu/DD-ft.2
SSF DGA3	51%	
Auxiliary Heat DGA3	98.5	Therms
Auxiliary Heat DGA3	2886	kWh
Ref. Auxiliary Heat DGA3	200.1	Therms
Ref. Auxiliary Heat DGA3	5864	kWh
int. thermal mass area	1711	ft^2
sunspace d	7	ft
sunspace w	10	ft
sunspace h	7	ft
Ap SSA5	70	ft^2
Ap SSA5+DGA3	259	ft^2
Mass:Ap ratio	7	
BLC	5227.9	Btu/DD
HL rate	4.4	Btu/DD-ft^2
LCR	20	Btu/h-F-ft.2-F
SSF SSA5	57%	
SSF combined	52%	
Auxiliary Heat DGA3+SSA5	90.5	Therms
Auxiliary Heat DGA3+SSA5	2652	kWh
Ref. Aux. Heat DGA3+SSA5	190.4	Therms
Ref. Aux. Heat DGA3+SSA5	5580	kWh

Analysis: Life-Cycle Cost

BLCC results:

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$95,074	$100,274	-$5,200
Future Costs:			
Energy Consumption Costs	$11,237	$10,286	$951
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Recurring and Non-Recurring OM&R Costs	$0	$0	$0
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
Subtotal (for Future Cost Items)	$11,237	$10,286	$951
Total PV Life-Cycle Cost	$106,311	$110,560	-$4,249

What is the life-cycle cost of a "SSA5" sunspace (ref.: Passive Solar Design Handbook 1984), considering only first and energy costs? Assume it adds 50% of its cost to the market value of the home.

A 700s.f. sunspace with an initial cost of $10,377, would save 550 therms of natural gas, about $950, over a 25 year period. The life-cycle cost would be $4249.

Results: IECC Compliance

REScheck results:

Construction Site:	Owner/Agent:	Designer/Contractor:
SW 20 St. & 10 Ave. Pratt, KS 67124	Amy Newby 617 S. Mound Street Pratt, KS 67124 620/672-6727 amy_m_newby@hotmail.com	W. Brent Swain Swain Studio 2620 Stratford Road Lawrence, KS 66049 785/841-0390 bswain@swainstudio.com

Compliance: Passes on UA

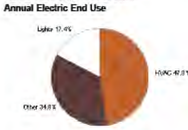
Compliance: 17.5% Better Than Code   Maximum UA: 315   Your UA: 260

Assembly	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: Structural Insulated Panels (SIPs)	1178		38.0		33
Wall 1: Structural Insulated Panels	769		23.3		35
Wall 2: Masonry Block with Integral Insulation:w/ Additional Exterior Insulation	322	0.0	10.0		5
Window 1: Wood Frame:Double Pane with Low-E SHGC: 0.40	251			0.320	80
Floor 1: Slab-On-Grade:Unheated Insulation depth: 2.0'	139		10.0		107
Heat Pump 1: Air Source7.7 HSPF, 13 SEER					

Results: GBS (schematic)

Sample GBS results:

Energy End-Use Charts
Click on chart for more or less detail.
Annual Electric End Use



Annual Fuel End Use

General Information
Project Title: Newby
Run Title: Low Energy Alternative
Building Type: SingleFamily
Floor Area: 1,069 ft²

Estimated Energy & Cost Summary

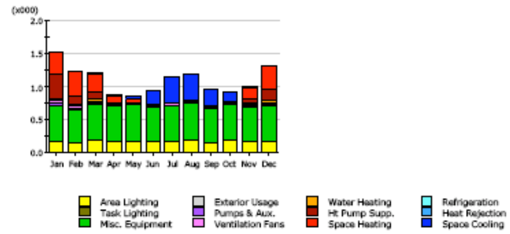
Annual Energy Cost	$1,679
Lifecycle* Cost	$22,870
Annual CO_2 Emissions	
Electric†	13.8 tons
Onsite Fuel	3.1 tons
H3 Hummer Equivalent	1.5 Hummers

Results: Energy-10 (schematic)

Sample Energy-10 output

Results: eQUEST (performance)

Sample eQUEST output



Results: eQUEST (performance)

Sample eQUEST output

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.00	-	0.01	0.40	0.25	0.13	0.02	0.00	1.45
Heat Reject.	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-
Space Heat	0.34	0.37	0.29	-	0.01	0.01	0.18	0.37	1.77
HP Supp.	0.38	0.13	0.11	-	0.00	0.00	0.06	0.17	0.85
Hot Water	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.19
Vent. Fans	0.05	0.04	0.03	0.04	0.02	0.01	0.02	0.04	0.32
Pumps & Aux.	0.03	0.02	0.02	-	0.00	0.01	0.03	0.03	0.16
Ext. Usage	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.54	0.49	0.55	0.56	0.51	0.55	0.52	0.53	6.39
Task Lights	-	-	-	-	-	-	-	-	-
Area Lights	0.17	0.15	0.17	0.18	0.15	0.17	0.16	0.16	1.98
Total	1.53	1.22	1.20	1.18	0.95	0.90	1.00	1.32	13.12

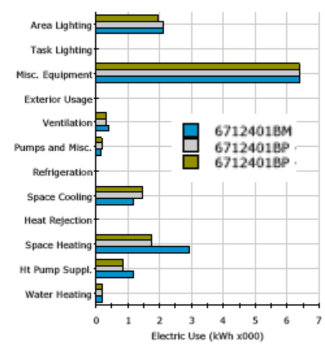
Results: eQUEST (performance)

Sample eQUEST output:

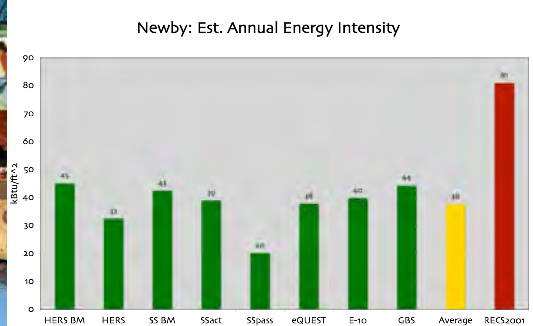
BM = Building America Benchmark (a 1990's consumptive home.

BP, white = Newby design, but comparable to BM.

BP, bronze = Newby design, with a number of energy-eff. Measures including daylighting.



Results: Summary Data



Conclusions

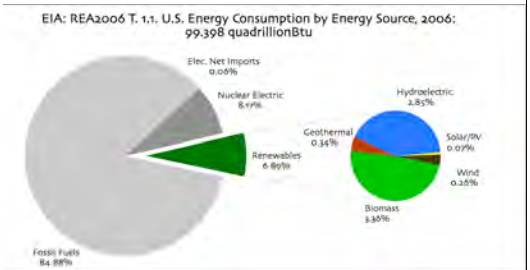
Green Building Studio and Energy-10 data are schematic energy analysis tools, while eQUEST provides full performance simulation. All three sources predicted values between the HERS benchmark and the HERS- & SS- predicted performance. The BIM data agreed well with all, with predicted passive being substantially lower than all other estimates.

In addition to accurately predicting building performance, BIM was especially useful in iterative calculations to optimize fenestration, insulation schemes, and to evaluate passive-solar systems.

Changes were evaluated in minutes to optimize performance and facilitate design decision-making with comparative charts to achieve the potential for an additional 2100kWh, or $230 in energy savings through passive solar heating strategies alone.

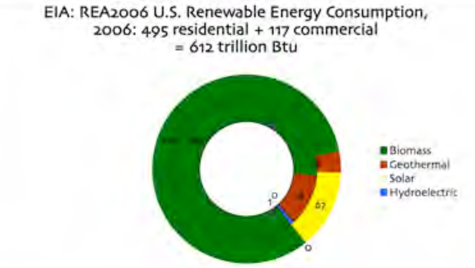
The design saves 75% compared to current residential energy intensity – close to the goal of 80%, with the help of BIM.

Appendix: Energy Disposition & Goals



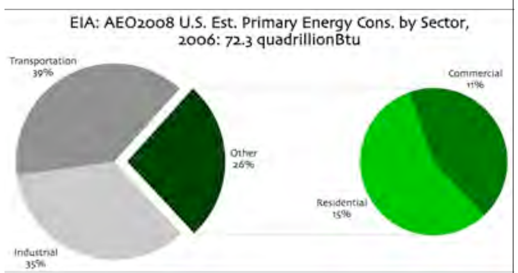
According to the Energy Information Administration, current U.S. energy consumption is 99.4 quadrillion Btu (quadBtu), of which 7%, is generated from renewables.

Appendix: Energy Disposition & Goals



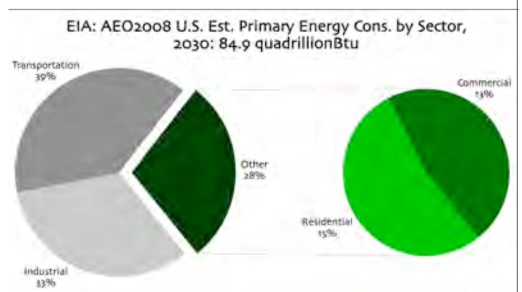
The commercial and residential sectors, those most impacted by building envelope design, are lagging behind the 7% average of renewable consumption – at 1.5% and 4.6% respectively.

Appendix: Energy Disposition & Goals



The U.S. commercial and residential sectors currently consume 18.8quadBtu total annually, or 26% of the total.

Appendix: Energy Disposition & Goals



By 2030, those sectors are expected to consume 23.8quadBtu, up 26%. An equal 12.6quadBtu offset would be a step towards sustainability, but a worthy goal.

Evaluation

Speakers

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