Study of Multifamily Energy Retrofit using Flexible, Multizone Building Simulation Model

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Presented at
Building America Technical Update Meeting

April 29-30, 2013

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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Outline

- Multifamily Energy Audit Tool
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  - Needs for MF Audit Tool
  - Existing MF Tools
  - Modeling Approach
  - Development Status
- Case Study
  - Background
  - Pre/Post Retrofit Building characteristics
  - Whole Building Energy Analysis
- Summary

Background

- New MF Building Energy Audit Tool sponsored by U.S. DOE
- Collaboration of ORNL and LBNL
- National web-based workshops for multifamily audit methods experts and practitioners to obtain
  - Audit methods
  - Issues
  - Potential improvements

Weatherization Assistance Program (WAP)

Increased attention to Multifamily Building Weatherization

Audit need assessment through National Web Meetings

Development of MulTEA (Multifamily Tool for Energy Audit)

Background: Needs for MF Audit Tool

- Desired Modeling & Analysis Capabilities
  - ➢ *Outcome of National Web Meetings*

- Better handing of multiple zones and decentralized systems
- Improved treatment of ventilation systems and infiltration assessment
- Distribution systems (pipes, ducts, tank losses)
- Multiple fuel systems
- Inclusion of rules-based savings calculations
- More flexibility with heating and cooling equipment efficiencies
- Utility bill reconciliation
  - ➢ *Development of ORNL's new Multifamily Audit Tool (MulTEA)*

Currently Used MF Tools

	eQuest	EA-QUIP	TREAT-MF	NEAT
Applicability	Case-by-case basis	Small and large MF buildings	Small and large MF buildings	Small MF buildings
Calculation Engine	DOE-2.2	CIRA, VBDD calculation	SUNREL Thermal network model	CIRA, VBDD calculation
Features	Multiple zones and multiple systems	Single zone, central system focus	Multiple zones and multiple systems	Single zone, Multiple systems
Utility bill input	Not available	Required	Required	Optional
Software use	Desktop	Desktop, Web-based	Web	Desktop, Web-based under development

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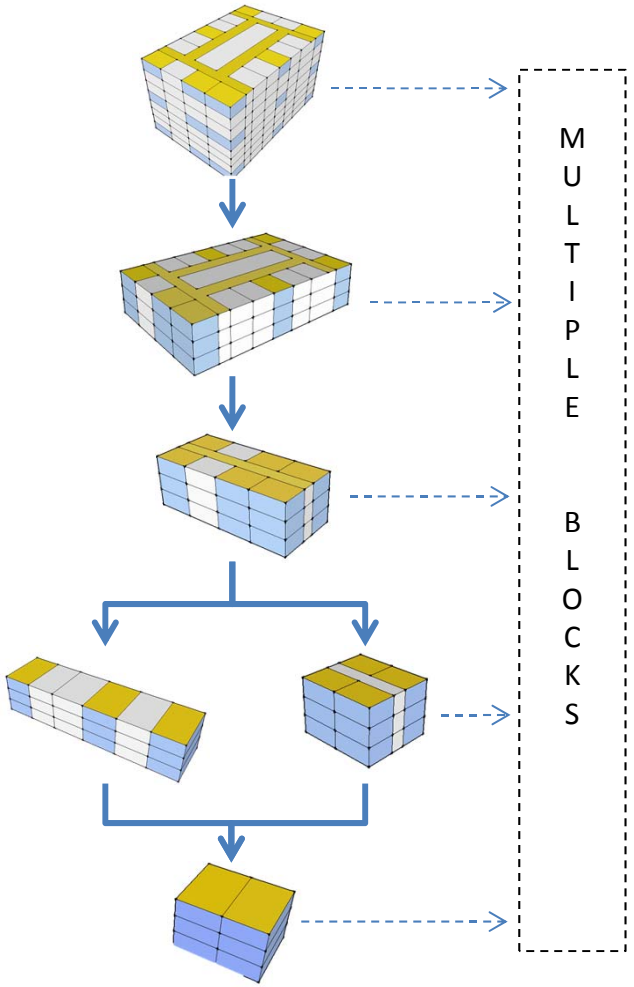
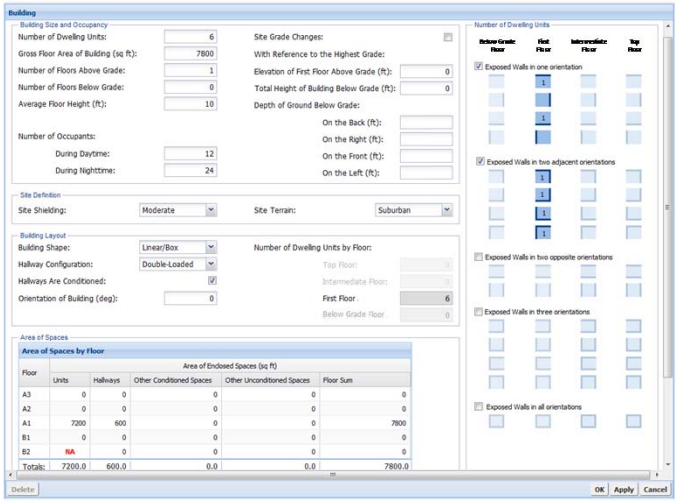
MulTEA: Modeling Approach

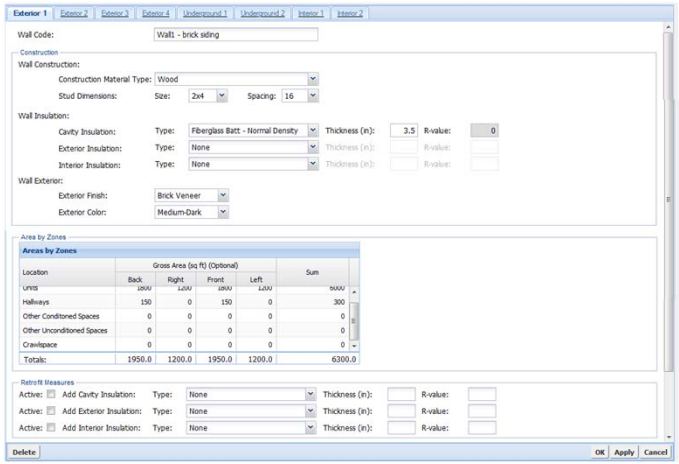
- Hourly Simulation Engine (DOE-2 Engine)
- Multiple Thermal Zones
- Representative Building Typologies
  - Flexible building shape
- Multiple Systems
  - Decentralized systems
  - Centralized systems (HVAC & DHW)
- Infiltration/Ventilation
- Representative Internal Load Schedules



Development Status (as of April 2013)

- Beta Version 1
  - Low rise, decentralized HVAC, centralized DHW
  - Version 2 will handle centralized HVAC
- Version 1 is being tested
- Case study – Maplewood apartment

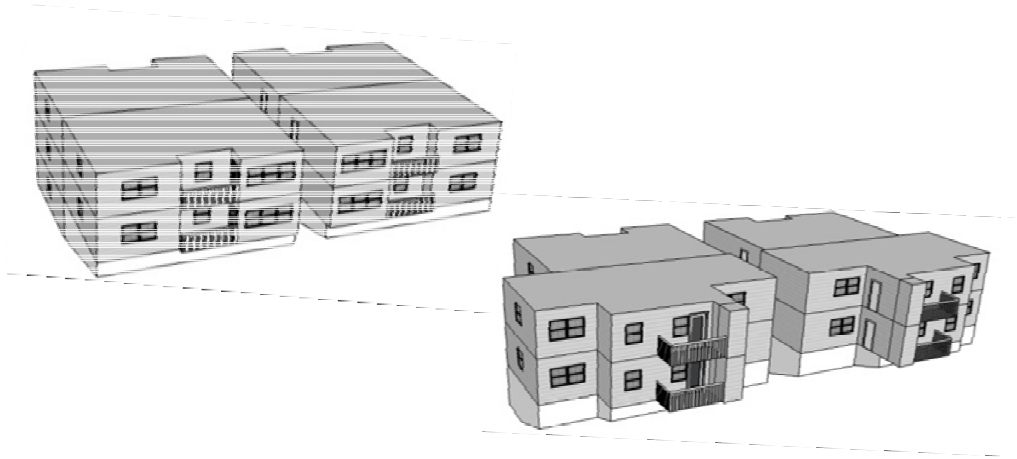


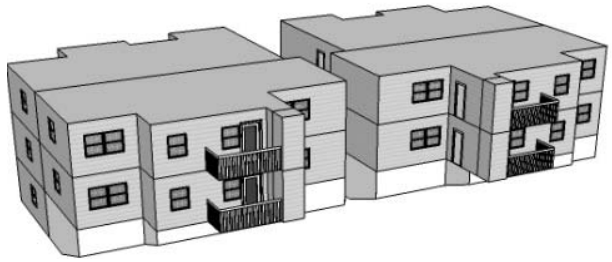


Case Study
Maplewood Apartment

Case Study: Maplewood Apartment

- Case Study
  - Built in 1993
  - Union City, GA
  - 11 buildings (110 units - 10 units per building): 126,878 sq.ft.
  - Three different plans (Types)
- Retrofit Energy Target: 20~30% energy savings
- Funding Process: Combined affordable housing subsides (e.g., LIHTC) and private equity
- To bring the buildings up to the current Georgia Code (2009 IECC)
- Whole Building Approach
  - Envelope
  - HVAC systems
  - DHW
  - Lighting
  - Appliances





Case Study: Maplewood Apartment

- Case Study: Building #7
  - Three story, 11,545 sq.ft.
  - 10 units
  - Two different plan (5 - two bedrooms & 5- three bedrooms)
  - Unit A: Two bedrooms (1,049 ft2)
  - Unit B: Three bedrooms (1,260 ft2)
  - Partial Slab-On-grade & vented crawl space

Case Study: Pre & Post-retrofit Characteristics

Measures	Existing*	Improvements
Foundation	Slab & vented crawl spaces	No Change
Foundation Insulation	No effected insulation for crawl space ceiling	R-19 fiberglass batt under crawlspace ceiling
Wall Insulation	Exterior wall: R-13 Fiberglass batt Party wall: R-11 Fiberglass batt Wall finish: Vinyl siding and brick veneer	No Changes for Walls Finish: Fiber cement siding and brick fascia
Ceiling Insulation	R-30 (previous renovation in 2008)	R-38 (additional 4 inch of blown-in fiberglass)
Window Performance Ratings	Single-pane, aluminum frame (1.31 U-value, 0.80 SHGC)	Double-pane, low-e, vinyl frame (0.35 U-value, 0.27 SHGC)
HVAC	Unit A: 18 kBtu/h, 12 SEER, 7.5 HSPF heat pump; Units B and C: 24 kBtu/h, 12 SEER, 7.5 HSPF heat pump	Unit A: 18 kBtu/h, 14.5 SEER, 8.3 HSPF heat pump; Units B and C: 24 kBtu/h, 14.5 SEER, 8.5 HSPF heat pump
Supply Duct Location	Conditioned Space	Conditioned Space
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DHW Size and Efficiency	40 Gallons - 0.90 EF Elec. water heater	40 Gallons - 0.93 EF Elec. water heater
Lighting	Unit A: Two T12 lamps, a 15W pin-base tube, and 18-60W incand. lamps; Units B and C: Two T12 lamps, a 15W pin-base tube , and 21-60W incand. lamps	Unit A: Two T12 lamps and 18-13W CFLs; Units B and C: Two T12 lamps and 21-13W CFLs
Appliances	Standard efficiency cooking range/oven, refrigerator and dishwasher	Standard cooking range/oven, Energy Star qualified refrigerator and dishwasher
Air Sealing	Gaps around service penetrations through walls and ceiling	Air sealing and caulking that reduced air leakage by 25%

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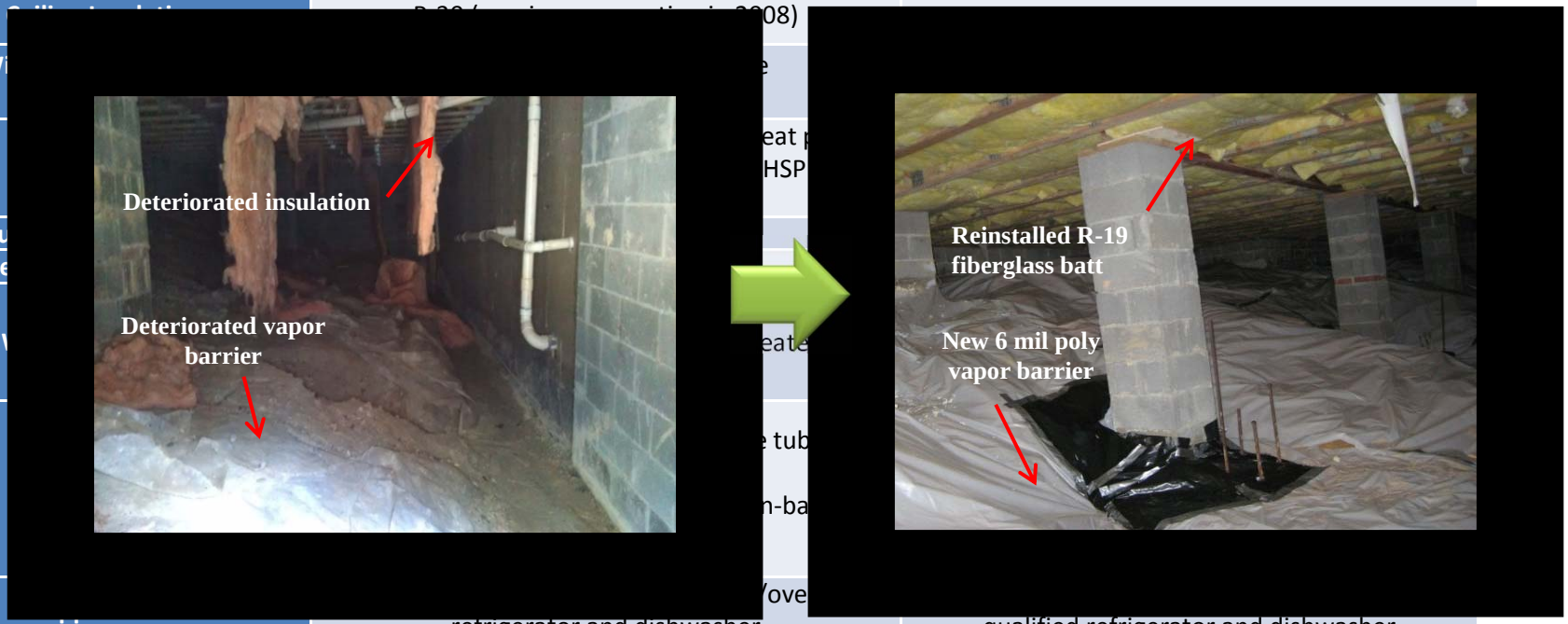

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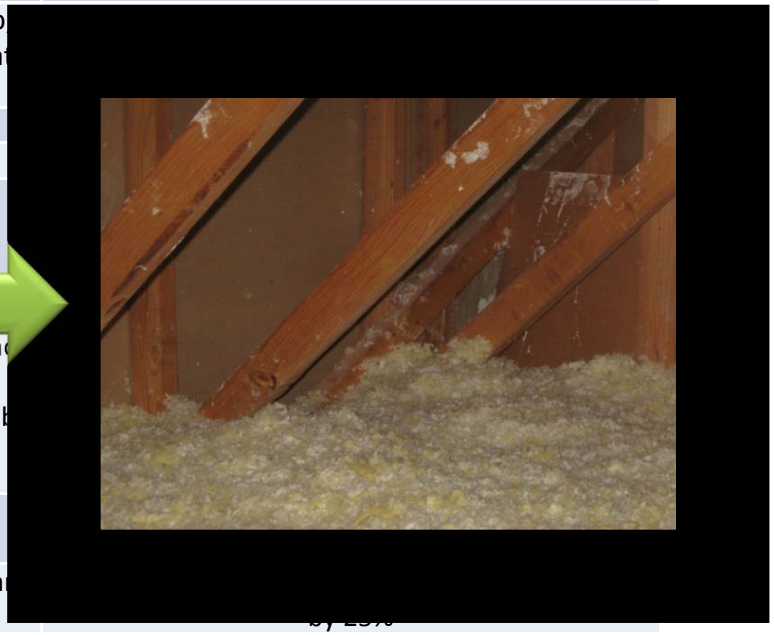

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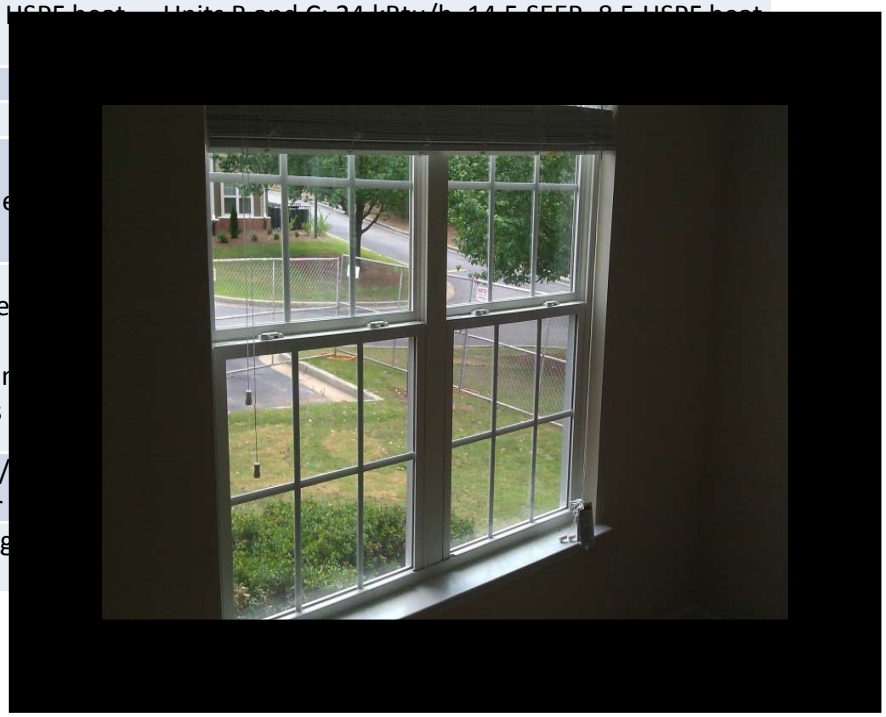

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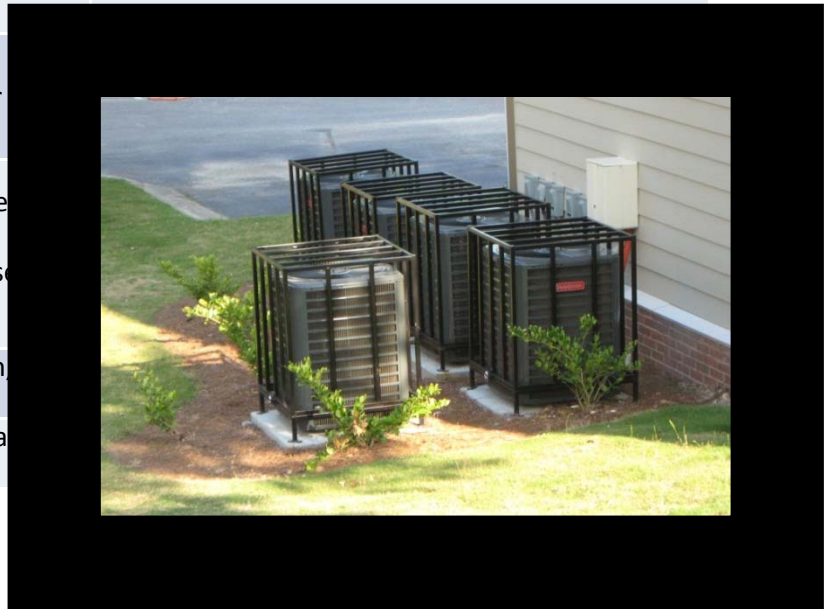

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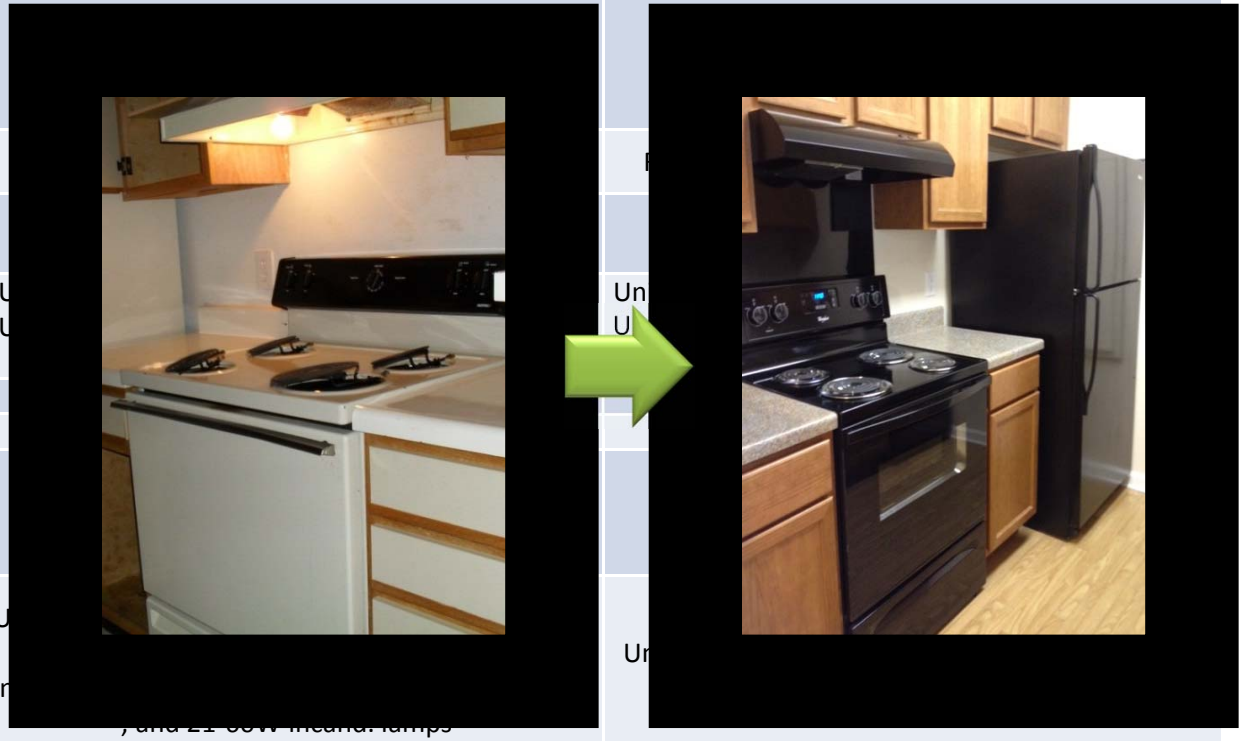

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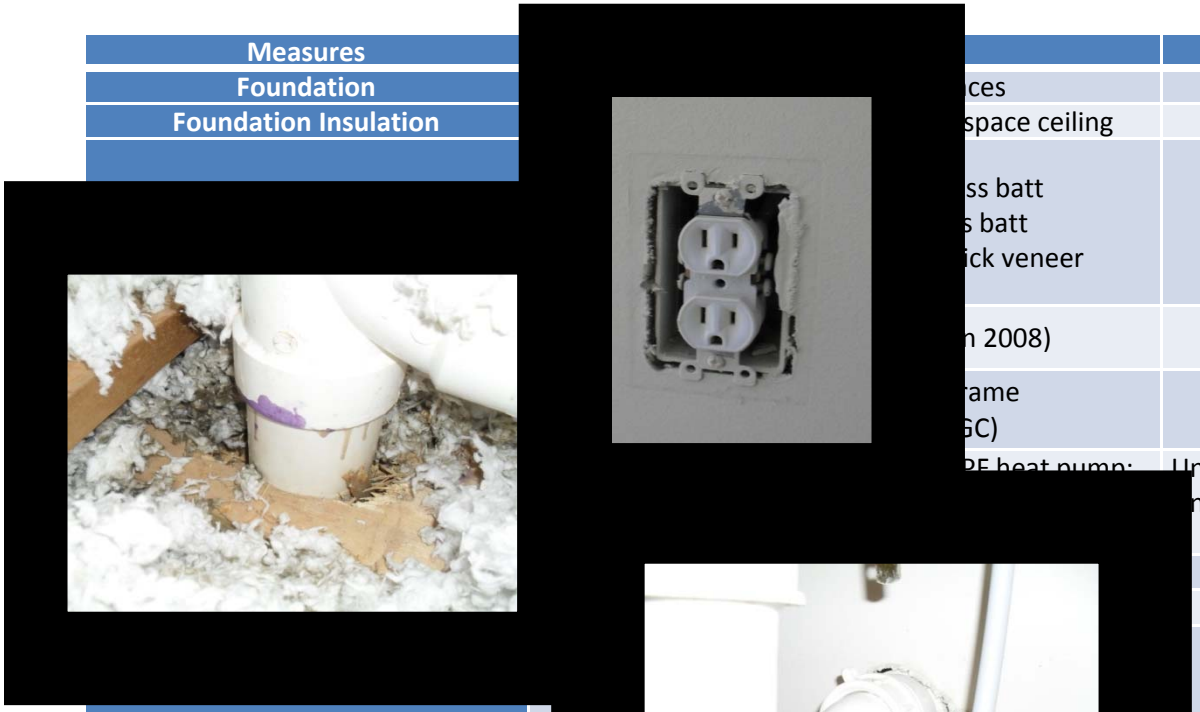
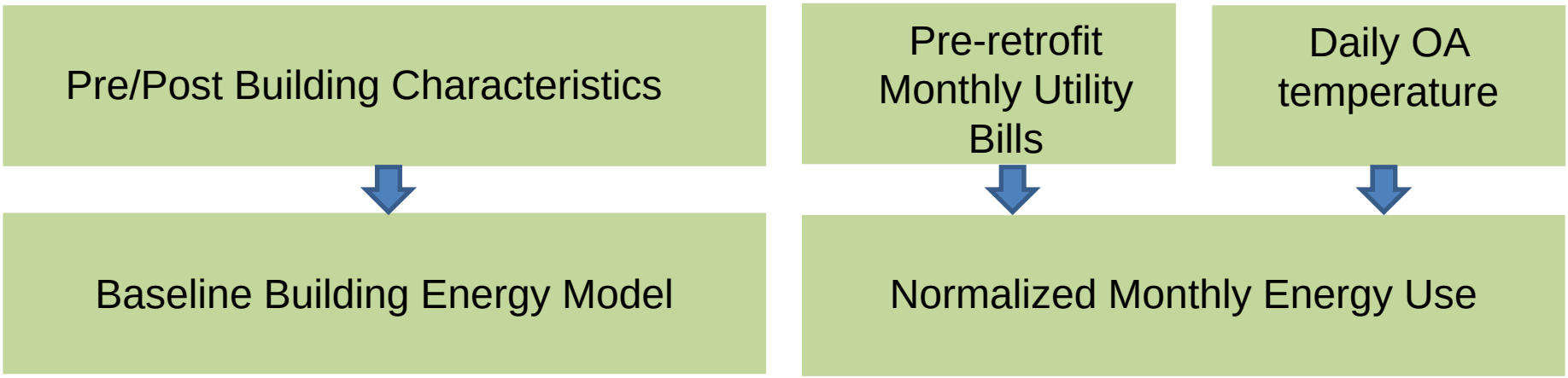


Whole Building Energy Analysis

Pre/Post Building Characteristics

Baseline Building Energy Model

Whole Building Energy Analysis



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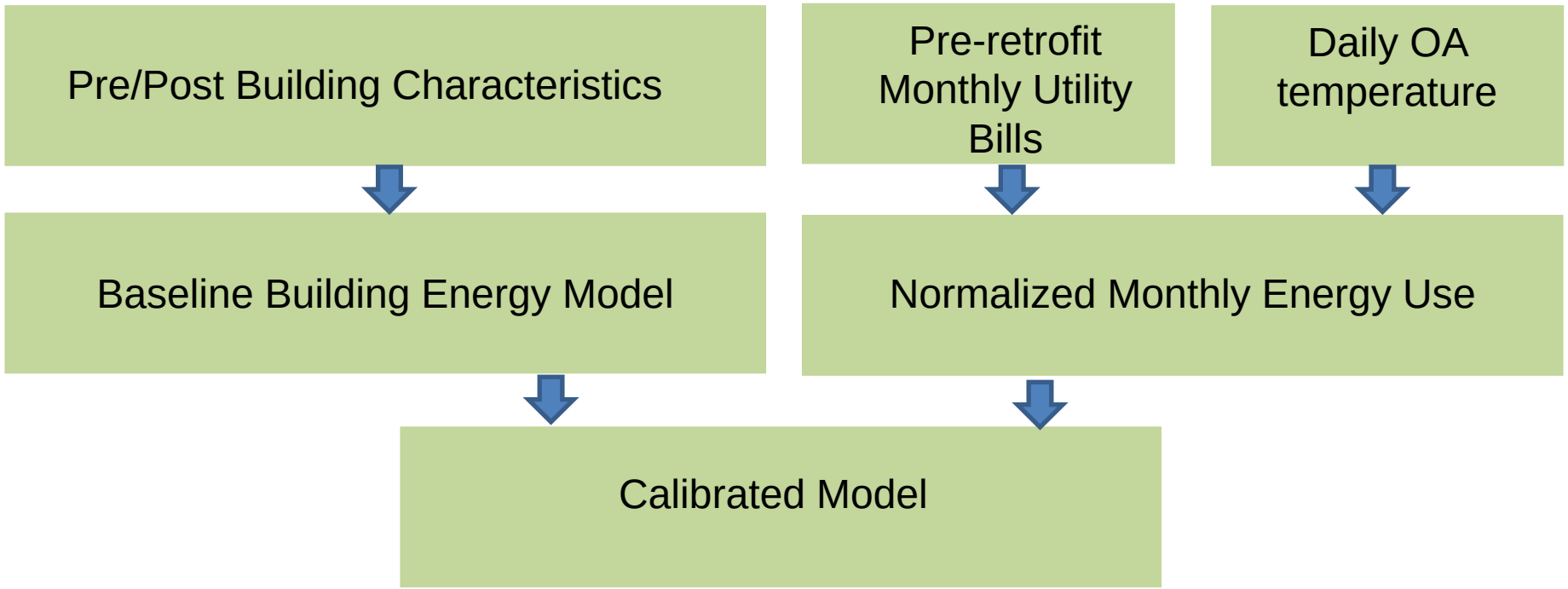

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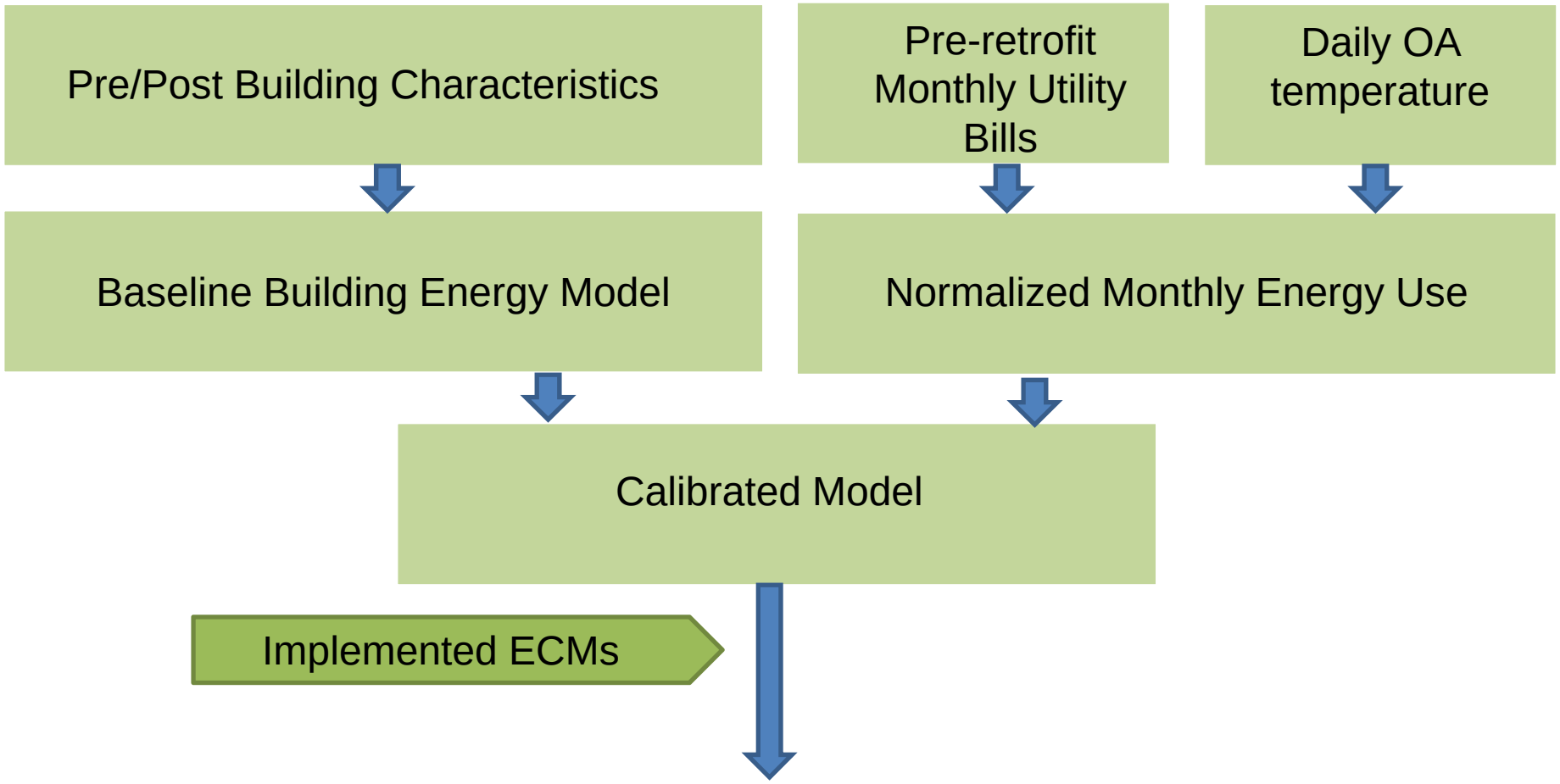

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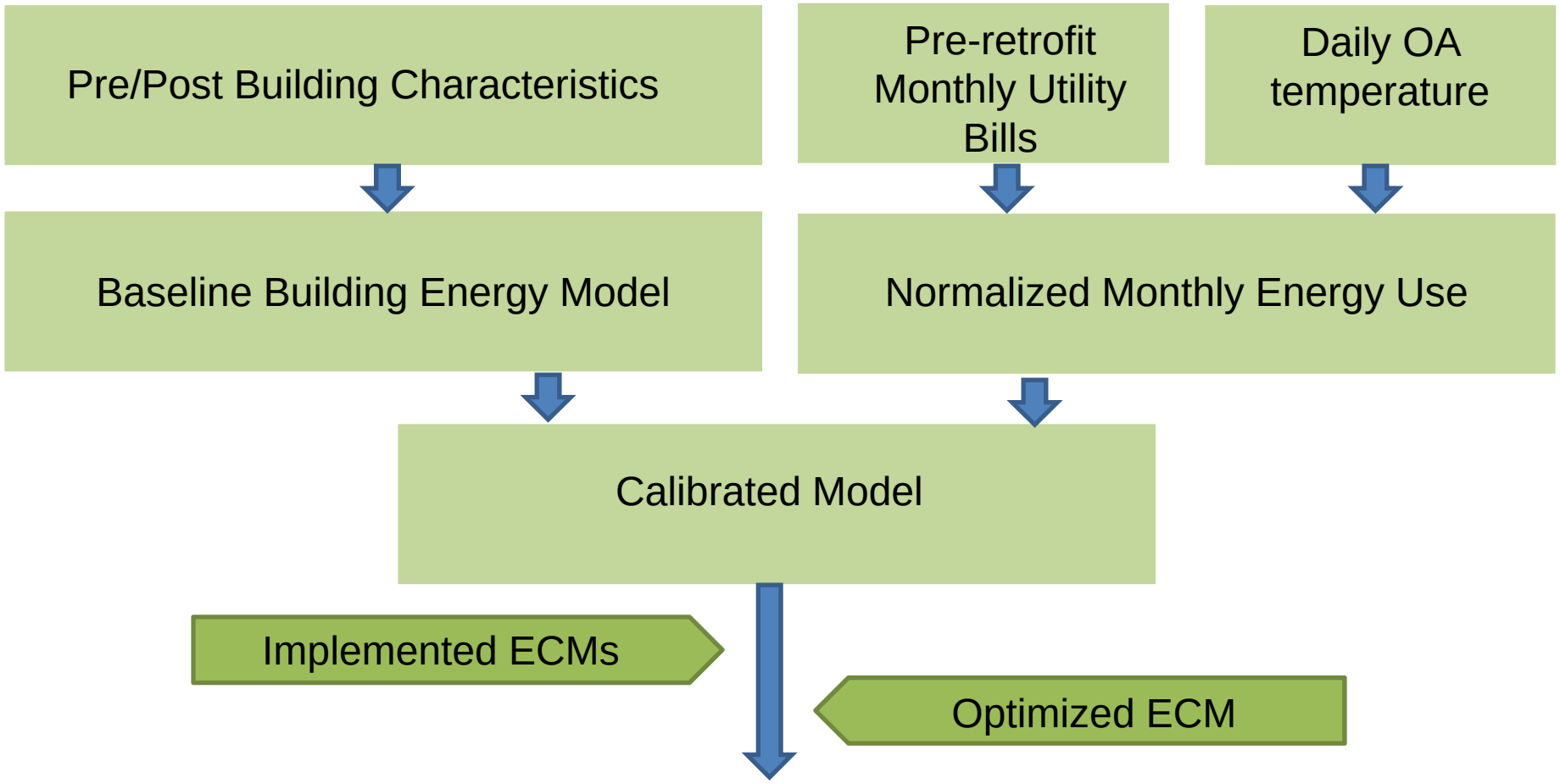

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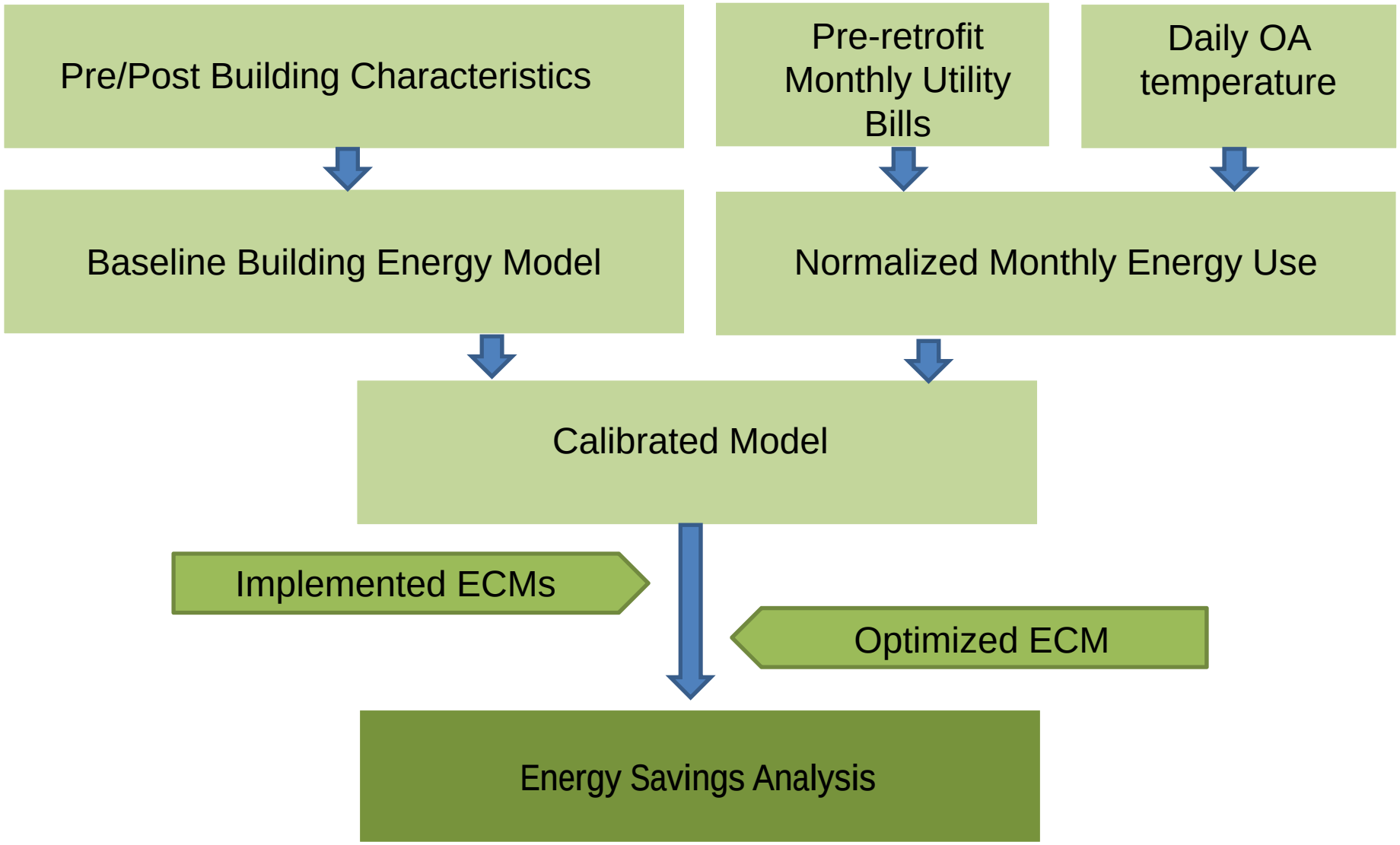
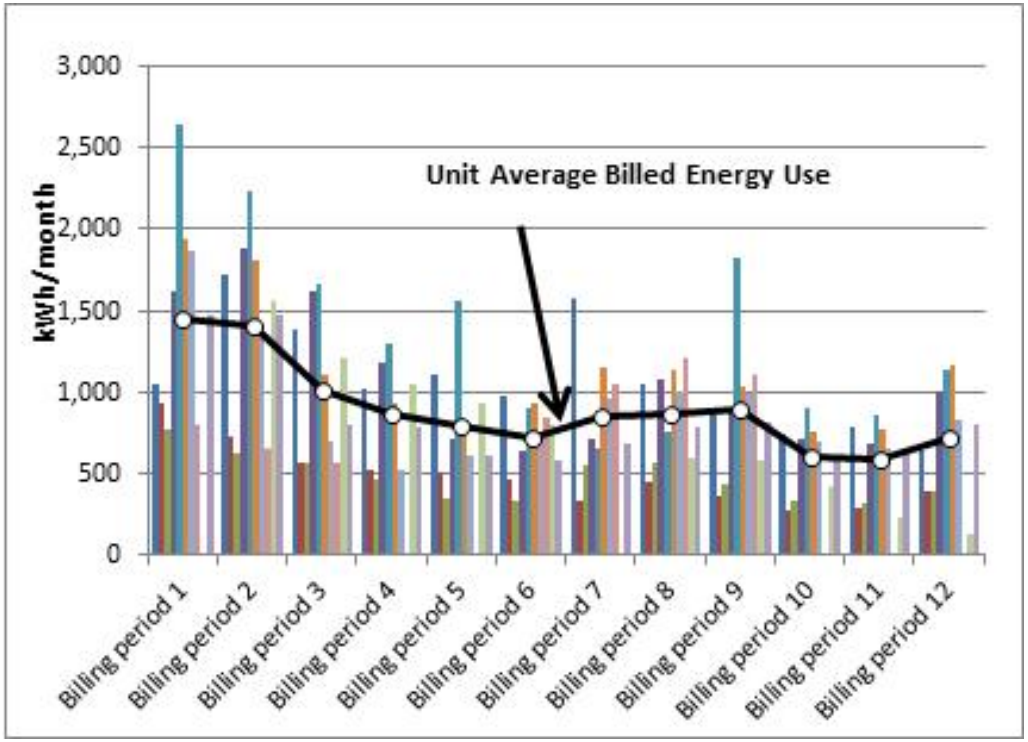


Calibrated Baseline Model

- Above grade wall: R-11 (19% derating from R-13)
- Attic: R-24 (19% derating from R-30)
- Crawlspace (uninsulated – deteriorated insulation)
- 0.42 ACH for units (from whole building blower door test)
- Assuming 2 occupants/Unit
- Lighting: 0.36 W/ft2, Equipment: 0.51 W/ft2 (57% as sensible and 14% as latent heat gains)
- 10.6 SEER, 6.6 HSPF (derated from 12 SEER, 7.5HSPF 3% maintenance factor)

Weather Normalization/Calibration



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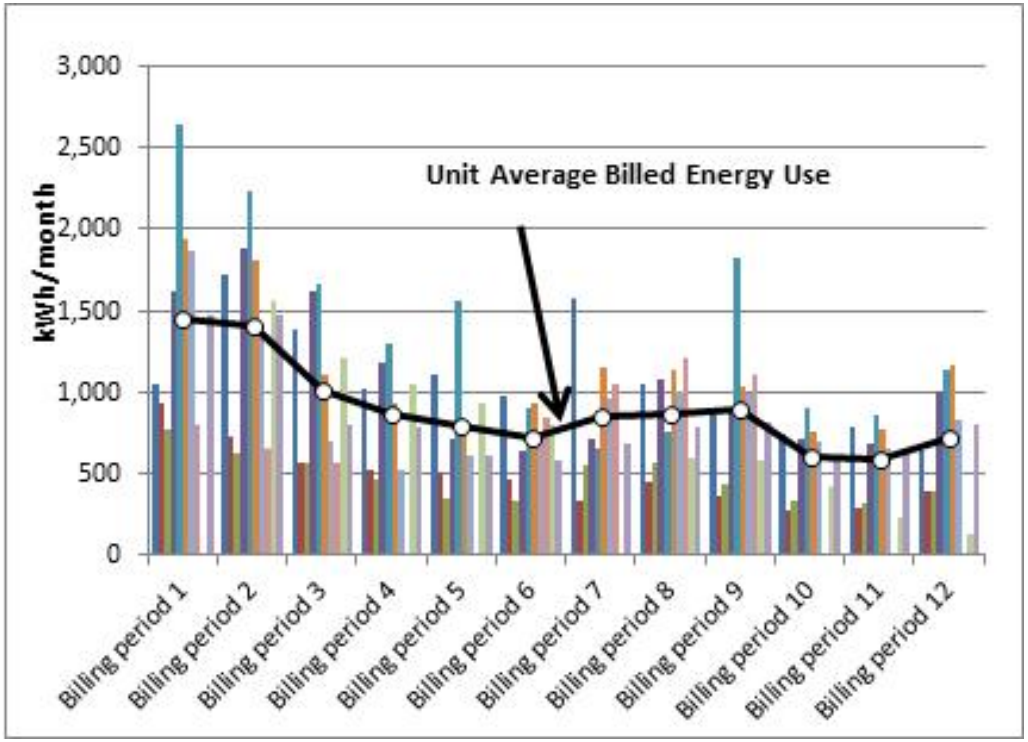

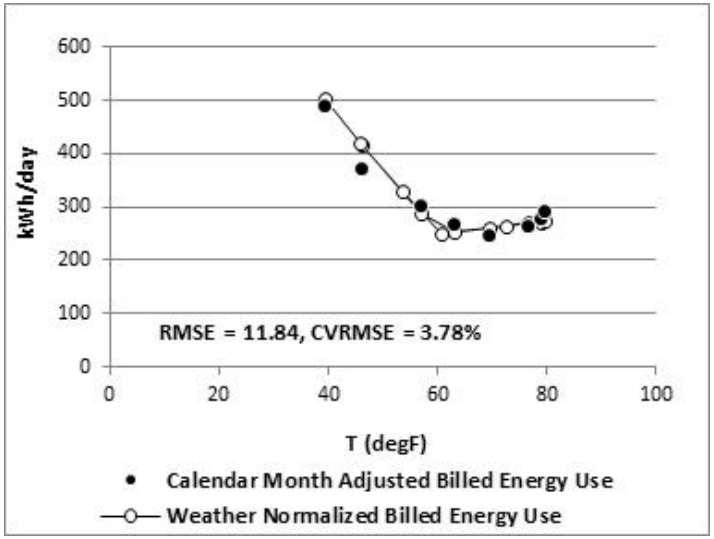

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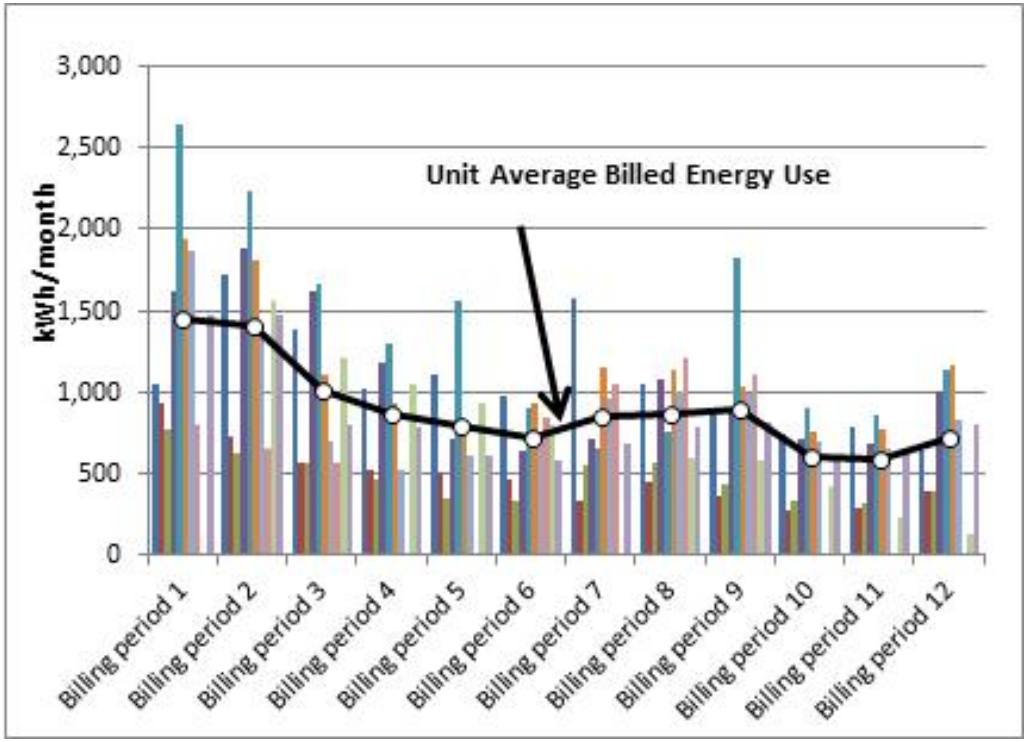

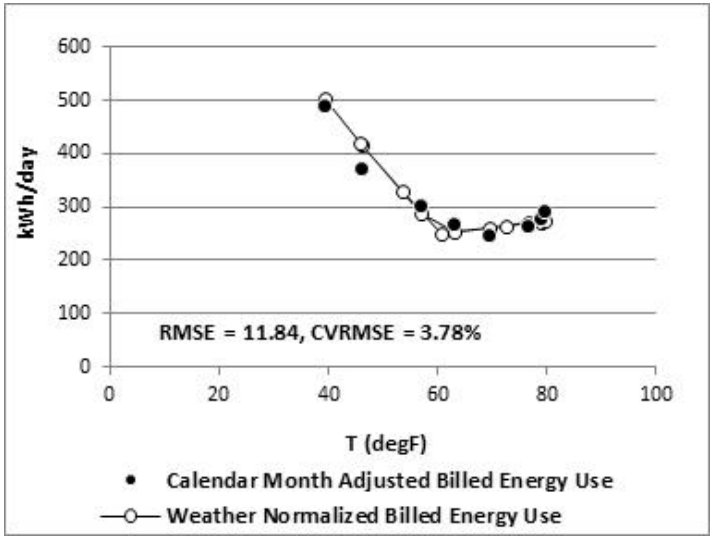

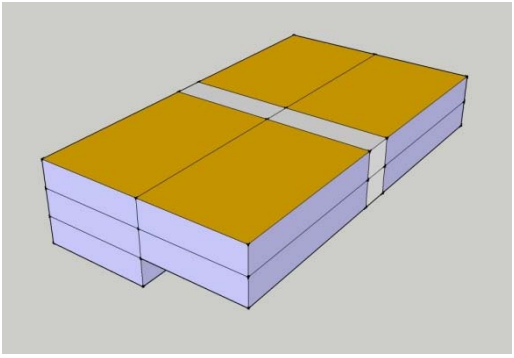

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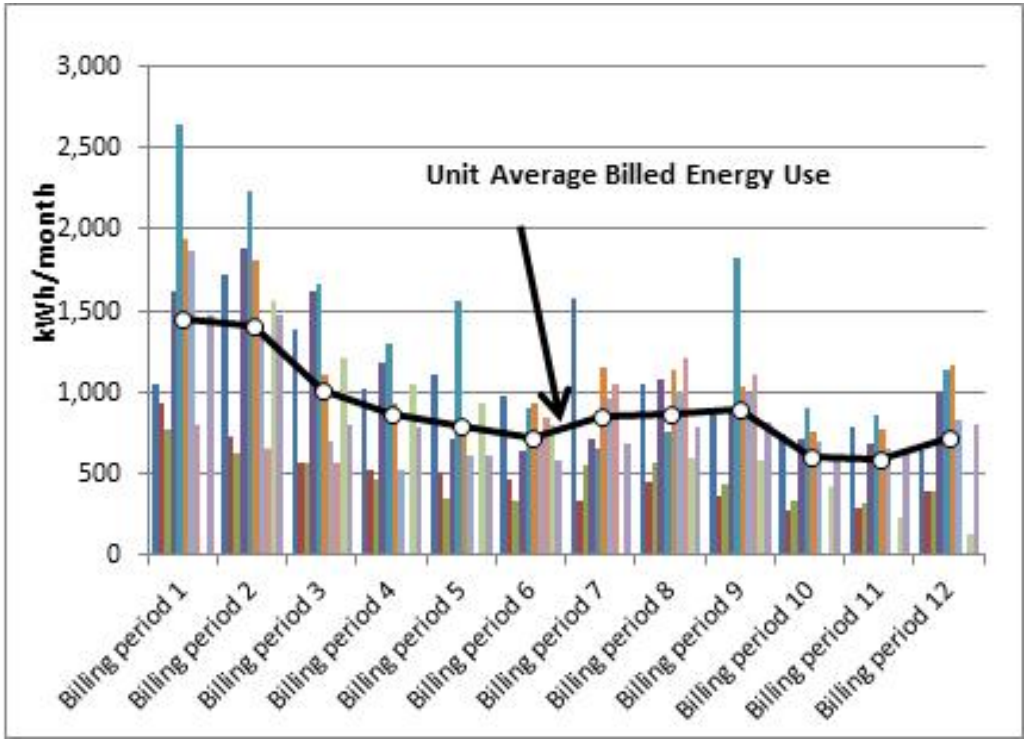

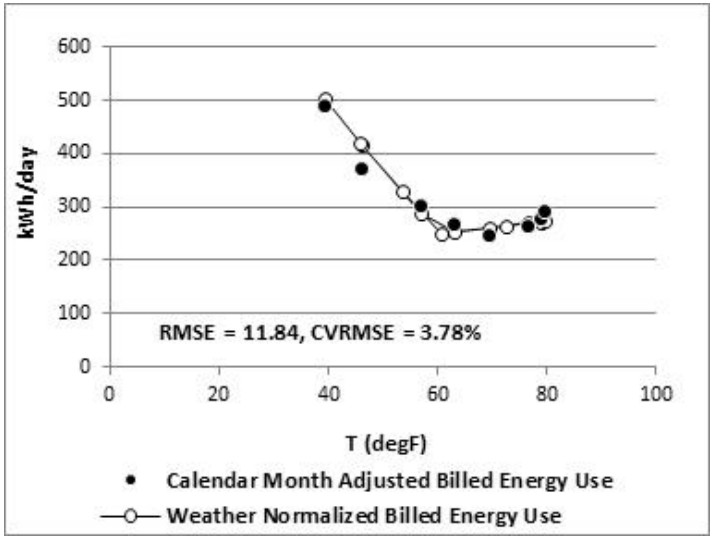

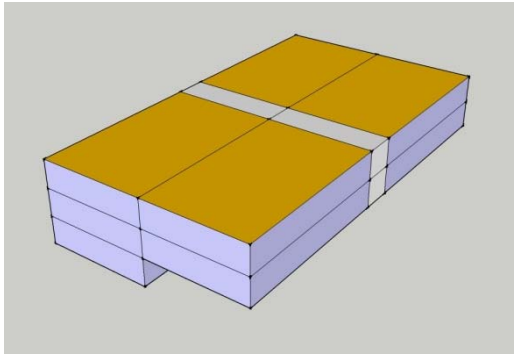

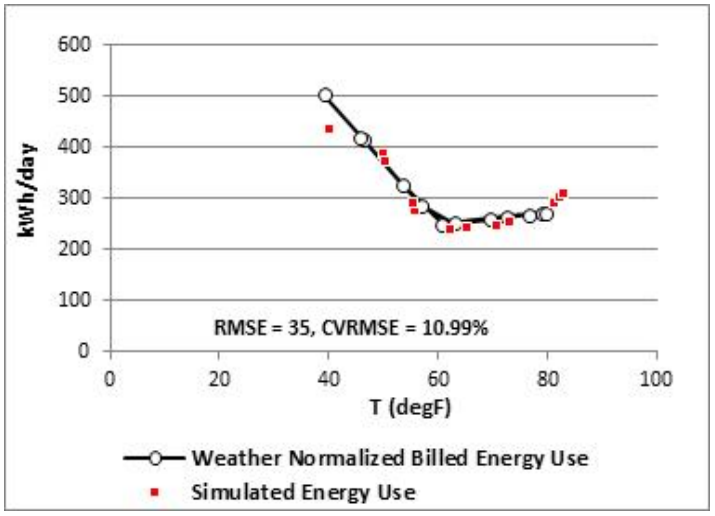

Energy Savings (Implemented EEM Packages)

		Energy use	Savings			Measure cost ($)	Payback (year)
	EEM	(kWh x 1,000)	(kWh x 1,000)	%	$		
	Baseline	110	-	-	-	-	-
1	Insulate crawlspace ceiling with R-19 batt insulation	109	1.9	1.7%	$276	$300	1.1
2	Increase attic insulation from R-30 to R-38	110	1.4	0.1%	$20	$1,205	61.5
3	Replace windows	100	10.4	9.4%	$1,511	$5,850	3.9
4	Replace 12 SEER, 7.5 HSPF heat pump with 14 SEER, 8.3/8.5 HSPF unit	103	7.9	7.2%	$1,149	$5,871	5.1
5	Replace incandescent lamps and fixtures with CFLs	106	4.5	4.1%	$651	$7,851	12.1
6	Replace kitchen appliances	109	1.1	1.0%	$154	$10,544	68.7
7	Replace 0.9 EF water heater with 0.93 EF unit	107	3.0	2.7%	$436	$3,012	6.9
8	Air seal building to reduce air infiltration by 25%	108	2.3	2.1%	$339	$4,758	14.0
Implemented EEMs package (EEM 1 through 8)		**83**	**27.8**	**25.1%**	**$4,025**	**$39,390**	**9.8**

Energy Savings (Implemented EEM Packages)

		Energy use	Savings			Measure cost ($)	Payback (year)
	EEM	(kWh x 1,000)	(kWh x 1,000)	%	$		
	Baseline	110	-	-	-	-	-
1	Insulate crawlspace ceiling with R-19 batt insulation	109	1.9	1.7%	$276	$300	1.1
2	Increase attic insulation from R-30 to R-38	110	1.4	0.1%	$20	$1,205	61.5
3	Replace windows	100	10.4	9.4%	$1,511	$5,850	3.9
4	Replace 12 SEER, 7.5 HSPF heat pump with 14 SEER, 8.3/8.5 HSPF unit	103	7.9	7.2%	$1,149	$5,871	5.1
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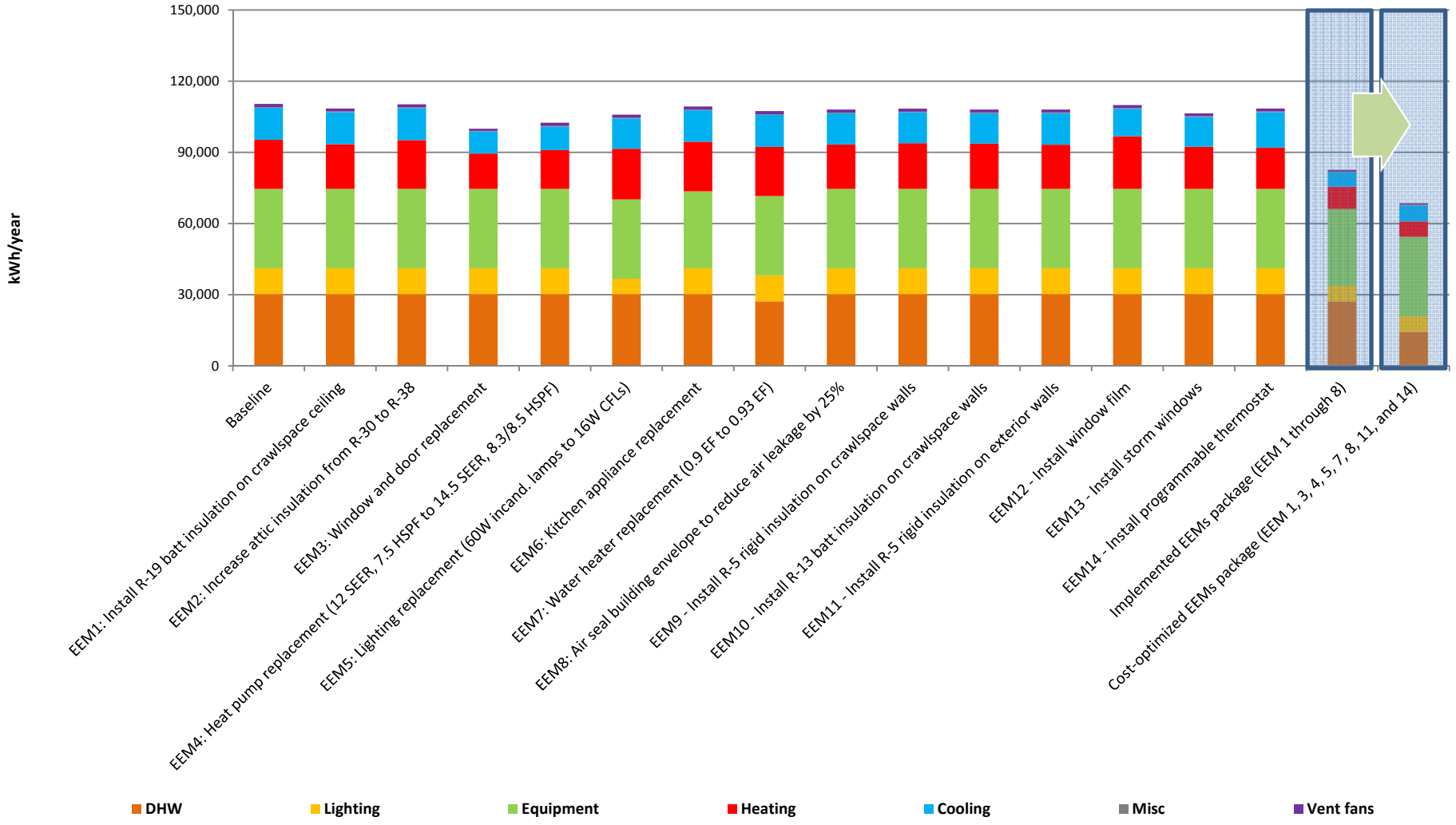
Energy Savings (Implemented EEM Packages)

		Energy use	Savings			Measure cost ($)	Payback (year)
	EEM	(kWh x 1,000)	(kWh x 1,000)	%	$		
	Baseline	110	-	-	-	-	-
1	Insulate crawlspace ceiling with R-19 batt insulation	109	1.9	1.7%	$276	$300	1.1
2	Increase attic insulation from R-30 to R-38	110	1.4	0.1%	$20	$1,205	61.5
3	Replace windows	100	10.4	9.4%	$1,511	$5,850	3.9
4	Replace 12 SEER, 7.5 HSPF heat pump with 14 SEER, 8.3/8.5 HSPF unit	103	7.9	7.2%	$1,149	$5,871	5.1
5	Replace incandescent lamps and fixtures with CFLs	106	4.5	4.1%	$651	$7,851	12.1
6	Replace kitchen appliances	109	1.1	1.0%	$154	$10,544	68.7
7	Replace 0.9 EF water heater with 0.93 EF unit	107	3.0	2.7%	$436	$3,012	6.9
8	Air seal building to reduce air infiltration by 25%	108	2.3	2.1%	$339	$4,758	14.0
Implemented EEMs package (EEM 1 through 8)		**83**	**27.8**	**25.1%**	**$4,025**	**$39,390**	**9.8**

Energy Savings (Optimized EEM Packages)

		Energy use	Savings			Measure cost ($)	Payback (year)
	EEM	(kWh x 1000)	(kWh x 1000)	%	$		
	Baseline	110	-	-	-	-	-
1	Insulate crawlspace ceiling with R-19 batt insulation	109	1.9	1.7%	$276	$300	1.1
3	Replace windows	100	10.4	9.4%	$1,511	$5,850	3.9
4	Replace 12 SEER, 7.5 HSPF heat pump with 14 SEER, 8.3/8.5 HSPF unit	103	7.9	7.2%	$1,149	$5,871	5.1
5	Replace incandescent lamps and fixtures with CFLs	106	4.5	4.1%	$651	$7,851	12.1
7	Replace 0.9 EF water heater with 0.93 EF unit	107	3.0	2.7%	$436	$3,012	6.9
8	Air seal building to reduce air infiltration by 25%	108	2.3	2.1%	$339	$4,758	14.0
11	Install R-5 rigid insulation on exterior walls	108	2.3	2.1%	$338	$3,371	10.0
14	Install programmable thermostat	109	1.9	1.7%	$275	$1,700	6.2

Annual Energy Use for all EEMs



Summary

- ORNL's new MF Audit Tool (MulTEA)
  - National Web Meeting: Desired modeling & analysis capabilities for MF audit tool
  - MulTEA: Flexible, multi zone, multi HVAC systems with ventilation and infiltration modeling
  - Version 1 (Beta) is available
- Case Study: Maplewood Apartment
  - 110 units, Union City, GA.
  - Built in 1993
  - 20 to 30% energy saving target
  - Whole building approach

Summary

- Case Study: Maplewood Apartment Complex
  - Energy savings analysis using MulTEA
  - Implemented EEM packages
    - Will save 27.8 MWh per year (25% savings)
    - 9.8 years of simple payback
  - Optimized EEM packages
    - Will save 41.8 MWh per year (38% savings)
    - 5.4 years of simple payback

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Installed cost of retrofit measures (1)

Retrofit Measures	ECMs	Average Cost per Unit ($)	% of Total
Energy Retrofit Measures			
Crawlspace insulation	R-19 fiberglass batt under crawlspace ceiling	30	0.4%
Attic insulation	Added 4” of blown-in fiberglass over existing insulation to achieve R-38	120	1.4%
Window replacement	Double-pane, low-e, vinyl frame (0.35 U-value, 0.27 SHGC)	585	6.9%
HVAC system replacement	Unit A: 18 kBtu/h, 14.5 SEER, 8.3 HSPF heat pump; Units B and C: 24 kBtu/h, 14.5 SEER, 8.5 HSPF heat pump	587	6.9%
Domestic water heater replacement	Electric 40-gal, 0.93 EF	301	3.5%
Lighting replacement	Unit A: Two T12 lamps and 18-13W CFLs; Units B and C: Two T12 lamps and 21-13W CFLs	785	9.2%
Appliance replacement	Standard cooking range/oven, Energy Star qualified refrigerator and dishwasher	1,054	12.4%
Air sealing	Air sealing and caulking that reduced air leakage by 25%	484	5.6%
Sub Total		**4,419**	**51.9%**

Installed cost of retrofit measures (2)

Retrofit Measures	ECMs	Average Cost per Unit ($)	% of Total
Other Retrofit Measures			
Wall siding replacement	Fiber cement siding	2,780	32.6%
Roofing replacement	Asphalt shingles	1,320	15.5%
Duct sealing	Mastic applied to the seams and joints of ductwork in the air handler	480	5.6%
Subtotal		**4,100**	**48.1%**
Total		**8,519**	**100.0%**