MultiFamily Deeper Energy Retrofits Successes and Challenges

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Better Buildings by Design conference
February 6, 2014

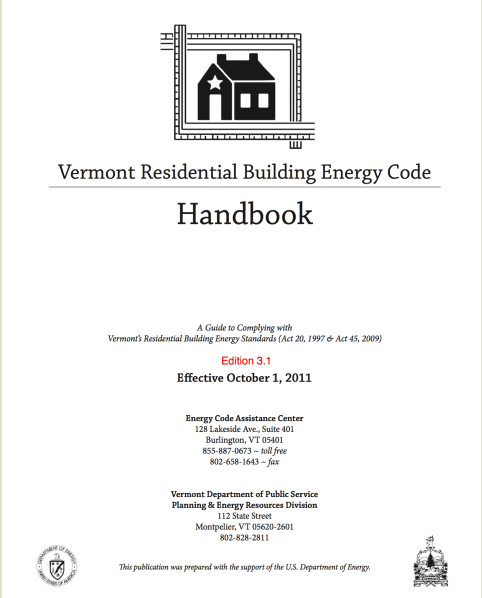
185 buildings / 1516 apartment units
43% savings / $3.44 savings per $1.00 costs

Goals

Improve sustainability of affordable multifamily housing

Make 30-year energy retrofit investments

"Deep energy retrofits"



Vermont Residential Building Energy Code

Handbook

A Guide to Complying with Vermont's Residential Building Energy Standards (Act 20, 1997 & Act 45, 2009)

Edition 3.1

Effective October 1, 2011

Energy Code Assistance Center
128 Lakeside Ave., Suite 401
Burlington, VT 05401
855-887-0673 – *toll free*
802-658-1643 – *fax*

Vermont Department of Public Service
Planning & Energy Resources Division
112 State Street
Montpelier, VT 05620-2601
802-828-2811

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How far to go?

VT RBES 2011

Table 4-1

Performance Requirements

Single-Family and Multi-Family Homes ~ *Fast-Track Method*

Component	*Package 1*	*Package 2*	*Package 3*	*Package 4*
1. Ceiling R-Value	R-49	R-38	R-38 or R-30+10	R-28 cont.
2. Above-Grade Wall R-value	R-20 or R-13+5	R-20+5 or R-13+7.5	R-20 or R-13+5	R-21 cont.
3. Floor R-value	R-30	R-30	R-30	R-30
4. Basement/Crawl Space Wall R-value	R-15/20	R-15/20	R-20 cont.	R-15/20
5. Slab Edge R-value	R-15, 4ft.	R-15, 4ft.	R-15, 4ft	R-15, 4 ft
6. Heated Slab R-value (Edge and Under)	R-15	R-15	R-15	R-15
7. Window and Door U-value	0.32	0.32	0.30	0.32
8. Skylight U-value	0.55	0.55	0.55	0.55

SECTION 4-R2: VERMONT MULTIFAMIL ENERGY DESIGN STANDARDS

VHCB & VHFA Multifamily Energy Design Standards-March 2012, Ver. 1.0

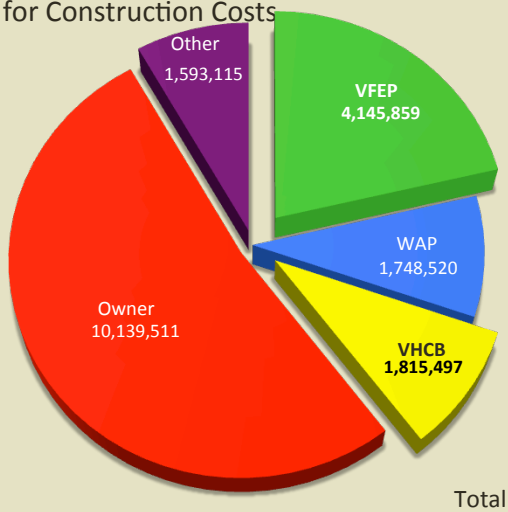
	Units	Ceiling / Attic R [1]	Wall R [2]	Window [3] R-value / U-Value	Foundation R-Value, Continuous	Slab Edge R	Air Sealing: MASP [5]	Mechanical [6]	Advanced Mechanical [8] Solar [7]	Biomass [8]	ASHP
Rehabilitation	All	60	25	R 3.3 / U.30	15	15	<3ACH 50	MMDP	Required 50% Load	*Not Required*	*Not Required*
New Construction	≥5	60	25	R 3.3 / U.30	15	15	<2ACH 50	MMDP	Required 50% Load	*Not Required*	*Not Required*
New Construction	≤4	60	25	R5/U.20 [4]	15	15	<2 ACH50	MMDP	Required 50% Load	*Not Required*	*Not Required*
Tier II Level	All	60	30	R 5 / U.20	15	15	<1ACH 50	HRV required	75%+ of load	75%+ of load	COP >3

http://www.vhfa.org/documents/developers/gbs.pdf

Vermont Fuel Efficiency Partnership

Sources for Construction Costs

Nov 2009 – Dec 2012



Total Costs: $19,442,502

Post-Retrofit Survey of Actual Usage

- Compare Actual Savings to Estimated
- What are Biggest Hits?
- What are Biggest Factors in Modeling?
- Refine Assumptions for Modeling & Estimating Savings

Attrition

	BUILDINGS	ANALYSIS TOOLS
ALL	184	**128**
Pre Sept 2012	164	**117**
Obtained Post-Data	90	**69**
Bad Data	(39)	**(29)**
Study Sample	51	**40**
Great Data	3	**3**
Good Data	31	**19**
OK Data	19	**19**
Still in Process	18	**13**

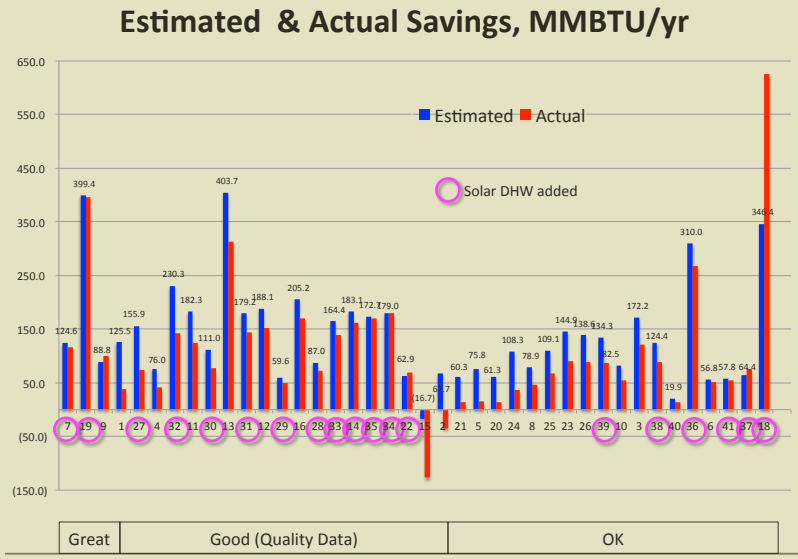
Why Projects Drop from Study

- In Service by Sept 2012
- Holes in data, pre- or post-
- Vacancies
- Infrequent fills
- Not actually fills
- Multiple fuels not accounted for
- Switch from Electric pre-

Calculating Actual Savings

- Determine usage relative to temperature during pre- period
- Use that relationship to calculate *what usage would have been,* without retrofit, using post-period temperature
- Subtract actual usage in post- period from calculated post without retrofit

Compare Actual Savings to Estimated



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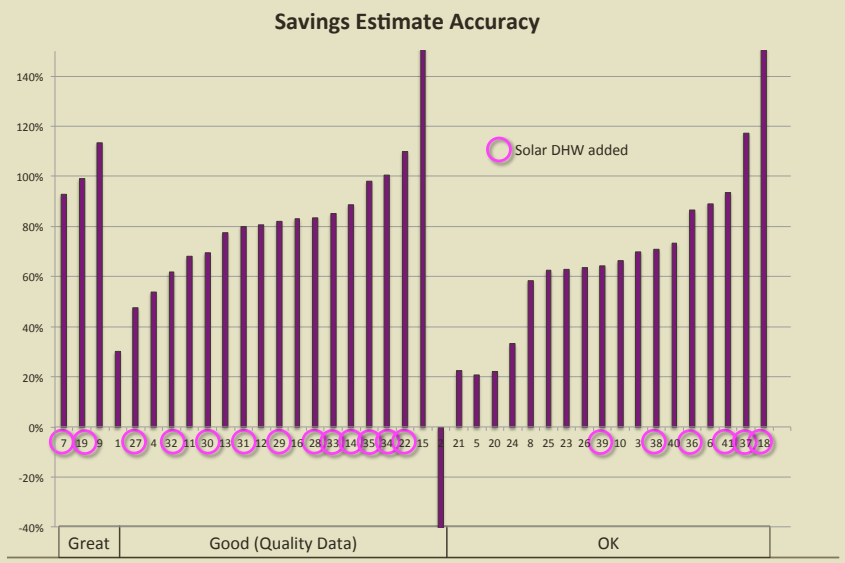

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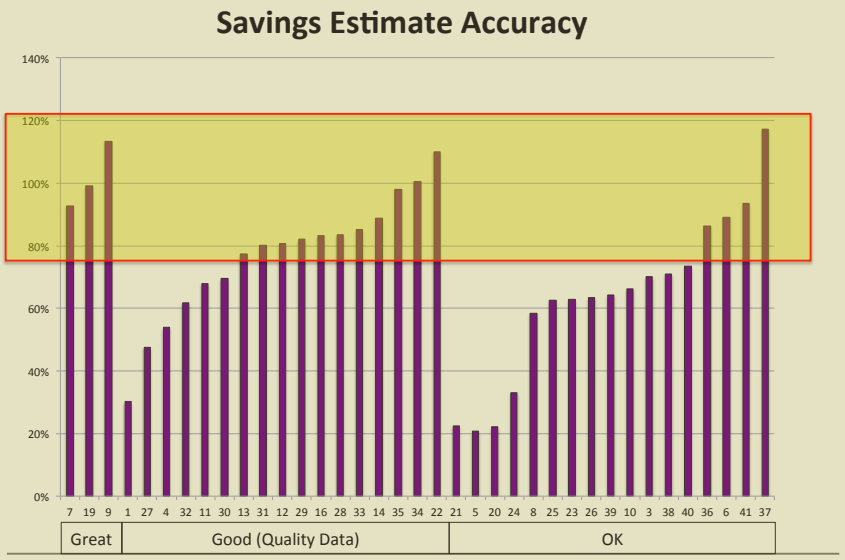

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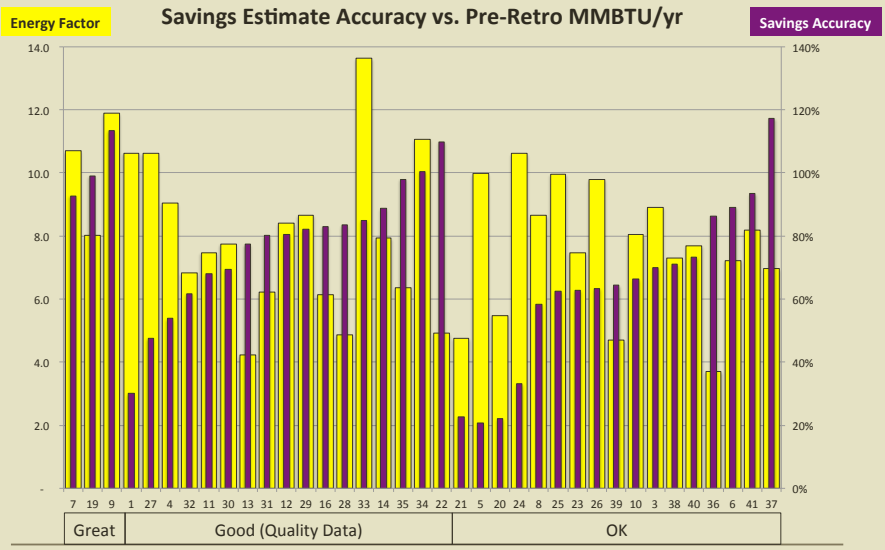

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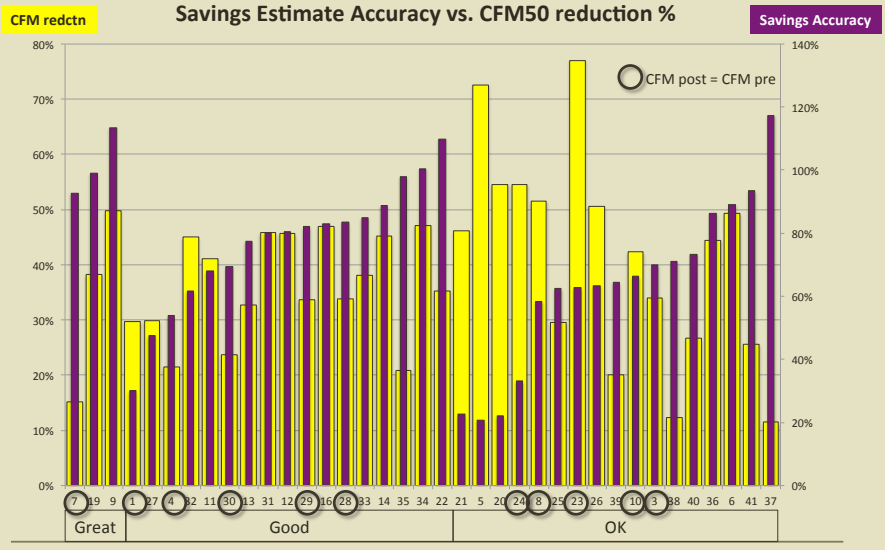
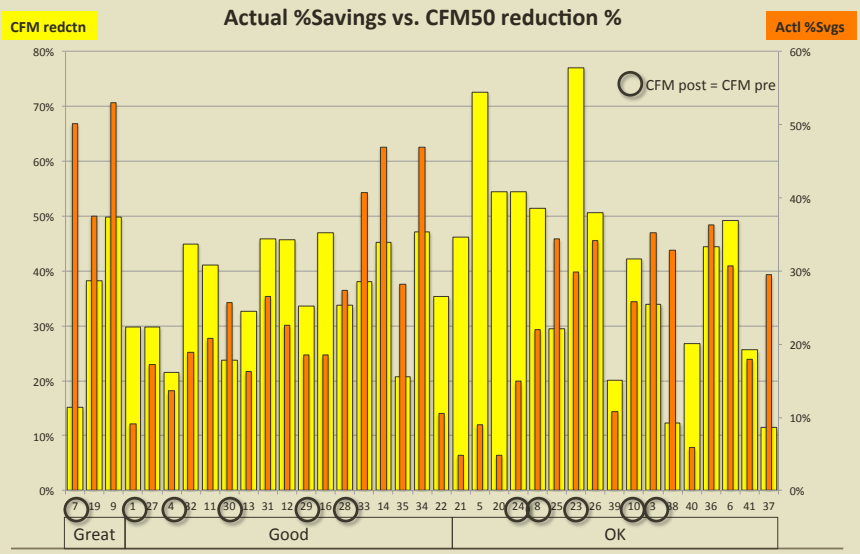


Biggest hits



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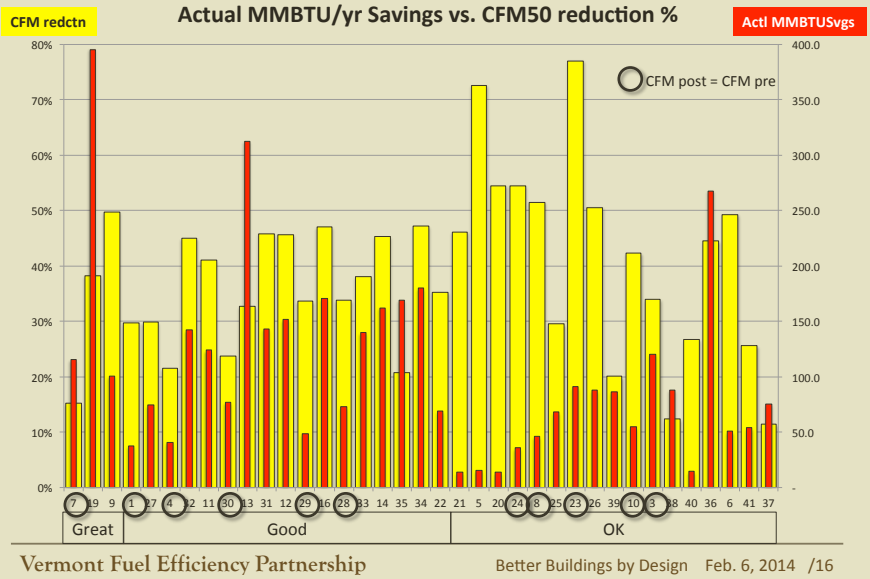

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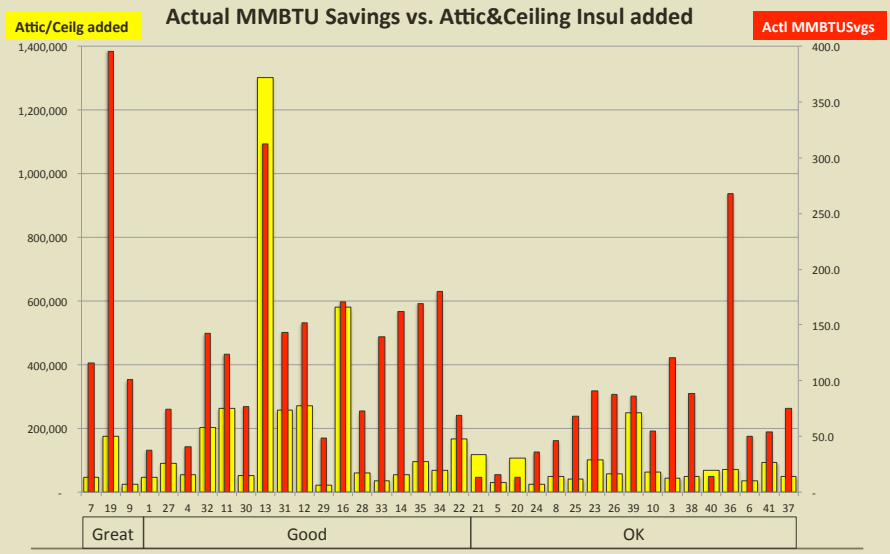

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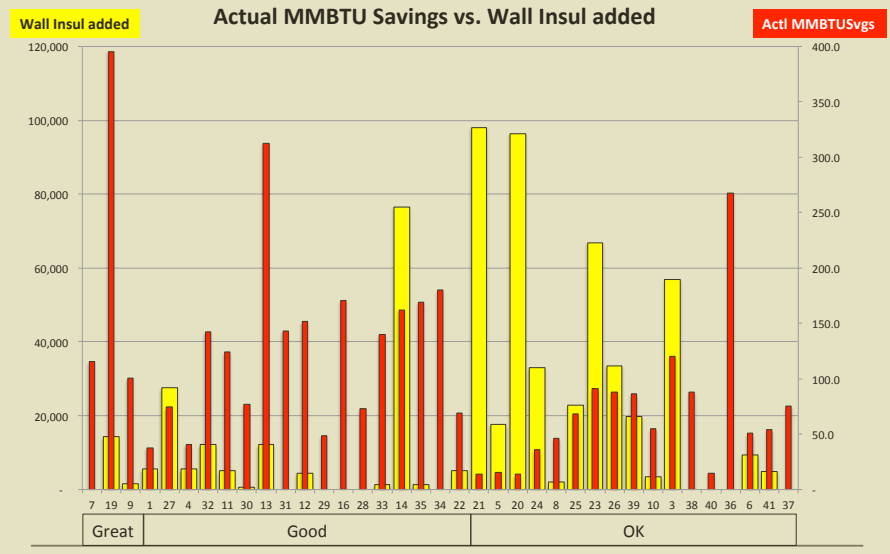

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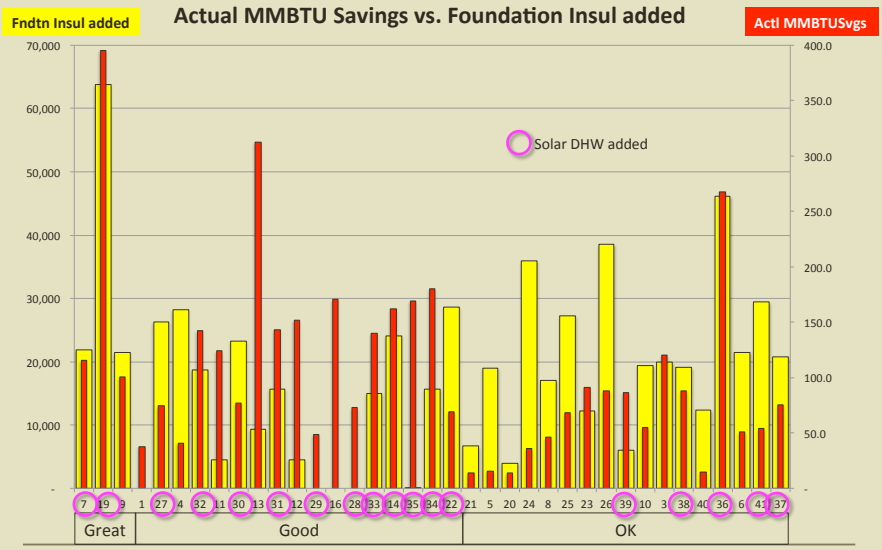
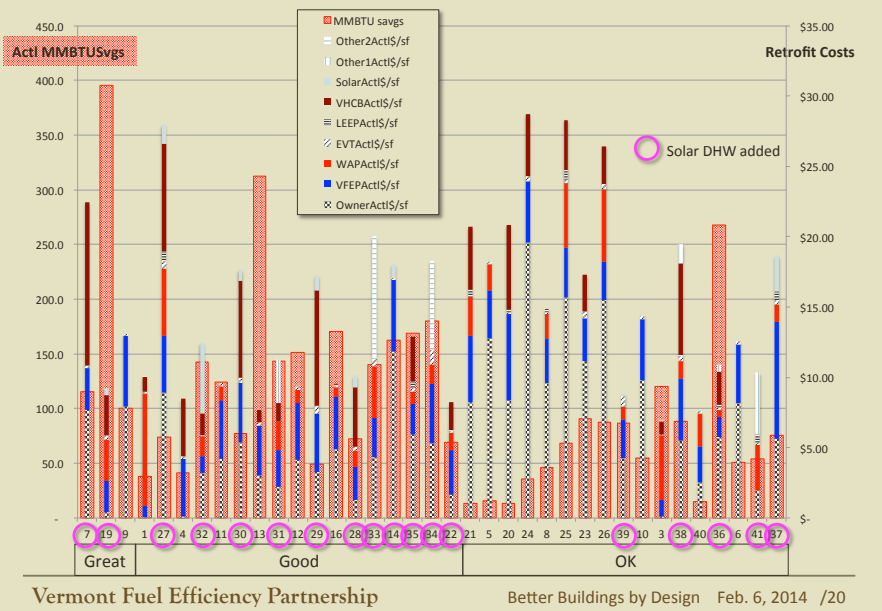


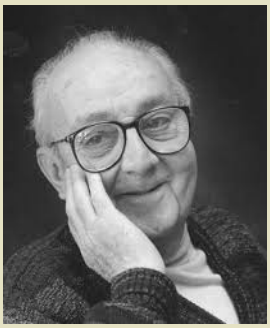
Vermont Fuel Efficiency Partnership Better Buildings by Design Feb. 6, 2014 /19

Biggest hits



Vermont Fuel Efficiency Partnership Better Buildings by Design Feb. 6, 2014 /20

Heat-Loss Modeling Tool



"Essentially, all models are wrong, but some are useful."

George E. P. Box (1919 – 2013)
Statistician, Fellow of the Royal Society

Factors affecting Modeling & Savings Estimates

A Useful Heat-Loss Modeling Tool

- Assists determination of best workscope
- Records bases for decisions
- Traps obvious errors
- Displays understandable results
- Offers reliable results when used with **accurate data** and **consistent assumptions**

Factors affecting Modeling & Savings Estimates

VFEP Heat-Loss Modeling Tool

- $Q = U * A * \Delta T$
- Six sides of enclosure
- Blower-Door measurement
- Internal heat gain from Electric plug load
- Adjust Modeled Usage to Historic usage data, discounted for AFUE & distribution efficiency
- Adjusted Model used to estimate savings from added R-value and CFM50 reduction

Factors affecting Modeling & Savings Estimates

Factors Affecting Modeling

- Pre-Retro Usage History
- Space/DHW disagg
- CFM50 test number
- Divide-by Factor: Building Height, Sheltering
- Accounting for all Surface Areas
- In-service R-value of assemblies, pre- & post-
- Ventilation: Actual CFM, and runtimes

Factors affecting Modeling & Savings Estimates

Squirrel Factors

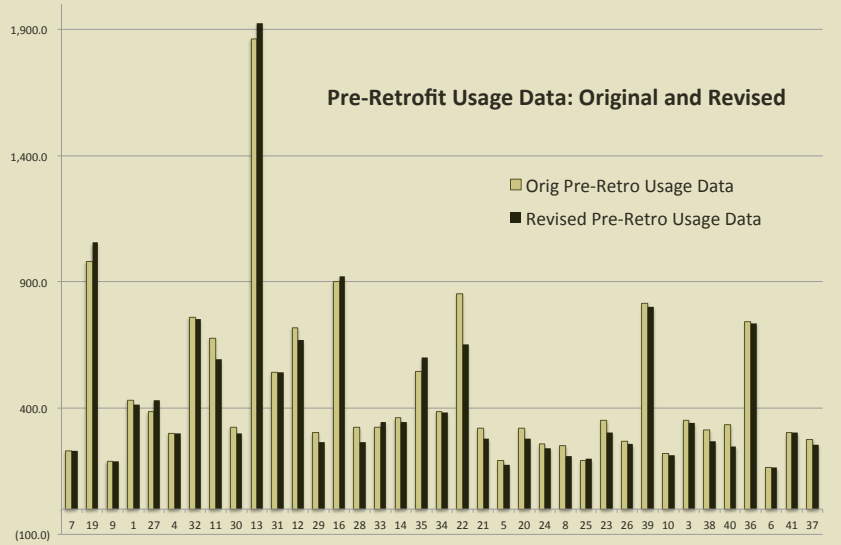
- Bulk fuel: Infrequent deliveries; not fills
- Disaggregation between space & DHW
- AFUE and Distribution efficiency
- Missing Portable space heaters?
- Divide-by Factor: Converting CFM50 into BTUs
- Future savings based on past climate conditions

Factors affecting Modeling & Savings Estimates

Squirrel Factors

- In-service R-value of assemblies, pre- & post-
- Post-Retrofit CFM50
- Tempering of Below-Grade Surfaces
- Ventilation: Actual CFM, and runtimes

Refining Modeling & Savings Estimates



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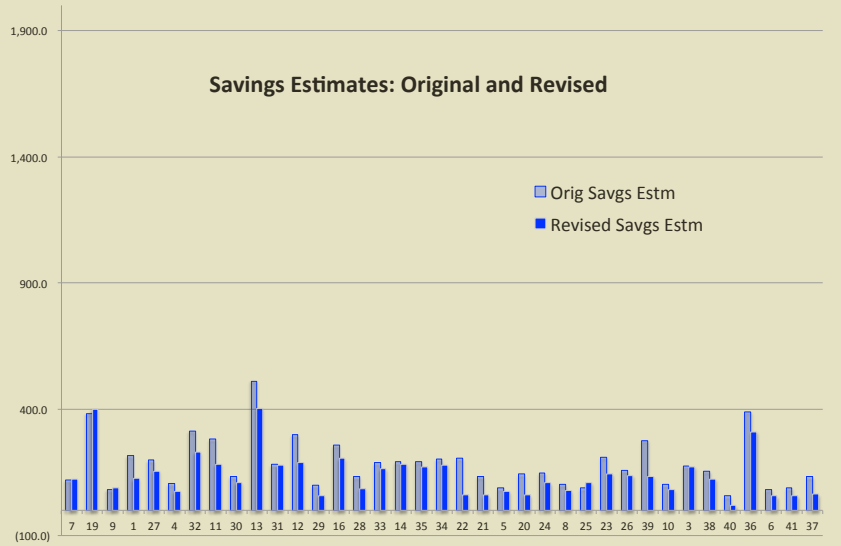
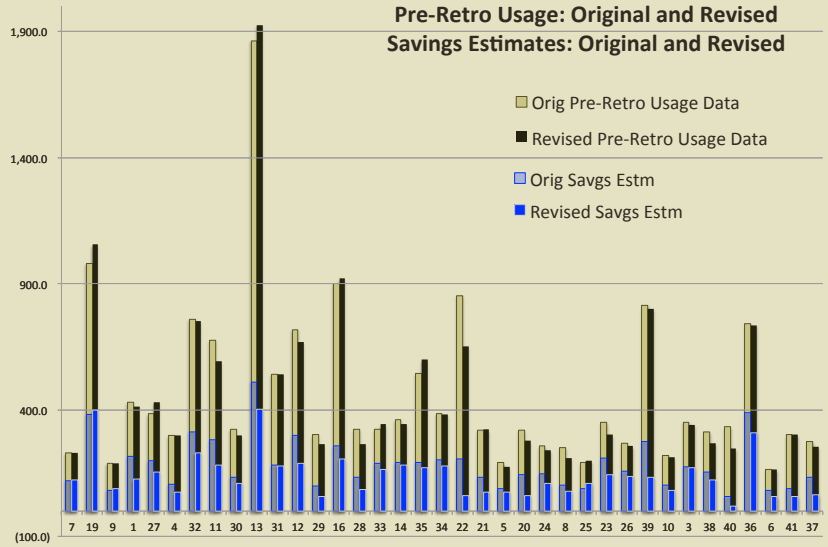
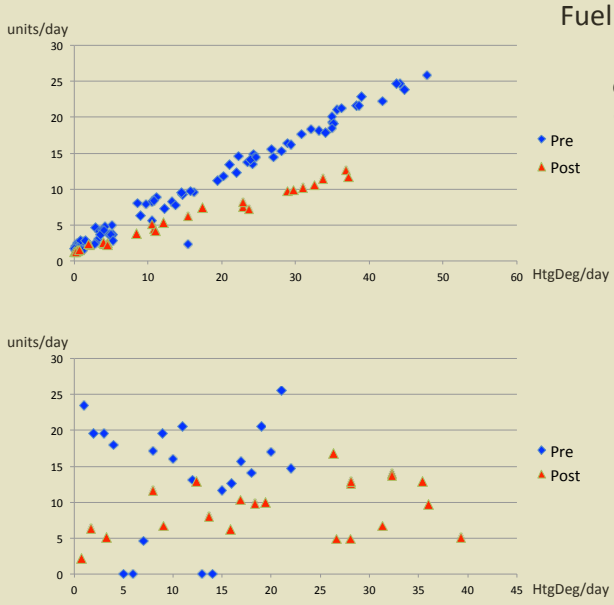


Refining Modeling & Savings Estimates



Fuel Usage Data



Refining Modeling & Savings Estimates

Over-Ventilation!

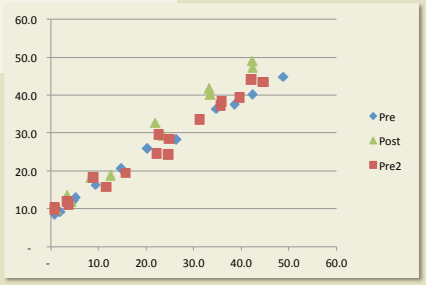
(40 units)

Case #15 (dropped)	pre-retro use	estm savgs
Original audit no ventilation	837.5	279.6
Original data, new tool add exhaust fans 30/80	837.5	189.3
Revised data, new tool more complete fuel data adj AFUE & Distrib% adj R-vals & tempered%	940.2	99.1
Adj for overventilation fans set to 50/80, 2h/da	940.2	(16.7)
Measured post- (normlzd)		(126.7)
Model: 50/80, 16h/da		(125.6)

Major measures installed
Attic airsealing & insul to R60
Foundation & Crawl Flr SPF
Repl bath fans w/ continuous
Repl boiler (81% -> 91%)

Pre-weatherization			Post-weatherization		
Intercept	Slope	R^2	Intercept	Slope	R^2
8.7674	0.7774	0.9860	9.2705	0.9334	0.9902

At Pre- Base Temp	
Intercept Reduction	-5.7%
Slope Reduction	-20.1%



Refining Modeling & Savings Estimates

Over-Ventilation?

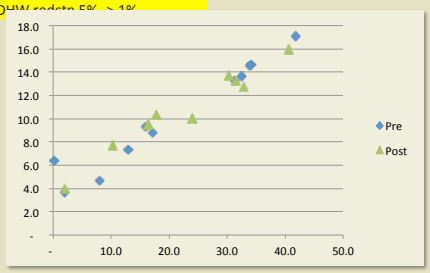
(8 units)

Case #20	pre-retro use	estm savgs
Original audit no ventilation	320.7	143.5
Original data, new tool add exhaust fans 30/80	322.5	81.0
Revised data, new tool more complete fuel data adj AFUE adj R-vals & tempered%	279.6	58.4
Measured post- (normlzd)		13.6
Model: 50/80, 8h/da		13.7

Major measures installed
Add 4" Iso continuous wall insul
Repl windows (u=0.3)
Attic airsealing & insul to R60
Add 1.5" XPS slab-edge insul
Repl fans 30continuous/80boost

Pre-weatherization			Post-weatherization		
Intercept	Slope	R^2	Intercept	Slope	R^2
3.8758	0.3073	0.9485	4.2719	0.2860	0.9525

At Pre- Base Temp	
Intercept Reduction	-10.2%
Slope Reduction	7.0%



Refining Modeling & Savings Estimates

Occupancy variation

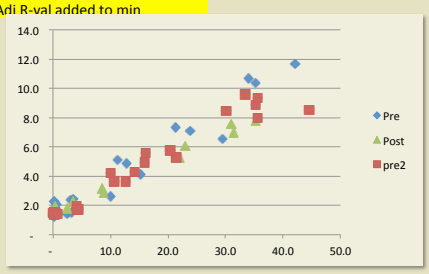
(2 units)

Case #5	pre-retro use	estm savgs
Original audit no ventilation	191.5	87.6
Original data, new tool add exhaust fans 30/80	191.5	94.1
Revised data, new tool more complete fuel data adj AFUE & Distrib% adj R-vals & tempered%	175.6	75.8
Measured post- (normlzd)		15.8
Model: 80 CFM, 24h/da		64.5

Major measures installed
Attic airsealing & insul to R60
Spot wall DP (2x4)
Rim bag & blow
Foundation SPF
Replace windows
Repl fans 30continuous/80boost
Adj R-val added to min

Pre-weatherization			Post-weatherization		
Intercept	Slope	R^2	Intercept	Slope	R^2
1.4243	0.2189	0.9344	1.5469	0.1812	0.9894

At Pre- Base Temp	
Intercept Reduction	-8.6%
Slope Reduction	17.2%



Refining Modeling & Savings Estimates

Good One

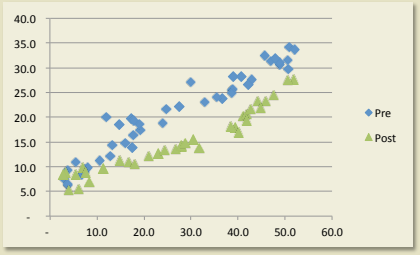
(16 units)

Case #19	pre-retro use	estm savgs
Original audit no ventilation	981.2	384.1
Original data, new tool add contin exhst @30/unit	984.8	341.0
Revised data, new tool more complete fuel data no adj to AFUE, Distrib% or R-values	1,055.4	399.4
Measured post- (normlzd)		395.5

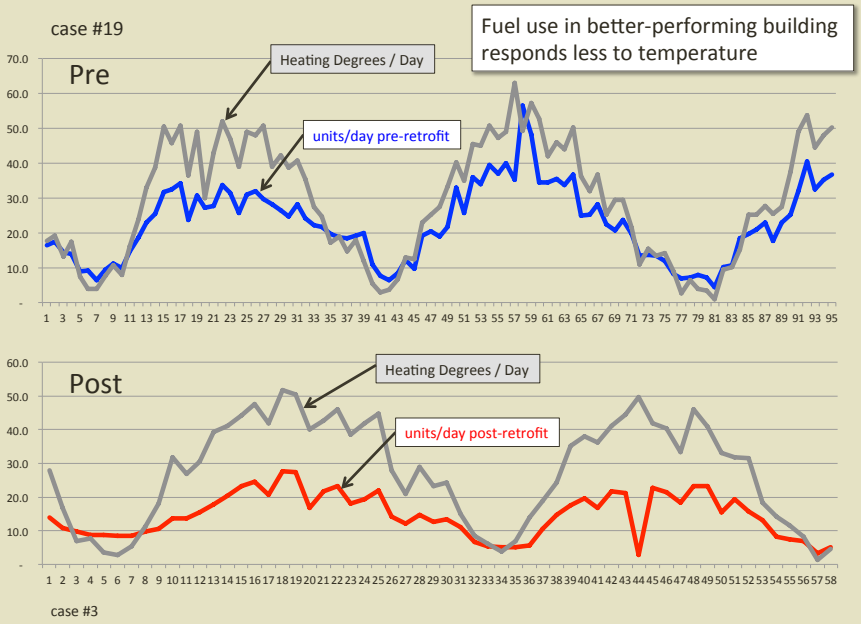
Major measures installed
Attic airsealing & insul to R60
Foundation SPF
Elevator shaft SPF
Repl boilers
Add Solar DHW
Repl central exhaust system

Pre-weatherization			Post-weatherization		
Intercept	Slope	R^2	Intercept	Slope	R^2
5.3969	0.5993	0.8903	4.5114	0.3716	0.7556

At Pre- Base Temp	
Intercept Reduction	16.4%
Slope Reduction	38.0%



case #19



case #3

Refining Modeling & Savings Estimates

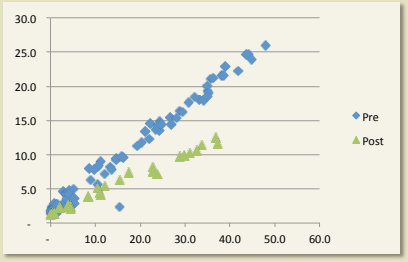
OK

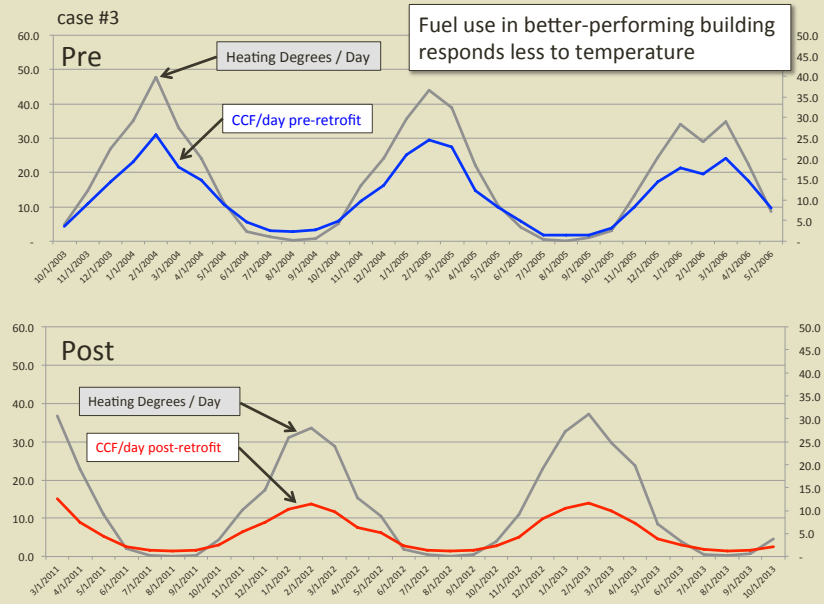
(6 units)

Case #3	pre-retro use	estm savgs	Major measures installed
Original audit no ventilation	353.2	176.7	Attic airsealing & insul to R60 Foundation SPF Spot wall DP (2x4) Repl boiler
Original data, new tool add exhaust fans 30/80	353.2	166.0	
Revised data, new tool more complete fuel data adj AFUE & Distrib% adj R-vals & tempered%	342.2	172.2	
Measured post- (normlzd)		120.5	DHW redctn 4% -> 1%
Model: see note		139.0	Further adj R-vals post

Pre-weatherization			Post-weatherization		
Intercept	Slope	R^2	Intercept	Slope	R^2
1.5548	0.5140	0.9795	1.3370	0.2904	0.9889

At Pre- Base Temp	
Intercept Reduction	14.0%
Slope Reduction	43.5%





Generally: Measures that work

- Solar DHW
- Infiltration reduction
- Foundation insulation
- Large buildings: Heating efficiency improvemt
- Large buildings: Careful with Ventilation!

Lessons Learned

- Start with detailed usage data; DHW meters?
- Do regular progress inspections
- Include building commissioning
- Ventilation at currently required rates is significant load, especially in large buildings: **Always consider HRV**

VFEP 2013 Fuel Study funded through

VERMONT
DEPARTMENT FOR CHILDREN & FAMILIES
OFFICE OF ECONOMIC OPPORTUNITY

State of Vermont
Weatherization Assistance Program
Office of Economic Opportunity

Efficiency Vermont

EVT-HPF: Efficiency Vermont
- Heating & Process Fuels funds

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Efficiency Vermont
Heating & Process Fuels funds

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Regional Greenhouse Gas Initiative

Energy Efficiency & Conservation Block Grant
an American Recovery & Reinvestment Act program

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