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The Low-Income Forum on Energy Presents:

Selected Results from the National Evaluations of the U.S. Department of Energy's Weatherization Assistance Program

Bruce Tonn, Three^3

February 24, 2016
1:30 p.m. – 2:30 p.m. ET

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Low-Income Forum on Energy

Working to help low-income New Yorkers address energy issues.

LIFE, the Low-Income Forum on Energy, is a unique statewide dialogue that brings together organizations and individuals committed to addressing the challenges and opportunities facing low-income New Yorkers as they seek safe, affordable and reliable energy.

Supported by the New York State Public Service Commission and the New York State Energy Research and Development Authority (NYSERDA), the LIFE dialogue encourages an interactive exchange of information and collaboration among the programs and resources that assist low-income energy consumers.

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FEMA's America's PrepareAthon and American Red Cross' Home Fire Preparedness Campaign

Eric Goldman, FEMA Region 2

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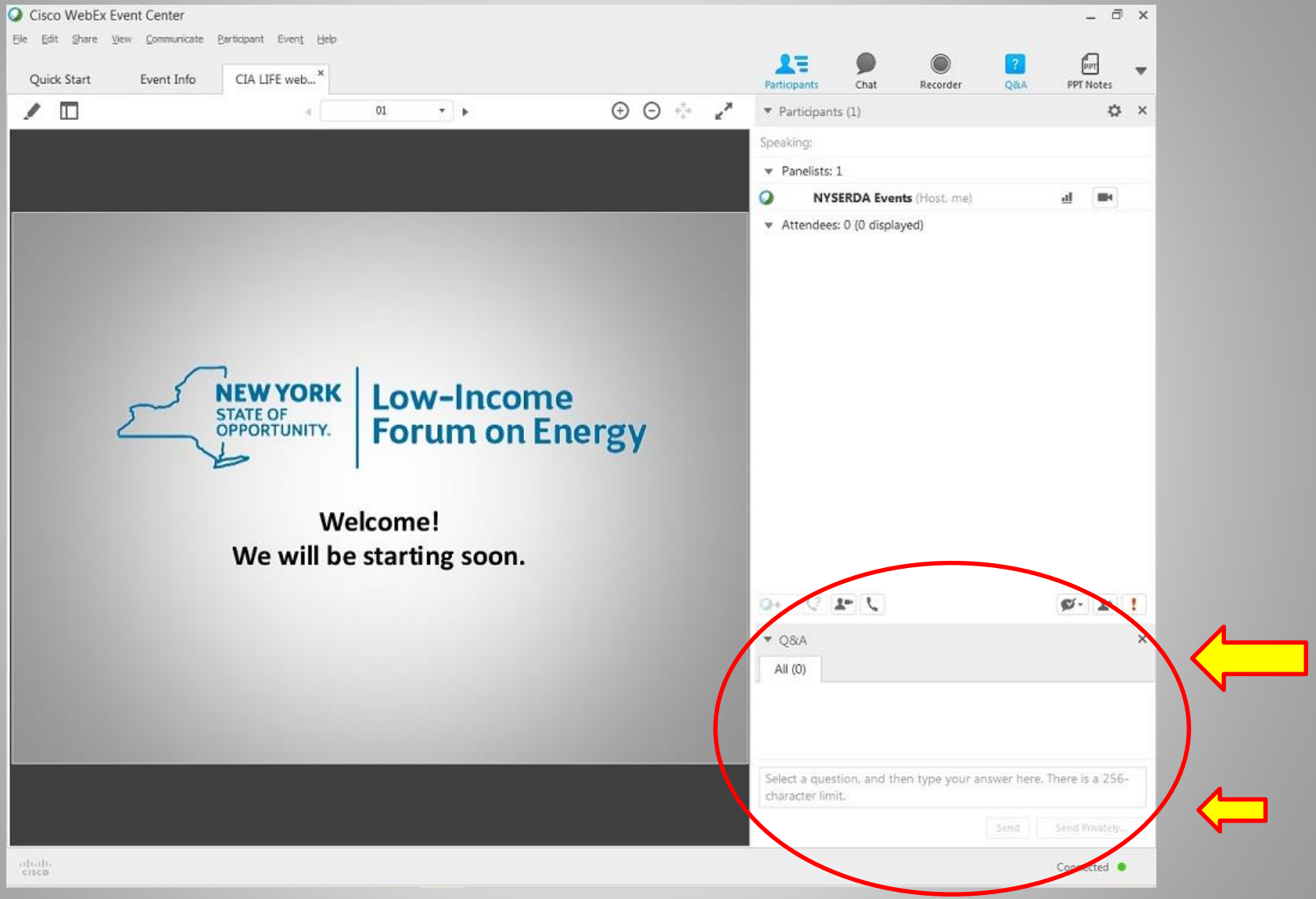

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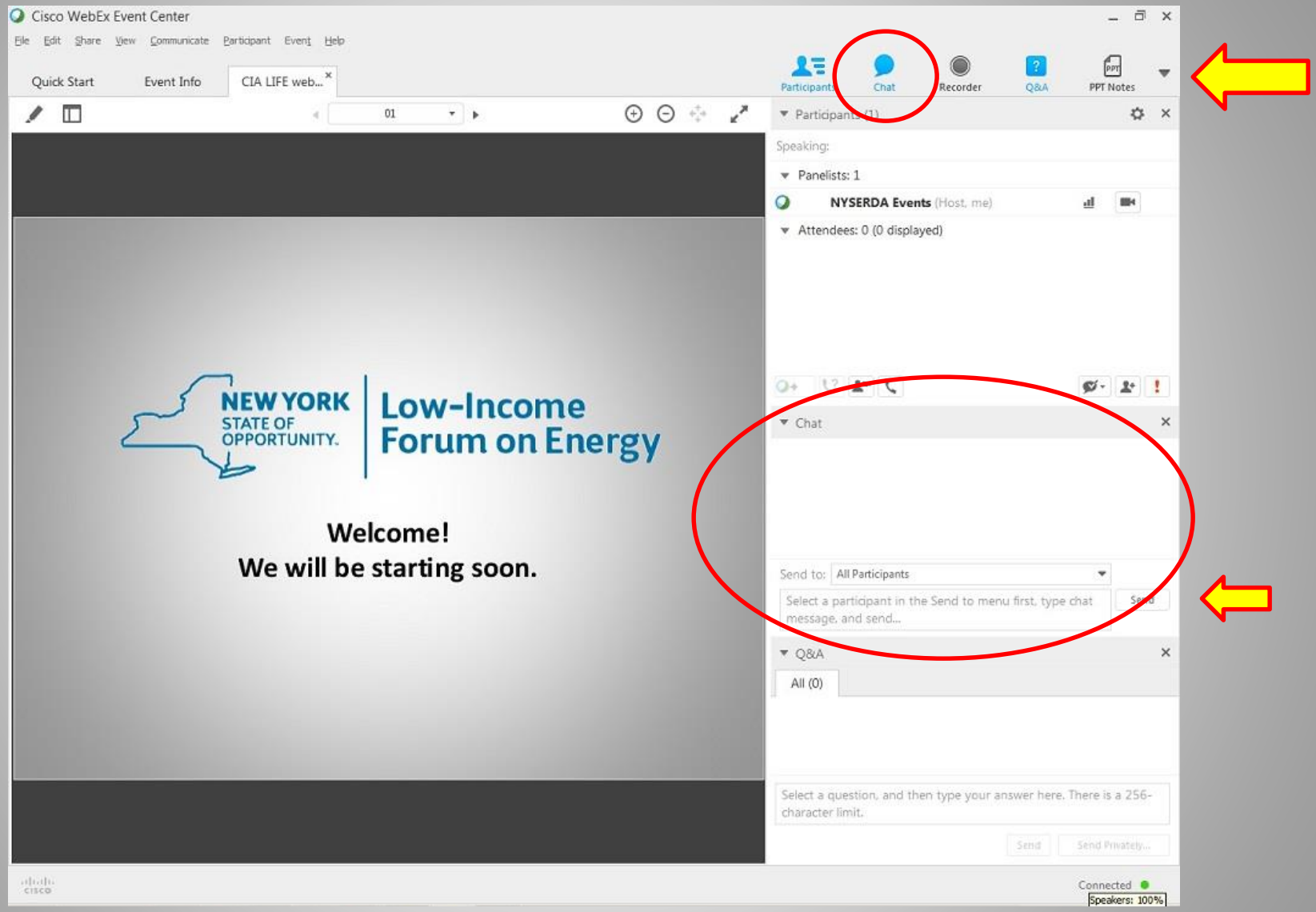

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Selected Results from the National Evaluations of the U.S. Department of Energy's Weatherization Assistance Program

Bruce Tonn

Three^3

Outline

- Energy Savings & Cost Effectiveness Results
- Non-Energy Benefits
  - Health & Household
- Indoor Air Quality Study Results
- Under and Over Performers Study
- Occupant Survey Results
  - Household budget issues, energy behaviors
- What is not covered and what deserves additional research

What is WAP?

The Weatherization Assistance Program has been in operation for over thirty years and is the nation's largest single residential energy efficiency program. It's primary purpose, established by law, is

"…to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, the persons with disabilities, families with children, high residential energy users, and households with high energy burden."

WAP Logistics

- U.S. Department of Energy (DOE) provides grants to states and territories based on funding formulas
- States provide grants to local weatherization agencies
- Local weatherization agencies deliver services
- States/agencies leverage DOE funds

Overview of Analyses and Studies

Energy Savings and Cost Effectiveness

Single Family

Mobile Homes

Large Multifamily (NYC & national)

Under and Over Performers Study

Sustainable Energy Resources for Consumers Grant

Others
-- Territories
-- Refrigerators
-- AC Pilot

Co-Benefits

Health & Household Related

Washington State Asthma Study

Emissions Reductions

Indoor Air Quality Study

Macro-Economic Impacts

Social Networks Assessment

Process Assessments

National Occupant Survey
-- Energy Behaviors
-- Health
-- Home Condition
-- Budget Issues

15 Case Studies of Local Wx Agencies

Weatherization Innovation Pilot Program Evaluation

Others
-- Program Characterization
-- Field Process Study
-- Deferral Study
-- Surveys of Wx Staff, Trainees, Training Centers

WAP Evaluation Peer Review

- Convened national weatherization network committee to shape the evaluation plan
- Convened external expert panel to peer review evaluation plan
- U.S. Office of Management and Budget twice reviewed and approved evaluation's methods and data collection instruments
- Re-convened external expert panel to peer review implementation of methods, data analysis approaches, and communication of results
- Engaged external and internal peer review of evaluation reports

Weatherized Units in Program Years 2008 and 2010 by Housing Type

Housing Type	2008 Units	2008 by %	2010 Units	2010 by %
Site Built Homes (1-4 units)	62,835	64%	215,445	65%
Mobile Homes	17,754	18%	48,267	14.5%
Large Multi-family Units (5+)	17,376	18%	68,153	20.5%
Total	97,965	100%	331,865	100%

Weatherized Units in Program Years 2008 and 2010 by Climate Zone

Climate Zone	2008 Units	2008 by %	2010 Units	2010 by %
Very Cold	24,749	25%	58,584	18%
Cold	42,233	43%	127,386	38%
Moderate	18,794	19%	56,006	17%
Hot/Humid	6,390	7%	55,157	17%
Hot/Dry	5,799	6%	34,732	10%
Total	97,965	100%	331,865	100%

Weatherized Large Multifamily Building Units: Selected Characteristics

		2008	2010/2011
Year Built	Pre 1940	27%	15%
	1940-1969	24%	16%
	1970 or Later	49%	69%
Space Heating Fuel	Natural Gas	71%	56%
	Electric	10%	35%
	Fuel Oil	19%	9%
Heating System	Central	84%	73%
	Room	14%	23%
	Other	2%	4%

Measures Installed in Multifamily Buildings

Measure	2008	2010/2011
Bypass Air Sealing	66%	66%
Attic Insulation	56%	31%
Wall Insulation	8%	4%
Other Insulation	10%	7%
Furnace Replacement	36%	33%
Water Heater Replacement	22%	11%
Refrigerator	42%	23%

Weatherized Large Multifamily Building Units in Program Years 2008 and 2010 by Climate Zone

Climate Zone	2008 Units	2008 by %	2010 Units	2010 by %
Very Cold	3,423	20%	7,576	10%
Cold	10,125	58%	34,454	47%
Moderate	1,301	8%	9,195	13%
Hot/Humid	418	2%	11,429	16%
Hot/Dry	2,109	12%	10,586	14%
Total	17,376	100%	73,240	100%

Estimated Energy Savings by House Type for PY 2008 and 2010

Program Year/Home Type	2008	2008	2010	2010
	Total MMBtu Saved	MMBtu/ Unit Saved	Total MMBtu Saved	MMBtu/ Unit Saved
Site Built Single Family	1,8400,000	29.3	5,730,000	26.6
Mobile Homes	284,000	16.0	790,000	16.4
Large Multi-family	144,000 (NYC)	26.9	1,086,554	15.9
Total	2,268,000		7,609,628	

* 1989 SFSB All Fuels savings 17.6 MMBtu/unit

Percent Energy Savings

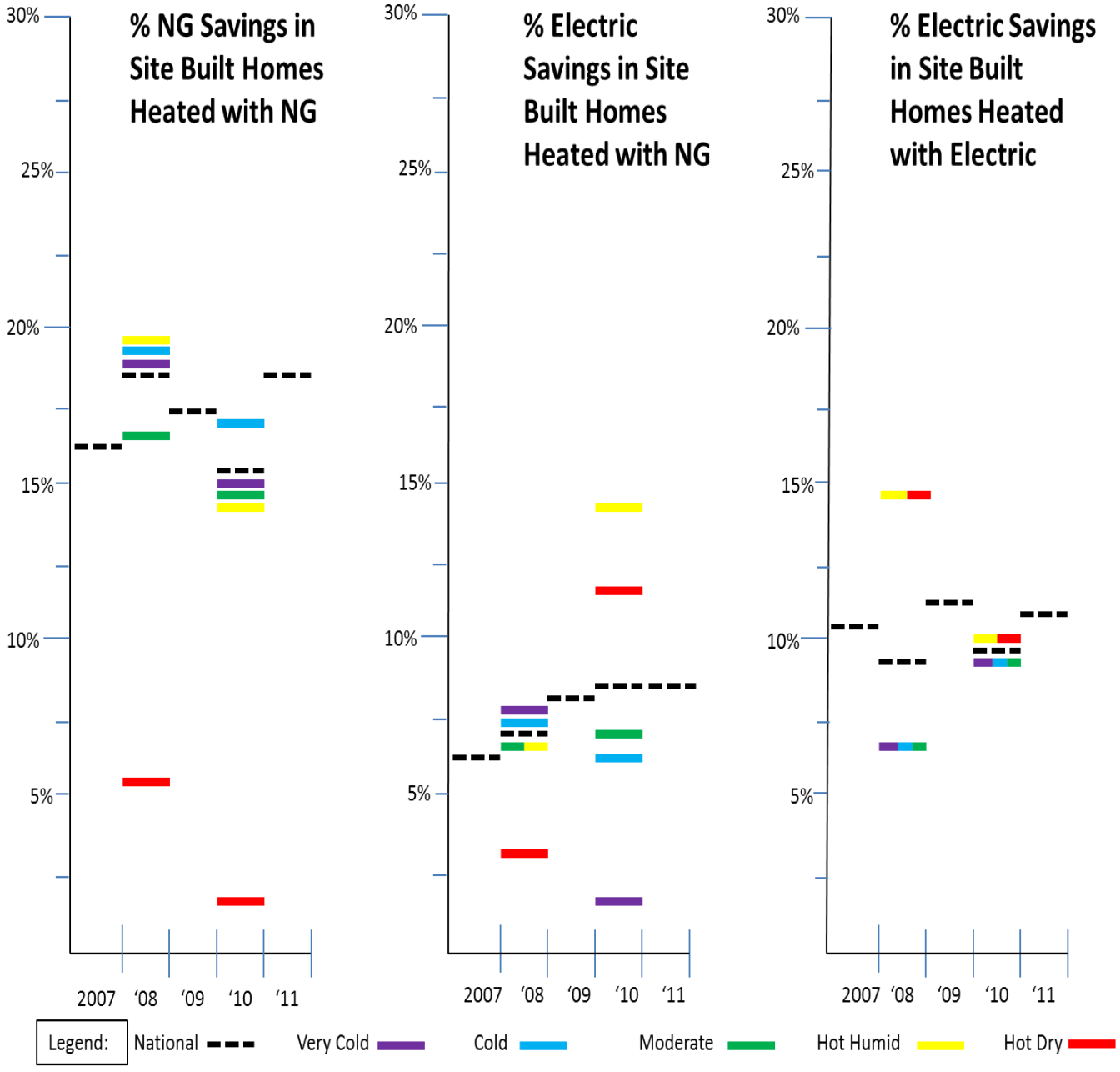
Fuel Type Saved/ Primary Heating Fuel	2008 NG NG Heat	2008 Elect NG Heat	2008 Elect Elect Heat	2010 NG NG Heat	2010 Elect NG Heat	2010 Elect Elect Heat
Site Built Single Family	17.8%	7.1%	9.0%	15.5%	7.8%	9.3%
Mobile Homes	12.6%	5.6%	7.5%	12.9%	7.6%	8.7%
Large Multi-family	18% (NG & FO)	18.3% (NG & FO)	---	14.2% (NG & FO)	6.4% (NG & FO)	10.9%

1989 SFSB All Fuels 13.5%

Large Multifamily Annual Energy Savings by Climate Zone: 2010-2011

	Heated with Natural Gas or Fuel Oil		Electric Main Heat	
	Net Savings (therms)	Net Savings (%)	Net Savings (kWh)	Net Savings (%)
All Climate Zones	99	14.2	810	10.9
Very Cold	71	13.9	354	5.7
Cold	105	13.9	705	9.8
Moderate	99	23.3	1,071	12.9
Hot/Humid	95	31.6	2,033	22.7
Hot/Dry	-3	-1.0	439	6.1

SFSB Homes Energy Savings- by Climate



Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Building and Fuel Type

	PY 2008			PY 2010		
	Energy Cost Savings	Measure Costs	SIR	Energy Cost Savings	Measure Costs	SIR
Single Family	$5,337	$3,096	1.72	$4,468	$3,990	1.12
Mobile Home	$3,053	$2,961	1.03	$2,957	$3,737	0.79
Small Multifamily	$4,618	$2,878	1.60	--	--	--
Large Multifamily	$6,460	$3,336	1.82	$1,996	$2,976	0.67
All types	$4,890	$3,070	1.59	$3,681	$3,745	0.98

(Present Value 2013 Dollars)

Benefits and Costs Scorecard

Benefits & Costs Scorecard	Present Value Per Unit PY 2008	Present Value Program PY 2008	Present Value Per Unit PY 2010	Present Value Program PY 2010
Energy Cost Savings	$4,890*	$420M	$3,681	$1,233M
Accrued to Households	$3,814	$328M	$2,872	$962M
Accrued to Ratepayers	$1,075	$92M	$809	$271M
Environmental & Water Benefits	$3,118	$267M	$2,130	$694M
Emissions Tier 1	$2,932	$252M	$1,944	$645M
Water Savings Tier 3	$186	$15M	$186	$49M
Health & Household-related Benefits	$14,148	$1,166M	$14,148	$3,826M
Tier 1	$7,823	$657M	$7,823	$2,156M
Tier 2	$2,154	$174M	$2,154	$570M
Tier 3	$4,171	$335M	$4,171	$1,100M
Total Benefits	$22,156	$1,853M	$19,959	$5,753M
Total Costs	$4,695	$403M	$6,812	$2,320M
DOE	$2,295	$197M	$5,926	$2,018M
Leveraged Funds	$2,400	$206M	$886	$302M

Health & Household Non-energy Benefits

- Explored the health & household non-energy benefits of ‘regular’ weatherization (i.e., installation of both ECMs and non-ECMs)
- Conducted a nationally representative survey of weatherization recipients (> 600) plus a comparison group (> 800) pre- and post-weatherization
- Monetized a subset of these benefits using a combination of survey results, measures installed, medical cost databases, and other valuable secondary sources

Changes in Physical Condition of Home

Physical Condition of Home	Pre-Wx	Post-Wx	Change
How often home too drafty (1= all the time, 4 = never)	2.86	3.60***	0.74
Outdoor noise (1=great deal, 4= none at all)	2.07	2.37***	0.30
How infested is home with cockroaches, other insects, spiders (1=extremely infested, 5=not infested at all)	4.19	4.37***	0.18
How infested is home with mice (1=extremely infested, 5=not infested at all)	4.61	4.73*	0.12
Frequent mildew odor or musty smell (%yes)	30%	21%***	-9%
How often have observed standing water in home (1= never, 5=always)	1.60	1.44**	-0.16
Have seen mold in home (%yes)	28%	19%**	-9%

*** p<.001; ** p <.01; * p<.05

Changes in Health and Well-Being

Health Impacts	Pre-Wx	Post-Wx	Change
Asthma Symptoms (< 3 months since last) (%yes)	70.5%	58.7%	-11.8%
Asthma Emergency Department Visits (%yes)	15.8%	4.3%*	-11.5%
Asthma Hospitalizations (%yes)	13.7%	10.6%	-3.1%
Kept home at unsafe temperature past year (1=almost every month, 4=never)	3.69	3.91***	0.22
Medical attention too hot (%yes)	2.4%	1.5%*	-0.9%
Medical attention too cold (%yes)	3.2%	1.5%	-1.7%
Number of days previous month physical health not good	10.3	5.4***	-48%
Number of days previous month mental health not good	7.1	3.7***	-48%
Number of days previous month did not get enough rest or sleep	11.7	6.6***	-44%

*** p<.001; ** p <.01; * p<.05

Changes in Budget/Trade Offs

Budget Issues/Trade Offs	Pre-Wx	Post-Wx	Change
How hard is it to pay your energy bills (1= very hard, 5= not at all hard)	2.18	2.88***	0.70
How often not purchased food to pay energy bills past year (1= every month, 3= every few months, 6= never)	5.00	5.23**	0.23
How often not paid energy bills to purchase food past year (1= every month, 3= every few months, 6= never)	5.31	5.55**	0.24
Household member went without food (past 4 weeks) (%yes)	7%	5%	-2%
Received food stamps or WIC assistance past year (%yes)	56%	50%*	-6%
Needed to see doctor but could not because of cost (%yes)	32%	24%**	-8%
Household member needed prescription medicines but couldn't afford (1= yes, 0= no)	.33	.22***	-11%
How often didn't fill prescription/took less to pay utility bill (1=every month, 3= every few months, 6= never)	5.28	5.51**	0.23

*** p<.001; ** p <.01; * p<.05

Monetized Health & Household Benefits: Present Value Per Weatherized SF/MH Home

Non-Energy Benefit	Tier	Value
Asthma	1	$2009
Thermal Stress-Cold	1	$3911
Thermal Stress-Heat	1	$870
Food Assistance Reduction	1	$832
Reduction Missed Days at Work	1	$201
CO Poisoning	2	$154
Improvement in Prescription Adherence	2	$1929
Reduction in Use of Short-Term Loans	2	$71
Home Fires	3	$831
Increased Productivity at Work Due to Improved Sleep	3	$1813
Increased Productivity at Home Due to Improved Sleep	3	$1329
Reduction in Low-Birth Weight Babies	3	$198
Average Per Weatherized Home		**$14,148**

Indoor Air Quality Study

- Question: What are the impacts of weatherization on indoor air quality?
- Nationally representative sample of over 500 single family homes
- Random control trial design; control homes in same locales as treatment homes
- Measured CO, radon, formaldehyde, temperature, humidity pre- & post-weatherization in winter, closed home conditions

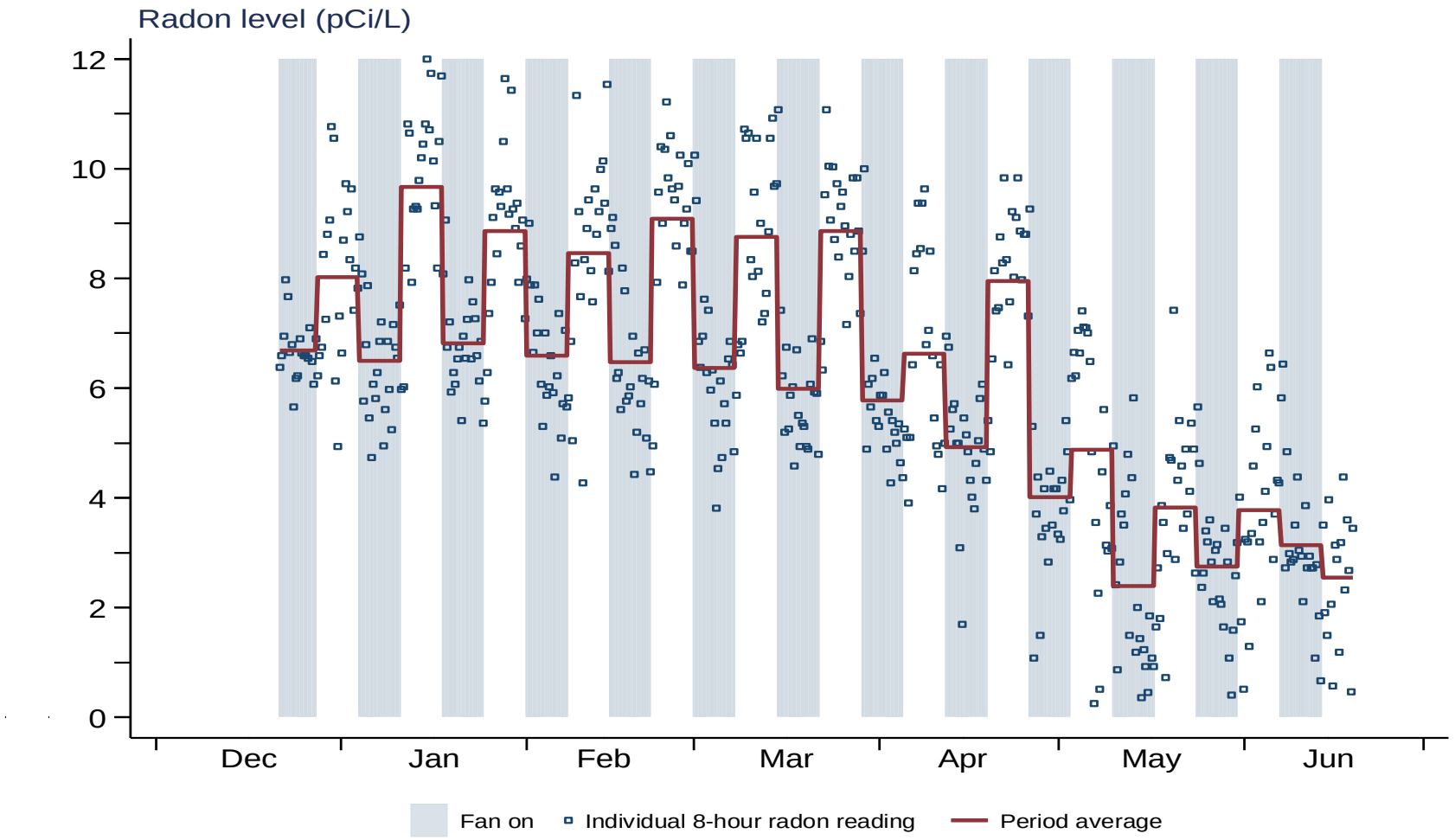
Radon Results

Radon Results (Arithmetic Means)	N	Pre-weatherization, pCi/L				Change (Post – Pre), pCi/L					
		Treatment Group (n=285)		Control Group (n=162)		Treatment Group		Control Group		Net (Treatment – Control)	
Overall											
all cases	447	2.0	±0.3	1.9	±0.3	+0.14	±0.13	-0.29	±0.18	+0.44	±0.18
preWX radon <10 pCi/L	438	1.6	±0.2	1.7	±0.3	+0.11	±0.12	-0.16	±0.12	+0.28	±0.14
EPA radon zone											
High (Zone 1)	234	2.4	±0.4	2.7	±0.5	+0.29	±0.18	-0.50	±0.33	+0.79	±0.31
Moderate (Zone 2)	170	2.3	±0.6	1.4	±0.3	+0.10	±0.26	-0.11	±0.25	+0.23	±0.28
Low (Zone 3)	43	0.6	±0.2	0.8	±0.3	-0.10	±0.14	-0.11	±0.13	+0.01	±0.20
Housing Type											
Site-built	362	2.4	±0.3	2.3	±0.3	+0.24	±0.16	-0.44	±0.21	+0.68	±0.24
Mobile home	85	0.8	±0.2	0.6	±0.1	-0.13	±0.16	+0.20	±0.24	-0.33	±0.29
Site-built homes in EPA Zone 1)	192	2.8	±0.4	3.3	±0.6	+0.46	±0.21	-0.62	±0.45	+1.08	±0.42

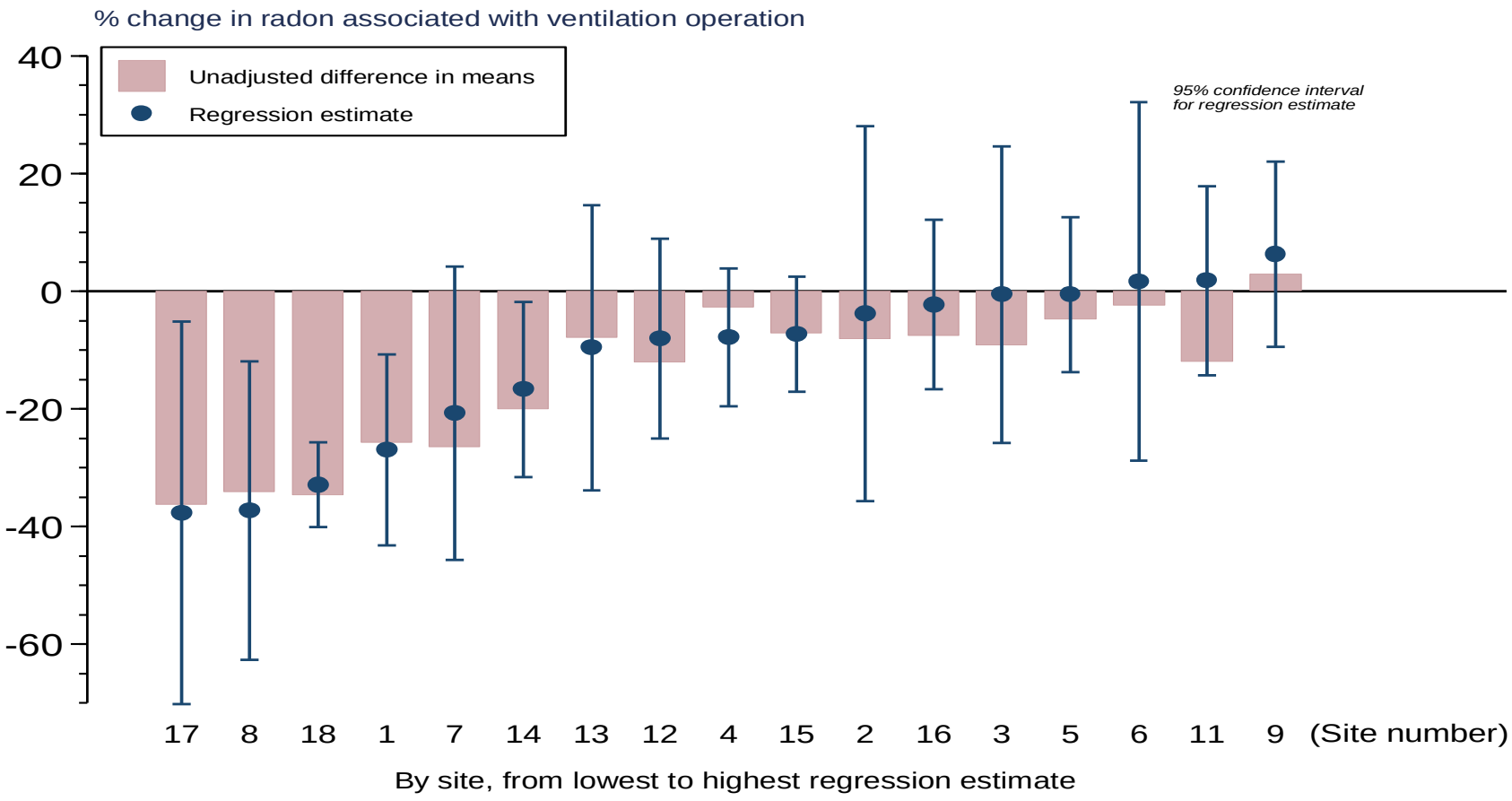
Impacts of 62.2 Ventilation on Radon Levels Post-Weatherization Study

- Question: Could ventilation installed according to 62.2 standards mitigate radon levels post-weatherization?
- Selected a small number of homes that tested above 4.0 pC/L post-weatherization in IAQ study
- Installed 62.2 ventilation
- Monitored radon with ventilation on one week, off one week, etc.

Sample Home Exhibiting Reductions in Radon When Ventilation is On/Off



62.2 Study Results – Ventilation Reduces Radon Levels



Results expressed as a percent of average fan-off radon level over the monitoring period.

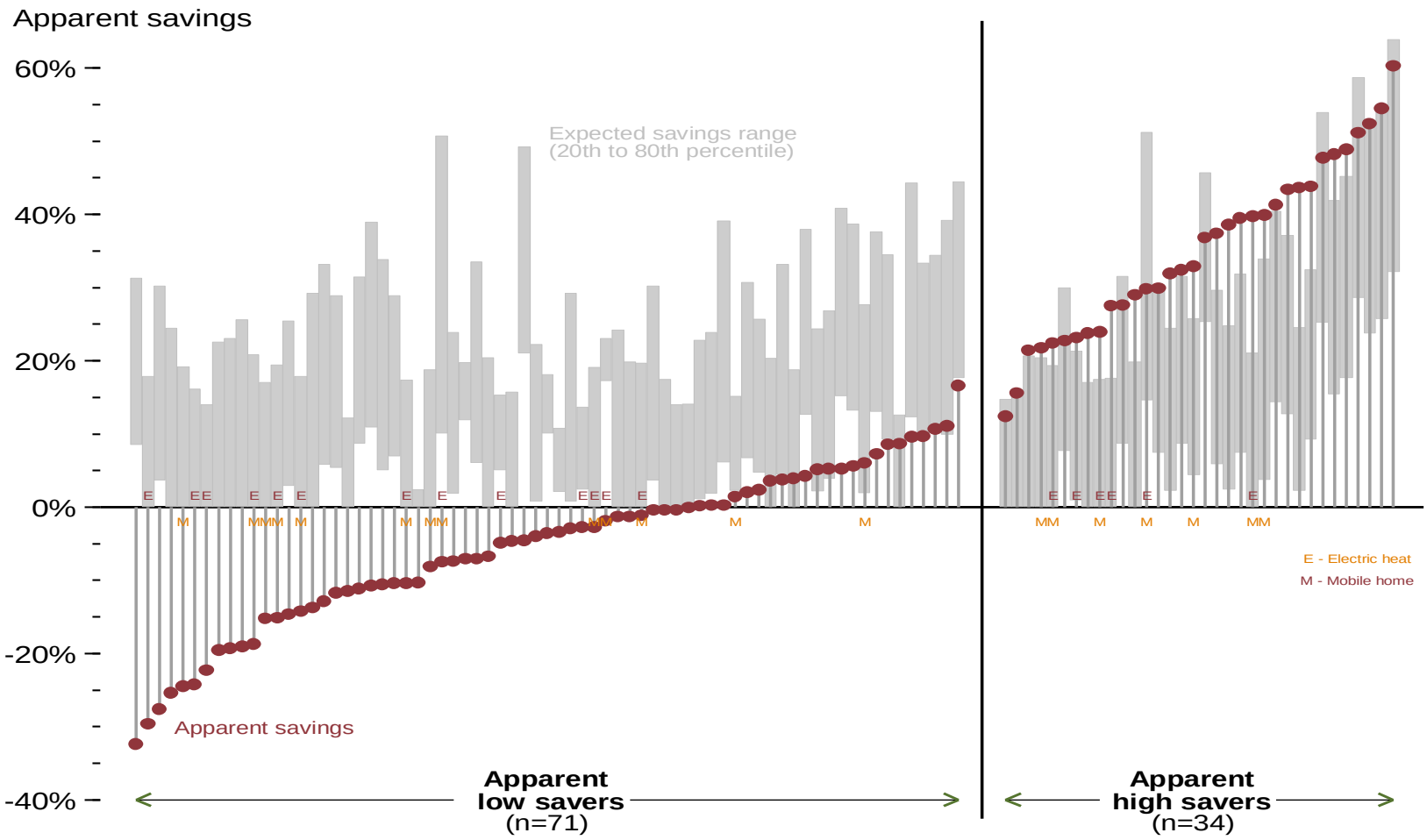
Other IAQ Results

- Carbon Monoxide
  - Heating Systems: 9 ± 6% units > 400ppm pre-wx; 1 home post-wx (not explainable why)
  - Water Heaters: 15 ±4% units inadequate draft pre-wx; none post-wx
  - Ovens and Ranges: 10-20% ovens > 800ppm pre-wx
  - Ambient: 66% never exceed 5ppm; 1/25 exceeded 5ppm 10% of time
- Formaldehyde
  - Small insignificant increase in mobile homes
- Indoor Temperature
  - Net change post-wx 0.3 ±0.2 ^{o}F (almost no take back)
- Indoor Humidity
  - Measured a 1.1 ±0.6% increase post-wx

Under- and Over-Performers Study

- Question: what can we learn about variation in observed energy savings?
- Question: To what extent are variations explained by factors other than work quality and take back effects?
- Identified over 100 homes that through regression analyses indicated they were under or over performers.
- Inspected the homes, reviewed project files, talked with residents

Observed Apparent Savings and Predicted Savings Range for Study Sample



Performers Study: Summary of Results

- Household Factors
  - Household Change (↓ ↑ 1 in 4)
  - Change in supplemental heating use (↓ 1 in 3)
  - Idiosyncratic consumption in warmer climates (↓ 1 in 10)
- Program Factors
  - Atypical Measure application (↓ 1 in 3 or 4; ↑ 1 in 7)
  - Issue with existing heating system (↓ replace broken)
  - Measure persistence (↓ measure failures)
  - Work quality (↓ 1 in 5 cases)
  - Additional measures (↑ 1 in 2)

↓ Underperformers
↑ Over-performers

Household Budget Issues (Cont.)

Cluster Description	Worst Case	Pervasive Bill Trade-off Issues	Best Case
N (%)	65 (10%)	87 (13%)	301 (47%)
Used one or more short-term, high interest loan	58%	37%	5%
Paid other utility bills before energy bills	95%	97%	2%
Paid energy bills before other utility bills	95%	92%	3%
Paid energy bills before buying food	86%	67%	6%
Bought food instead of paying energy bills	88%	95%	1%
Household member went without food	42%	1%	0%
Worried that cannot afford nutritious food	95%	11%	4%
Could not afford prescriptions	86%	41%	7%
Could not afford to see a doctor	77%	38%	7%
Received food assistance (e.g., WIC)	55%	78%	43%
Avg. # Issues Pre-Wx	7.8	5.6	0.8
Avg. # Issues Post-Wx	5.9	3.9	0.9
Change Pre- to Post-WX	-1.9	-1.7	+0.1

Other Occupant Survey Findings

- Energy consumption behaviors did not change post-weatherization
- Client education was largely ineffective in changing behaviors
  - Energy educators accompanying auditors had an impact
- Thermostat use became less active post-weatherization
- Knowledge of how thermostats work is lacking and did not improve post-weatherization

Some Conclusions from the Evaluations

- Weatherization Works
  - Effective – Energy is being saved cost-effectively
  - Competent – Most observed work high in quality, high satisfaction
  - Mission Oriented – Low income clients benefitting
- Significant Co-Benefits Include:
  - Environmental Emissions Reductions
  - Health & Households; Asthma & Thermal Stress
  - Social Network Effects
- Issues for Program Include:
  - Energy savings in mobile homes and large multifamily buildings
  - In-field work quality
  - Average investment levels in homes
  - Client education
  - Increasing energy efficiency of WAP eligible homes

Examples of Opportunities for Future Research

- Link specific measures installed, estimated energy savings, and health benefits
- Expand set of health impacts: mental health, trips & falls, heart disease
- Improve understanding of WX/HH and household budgets
- Measure health impacts of Wx in variety of multifamily buildings
- Improve health impacts methods/data (e.g., thermal stress & mortality records)
- Expand collection and analysis of medical cost records, school attendance and achievement records
- Measure impacts of WX on IAQ in multifamily buildings
- Conduct special studies: weatherization & wildfires, noise, pesticide drift…
- Measure persistence of energy savings over time
- Assess household/home resilience to extreme weather/climate change and synthesize resilience measures with Wx and HH measures
- Assess relationships between weatherization, thermal stress (hot), domestic violence

WAP Evaluation Results

- Now available at http://weatherization.ornl.gov
- Over 35 separate reports, including summary reports and evaluation plans
- My contact information:
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  - 865-766-2734

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