Reducing Electrical Loads:
Some Lessons Learned in the US

Energy Retrofits For Houses
PROG 5
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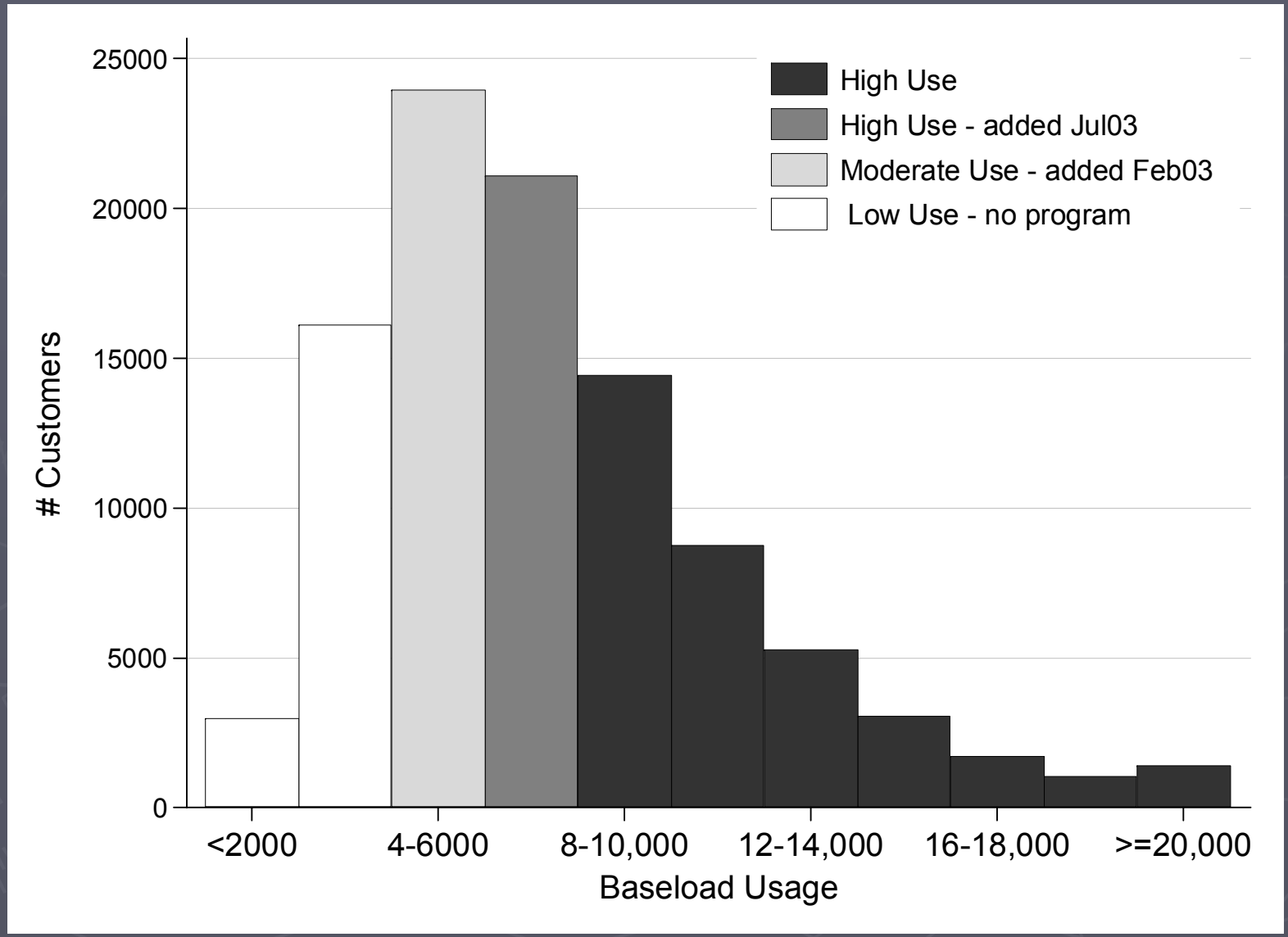
Electric Baseload Usage

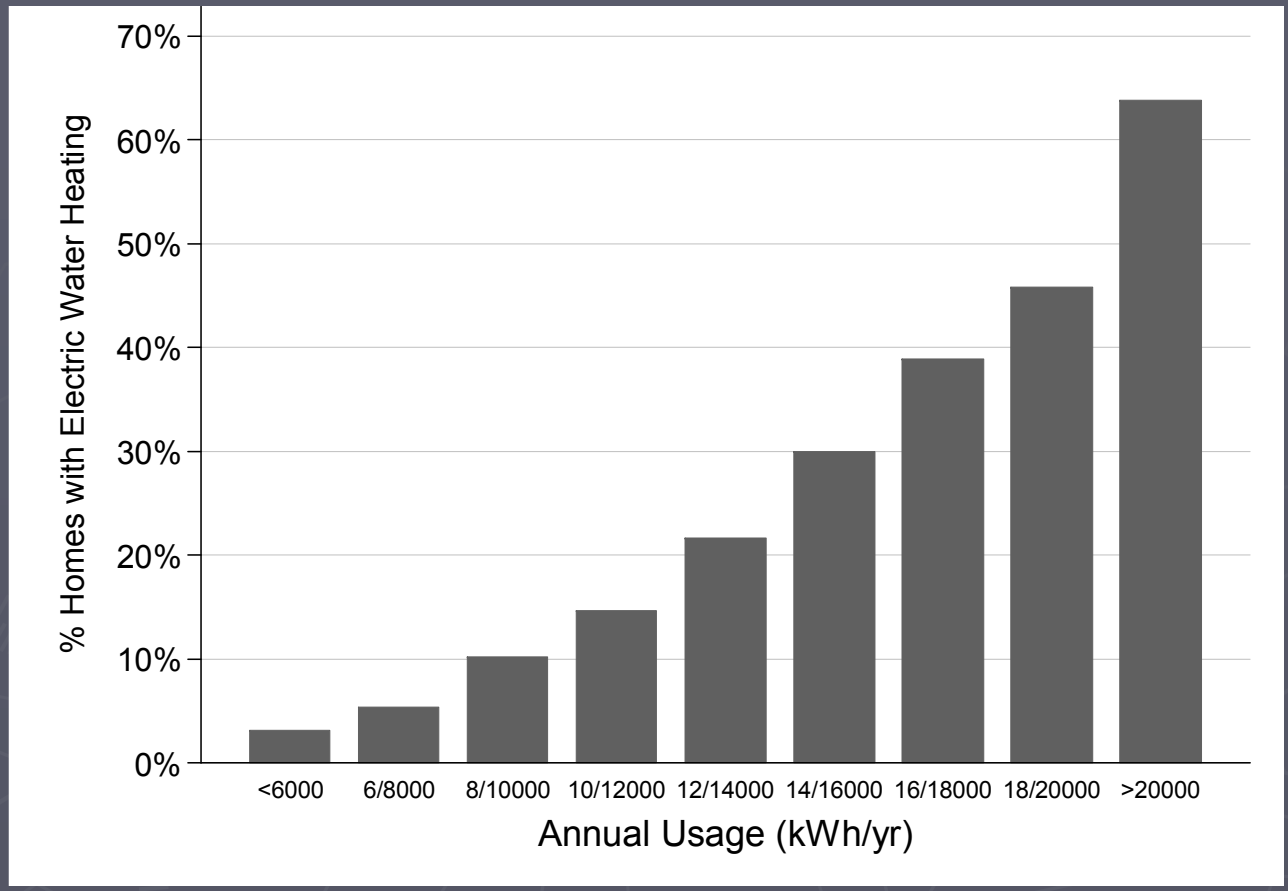
Ohio PIPP population



Ohio EPP Electric Baseload
Program Designs

- High Use Program
  - Baseload electric >6,000 kWh/yr
  - Detailed End Use Audit
    - Full end use inventory matched to actual usage
    - Refrigerators, Freezers, and Lighting
      - 16 CFLs, 0.58 fridges, and 0.2 freezers per home
      - Fridges/freezers include some 2-for-1 swaps and removals
    - Education action plan designed from end use inventory
- Moderate Use Program
  - Baseload Electric 4,000-6,000 kWh/yr
  - Simpler audit – fridge & lighting with education
    - 12 CFLs, 0.58 fridges and 0.11 freezers per home

Electric Baseload: Hot Water & High Use



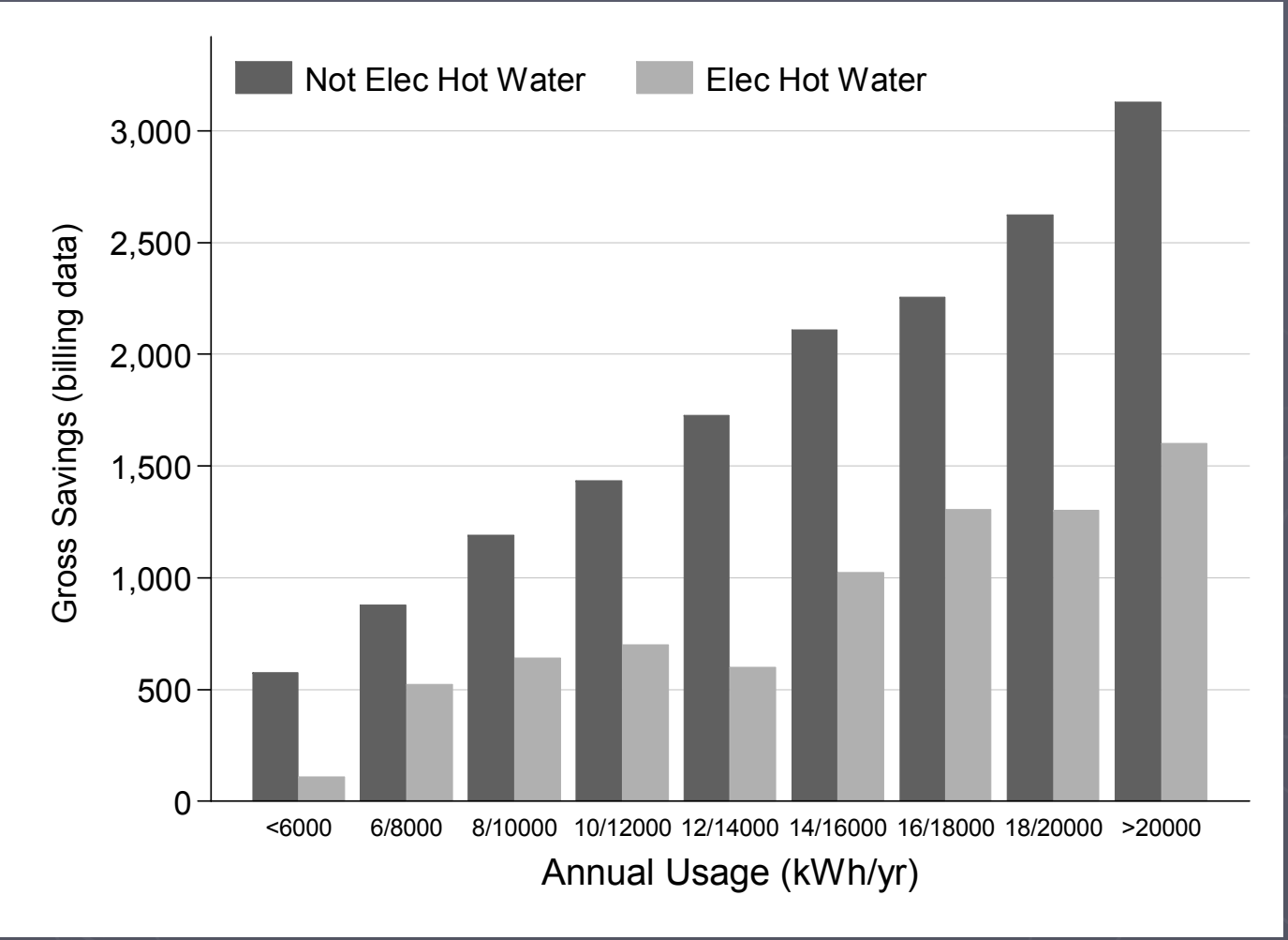
- Electric Water Heating Complicates Targeting
  - Many “high users” just have electric water heating, but are otherwise fairly efficient

Ohio EPP Electric Savings: High Use

- Savings=1,650–1,775 kWh/yr (past 3 studies)
  - 12%-13% of the 13-14,000 kWh average pre-use
  - ~700 kWh lighting, 700 kWh fridges/freezers
    - 41 kWh/bulb, 926 kWh/fridge, 760 kWh/freezer
  - Much higher kWh savings than similar programs
  - 68%-77% of the audit-predicted savings
    - Shortfall mostly lighting hours and some removal and burnout
    - Not much savings from DHW, other measures or education
  - Cost Effectiveness
    - Program costs averaged $879 in most recent evaluation
    - Equal to 53 cents per annual kWh of savings
    - Highly cost-effective: Overall SIR = 1.50
    - Program continued to decrease costs and improve cost-effectiveness over first 3 years

Electric Baseload: Usage vs. Savings

Ohio EPP High Users Program

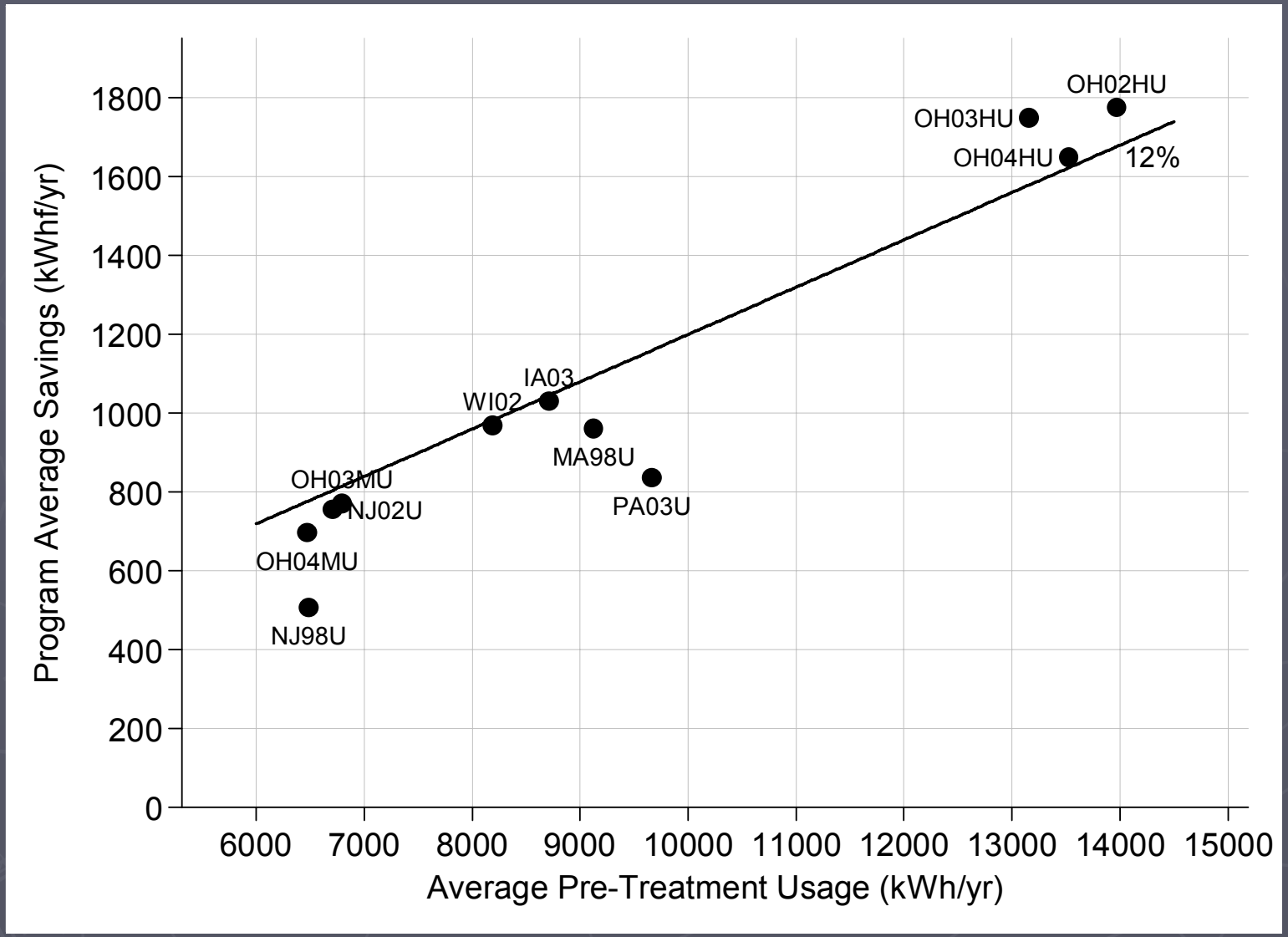


- Pattern depends on water heating type

Ohio EPP Electric Savings: Mod Use

- Savings= 697-772 kWh/yr (past 2 studies)
  - 11% of the 6,500-6,800 kWh average pre-use
  - Comparable or a little lower than other programs
  - 42%-46% of the predicted savings (vs. 68%-77%)
    - Fridge and lighting savings both fall short, education minimal
  - Cost Effectiveness
    - Program costs averaged $726 in most recent evaluation
    - Equal to $1.04 cents per annual kWh of savings
    - Not considered cost-effective: SIR = 0.87 (vs. 1.50)

Electric Baseload Programs: Evaluation Results



Electric Baseload Evaluation Results

usage and savings in kWh/year/home

Study	Year	# Units	Pre-Use	Savings	Save%
Ohio HiUse	2004	4,789	13,525	1,650	12%
Ohio HiUse	2003	4,525	13,159	1,750	13%
Ohio HiUse	2002	2,194	13,975	1,775	13%
Ohio ModUse	2004	1,355	6,468	697	11%
Ohio ModUse	2003	2,585	6,791	772	11%
Iowa	2003	294	8,711	1,031	12%
Wisconsin	'01-'03	8,675	8,191	970	12%
MA utility	1998	~2,000	9,125	962	11%
NJ Utility	2002	756	6,705	756	11%
PA Utility	2003	659	9,661	836	9%

- Savings ~ 12%, but varies 772-1750 kWh depending on usage
- Payback generally quicker than most gas heating measures
- Refrigerators, lighting produce most of savings, except some hot water (and fuel switching in WI)

Lighting

- CFLs typically save 20-50 kWh/yr/bulb on average
  - savings less than the 70-100 kWh predicted due to hours, removal, and burnout
  - still quite cost-effective
- Savings potential not fully met
  - Bulb selection too small?
  - Should carry small base, candelabra, 3-way, dimmable, globe, flood, tiny, instant on, color rendition alternatives, etc...
  - Motion detectors for security lighting

Refrigerators & Freezers

- Savings average 600-1000 kWh per fridge
  - Actual savings typically 80%-90% of predicted
    - if prediction based on short term metering
  - Average savings per unit increase with program usage threshold
  - Average savings per home decrease with program usage threshold
- Refrigerator Audit Methods
  - metering, rated usage lookup, age, other?

Hot Water

- Fix Hot Water Leaks
- High Efficiency Clothes Washer
  - Save ~ 800 kWh and 11,000 gals water vs. old units
  - Save ~ 300 kWh and 7,000 gals vs. std. new units
    - assuming electric HW and dryer, 1 load/day
  - Cost-effective retrofit if high utility costs or high laundry use
  - Or...you can just wash clothes in cold or warm more often
    - Save 350 kWh per year if 50% cut in hot water use
- Very Low Flow Showerheads
  - most showerheads low flow, but 1.6 gpm units may save ~ 200 kWh/yr

Shutting Things Off

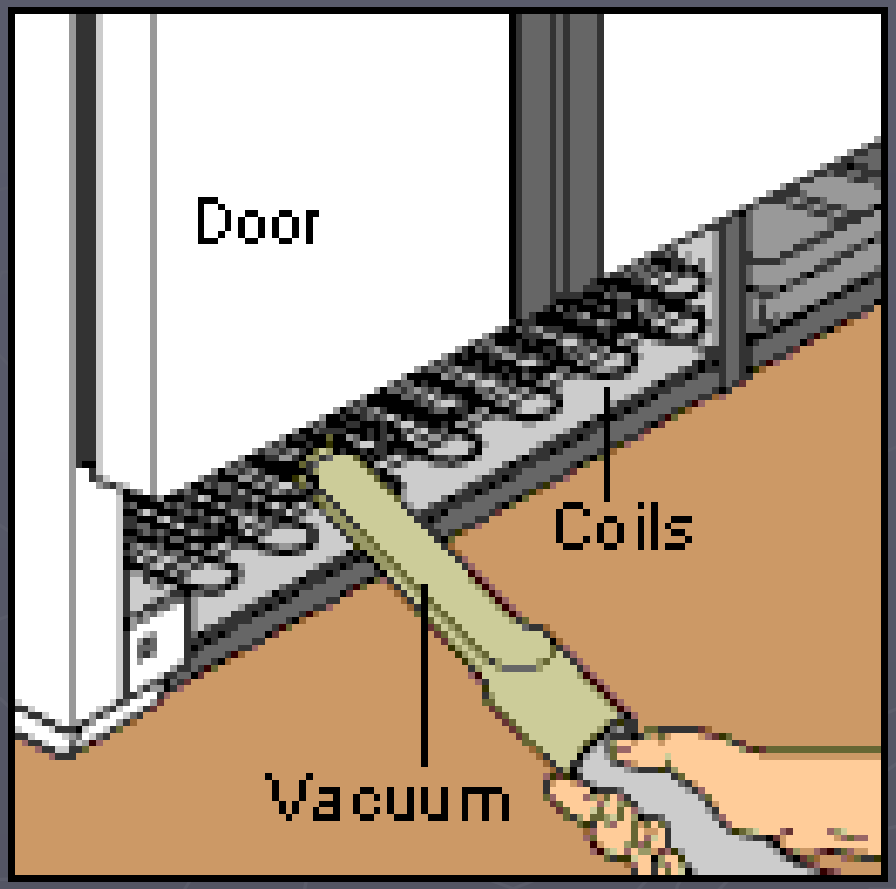
- Furnace Air Handler “ON” ~3,000 kWh/yr
- Secondary fridges, freezers ~400-2000 kWh/yr
- Unneeded 24 hour loads
  - Computers ~500+ kWh/yr
    - false belief about impact on computer lifespan
    - sleep and hibernate also work well
  - Lights ~ 250-750 kWh/yr
    - timers and motion detectors may help
  - TVs and Stereos ~300–600 kWh/yr
    - for background noise, people don’t realize cost
  - Vampire / Phantom / Standby loads
    - Not huge, but growing, use (smart) power strips
    - DVRs can be 400+ kWh/yr, shutting off is problematic

Behavior Change can be hard...

Things That May Not Save Much

- Energy Feedback Devices?
  - Claims of 5%-10% savings - shaky evaluations
  - Newer studies not finding much savings
- Informative Billing
  - some large experiments have shown promising results of about 2% savings
    - unclear how long savings last -- is message needed every month?
- Small behavior changes with trivial impacts
  - clean fridge coils, close fridge quickly, cook with lids on pots

Now we've got global warming licked...



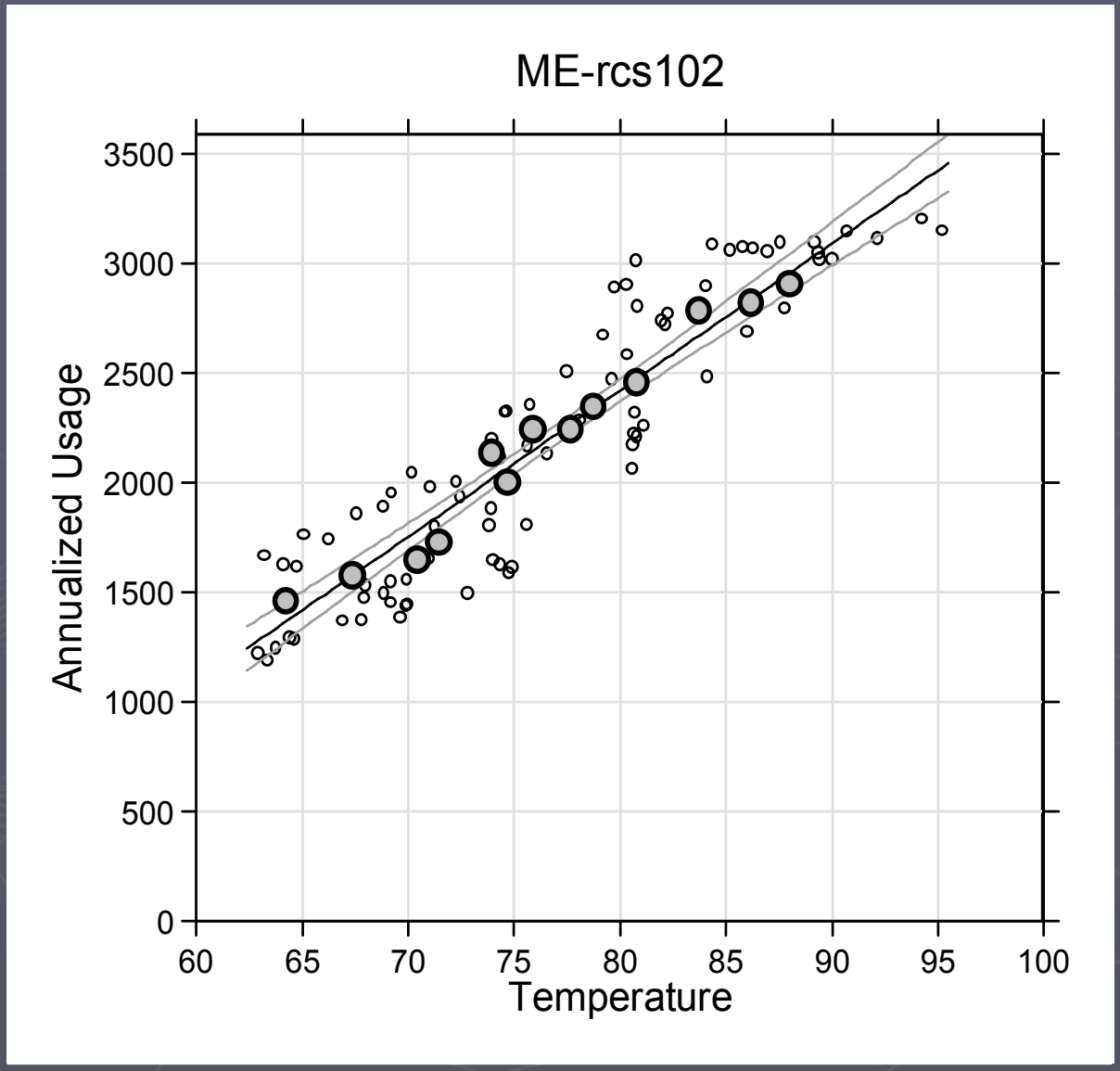
Refrigerator Audit Methods

- Adjusted Label-Rated Usage
  - Look up label-rated usage in AHAM or other database
  - Usually adjust rating for age, size, defrost, door style, etc.
- Short-Term Metering
  - Meter kWh for 30 minutes to 3 hours to 3 days (!?)
  - Calculate annual usage based on meter results
    - Temperature corrections: some adjust to a target temperature (e.g., 68°F), others for current vs. annual avg.
    - Defrost Cycles: some avoid or check for defrost, some adjust usage to account for defrost cycles (x1.08)
    - Time-of-day: some use a time-of-day adjustment factor
- Other Audit Methods
  - Refrigerator Age: e.g., remove units built before 1990
  - Power Factor: remove units with power factor <.75

Refrigerator Usage & room temperature

Data for one refrigerator with wide temperature range

Large gray circles are daily averages, smaller circles are 4 hour averages



Factors Affecting Refrigerator Usage

(values are % of label-rated value, apply to kitchen units)

Factor	Proposed Audit	Notes
# Occupants (primary unit only)	+5%/occupant	Only for primary refrigerators
Anti-Sweat On	+20%	expect ~15% higher
Icemaker thru-door	+15%	captures side-by-side effect
Door Seal gaps	+15%	Related to continuous running
Unit bought used	+20%	Related to continuous running
Average Room Temperature	+/- 5% if high or low T-stat	Adjust if avg T-stat setting <65° or >70°
Base Level Usage	85%	Usage if no occupants or other factors apply

Other Findings

- Factors not found to affect usage
  - Unit age (but all were fairly old)
  - Door style (thru-door ice captures effect best)
  - Internal icemaker
  - Occupant reported schedules or cooking
  - Unit location details, clearances, etc.
  - Auditor-estimated general condition, and many other factors examined
- Basement Refrigerators are Different
  - Usage hard to predict based on ratings
    - Some use much more than rated due to malfunction or seal
    - Most use less than rated due to cool temperatures, low loads
  - rated usage is poor predictor of actual usage for basement units – must use metering to audit

Assessing Audit Method Performance

1) Statistical Accuracy
   - How close is usage estimate to actual
   - Not really the point, except for research geeks
2) Decision Making: 2 types of mistakes
   - Lost Opportunities: should have been replaced, but audit missed
   - Mistaken Replacements: audit qualified, but shouldn't have
3) Net Program Benefits
   - Some decisions matter more than others
     - Replacing very high use units yields large benefit for program
     - Replacing very low use units reduces program benefits
     - Units close to the replacement cut-off don't matter much
   - The real value of an audit method is how it affects the program's cost effectiveness

Audit Method Performance

kitchen refrigerators (n=115)

program assumptions: lower savings value ($0.60/annual kWh)

new units cost $500 use 500 kWh, break-even replacement threshold=1333 kWh, 53% pass

	Accuracy	Decision Errors		Value
Audit Method	Avg. Error	Lost Opportunities	Mistaken Replacements	Net Benefits $/audit
2 week Metering	0%	0%	0%	$135
2 hr Metering	16%	10%	8%	$116
1 hr Metering	20%	12%	9%	$111
New Rated Audit	19%	18%	7%	$101
111% Rated	21%	21%	9%	$85
Pre-1990	n/a	4%	41%	$49
Power factor .75	n/a	30%	10%	$52

Audit Method Performance

kitchen refrigerators (n=115)

program assumptions: high savings value ($1.00/annual kWh)

new units cost $500 use 500 kWh, break-even replacement threshold=1000 kWh, 77% pass

	Accuracy	Decision Errors		Value
Audit Method	Avg. Error	Lost Opportunities	Mistaken Replacements	Net Benefits $/audit
2 week Metering	0%	0%	0%	$445
2 hr Metering	16%	8%	5%	$423
1 hr Metering	20%	10%	6%	$414
New Rated Audit	19%	3%	15%	$419
111% Rated	21%	3%	19%	$403
Pre-1990	n/a	8%	21%	$380
Power factor .75	n/a	51%	8%	$196

Audit Method Findings

- Short-term metering can work very well
  - 2 hour “ideal” metering is best audit approach if no cost difference
  - 1 hour metering nearly as good as 2 hour
    - If metering time affects decision then unit is usually not a big saver or loser
  - Actual contractor metering didn’t do as well due to sloppy field work
- Rated usage methods can work almost as well metering:
  - Proposed method nearly as good as metering for kitchen units
  - Simpler 111% rated usage method is only a little worse
  - Doesn’t work in basements/garages/porches
    - We found a net negative benefit if lower kWh value and $60-$80 /audit reduced benefits if high kWh value
- Other Methods
  - Power factor: Too many lost opportunities of high use & high p.f.
  - Unit Age: Replaces too many low use units, especially for programs with higher usage thresholds. It’s worth $20-$50 per audit to look up the rated usage.

Audit Recommendations: Rated Usage

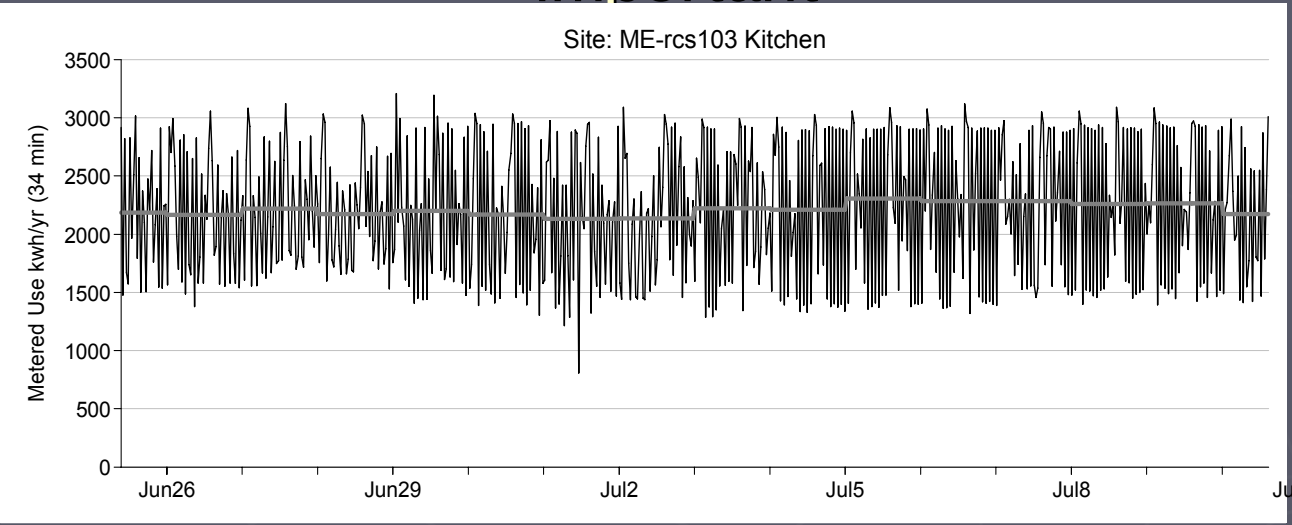
- Rated usage methods can work well
  - But only for units in the living space
    - Not for units in basements, garages, porches, etc.
  - 111% rated usage: simple, objective, and works OK
  - More complicated method works a little better
    - %rated=85+5/occupant+15 (icemaker ttd) +20 (anti-sweat on) +15 (noticeable gaps) + 20 (bought used)
    - Temperature adjustments:
      - +5% if high winter thermostat setting, – 5% if low
      - In hotter climates, adjust estimated usage up by 10%-20%
  - Need “smart” lookup table (in PDA or laptop?)
    - Use model # (ignore brand), use fuzzy matching
    - Can achieve ~90% match rate if done well

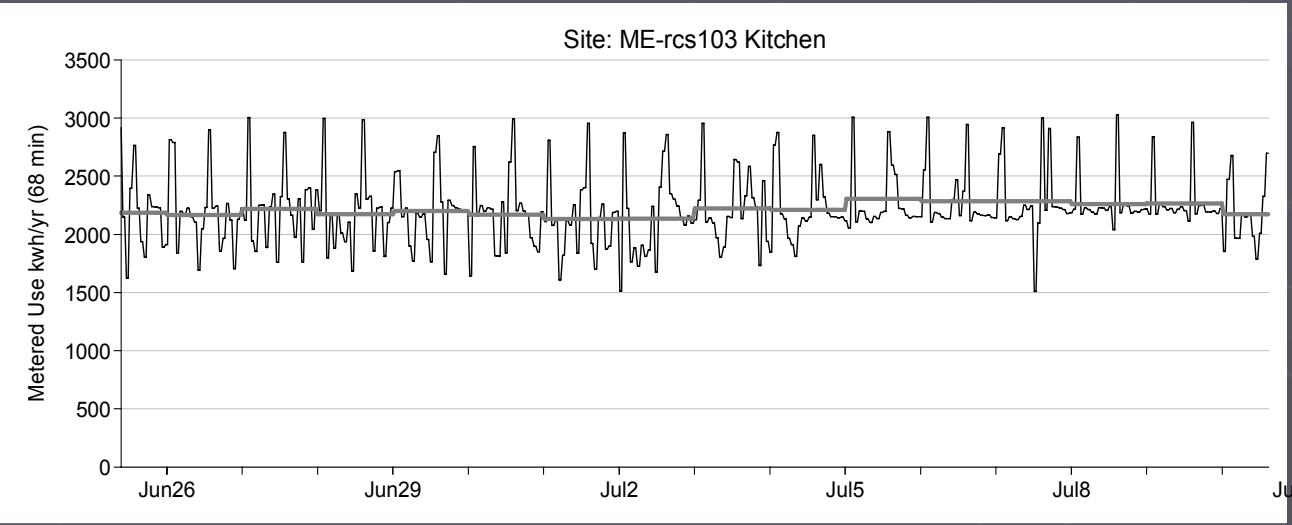
Audit Recommendations: Metering

- Metering is most accurate method
  - required for units outside the living space
- Clear protocols and consistent application are keys
  - Record time accurately
    - plug in kWh meter and start recording the elapsed time immediately after unplugging the unit (even if waiting for compressor reset)
  - Adjust for temperature
    - $Usage = Usage_{mtr} * (T_{annual} - 33) / (T_{test} - 33)$
    - For New England: T_{annual}=71°F inside, 65°F basement, 58°F garage/porch
  - Meter for longer if no cost
    - but 1 good hour is better than 2 sloppy hours.
  - Defrost cycles would be best avoided
    - but only affect a small % of results
    - Defrost becomes important if few units qualify (<25%)
  - Optional: set max usage at 1.8*rated or 8.8*watt draw
  - Do not adjust for time of day
    - Effect is already included in temperature

Some Raw Usage Data

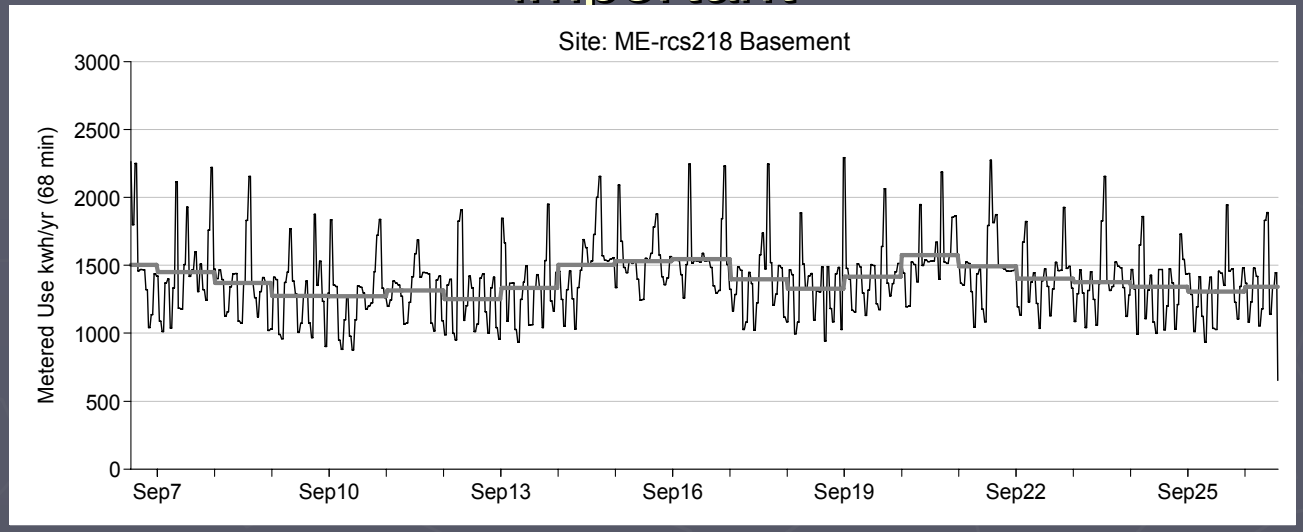
1/2 and 1 hour data, unit always high use, metering time less important

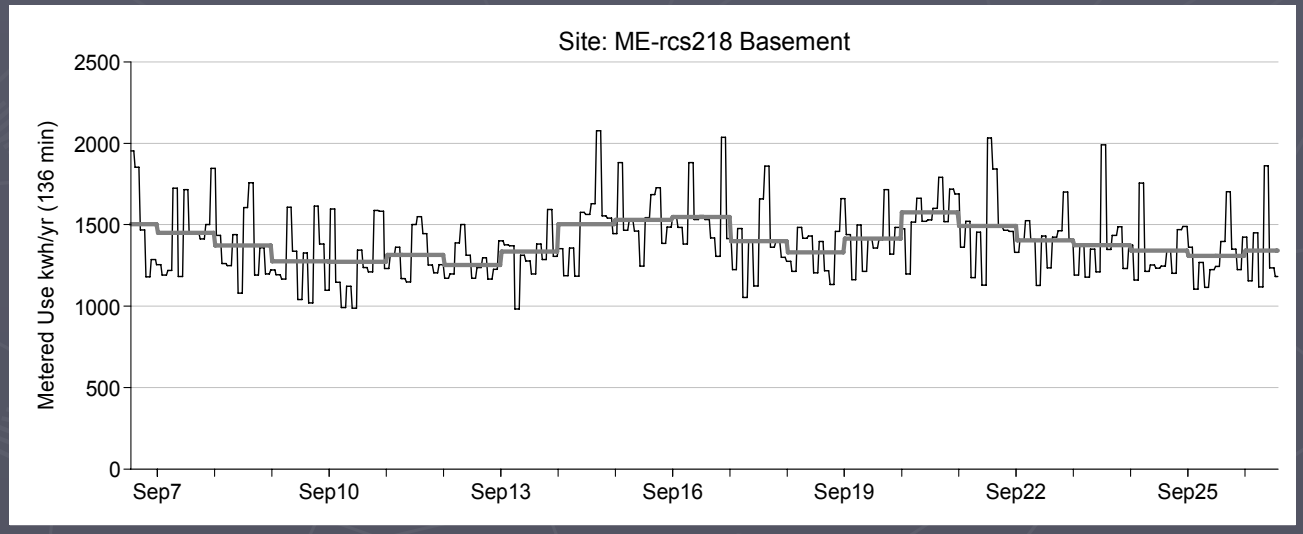




Some Raw Usage Data

1 and 2 hour data, close to threshold so metering time more important





Some Raw Usage Data

1 and 2 hour data, unit always low use, metering time less important