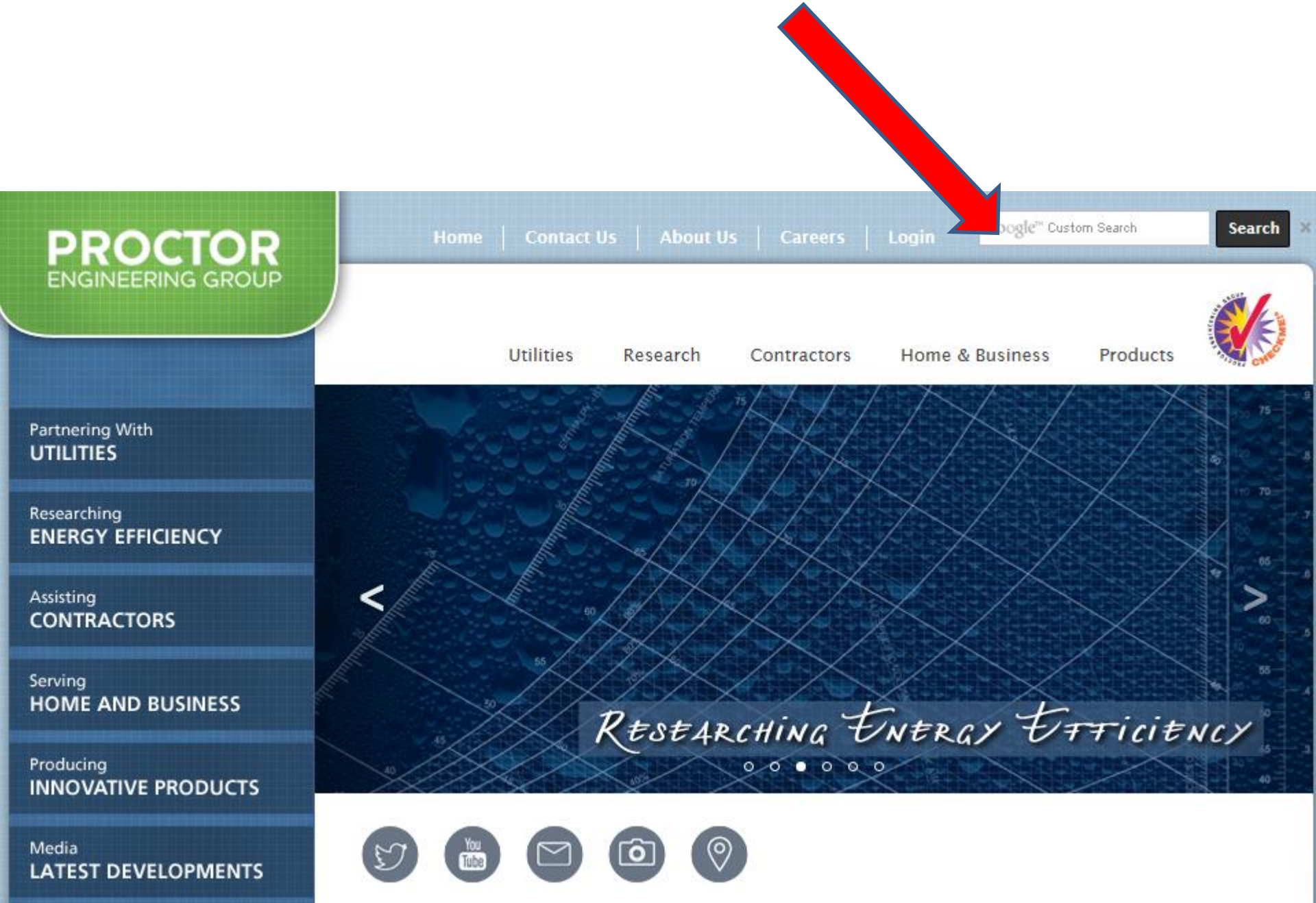

PROCTOR
ENGINEERING GROUP
Home
Contact Us
About Us
Careers
Login
Search
Utilities
Research
Contractors
Home & Business
Products
Partnering With
UTILITIES
Researching
ENERGY EFFICIENCY
Assisting
CONTRACTORS
Serving
HOME AND BUSINESS
Producing
INNOVATIVE PRODUCTS
Media
LATEST DEVELOPMENTS
RESEARCHING ENERGY EFFICIENCY

Data not Dogma

John Proctor

July 30, 2014

John Proctor, P.E.
Proctor Engineering Group, Ltd.
John@proctoreng.com.
http://www.proctoreng.com/energy-efficiency/climate-specific-ac.html

Randomness Happens

Randomness Produces Things

Dogma

Unquestionable Opinions taken as Truth

- Saul Alinsky
- “To the questioner, nothing is sacred. He detests dogma.”

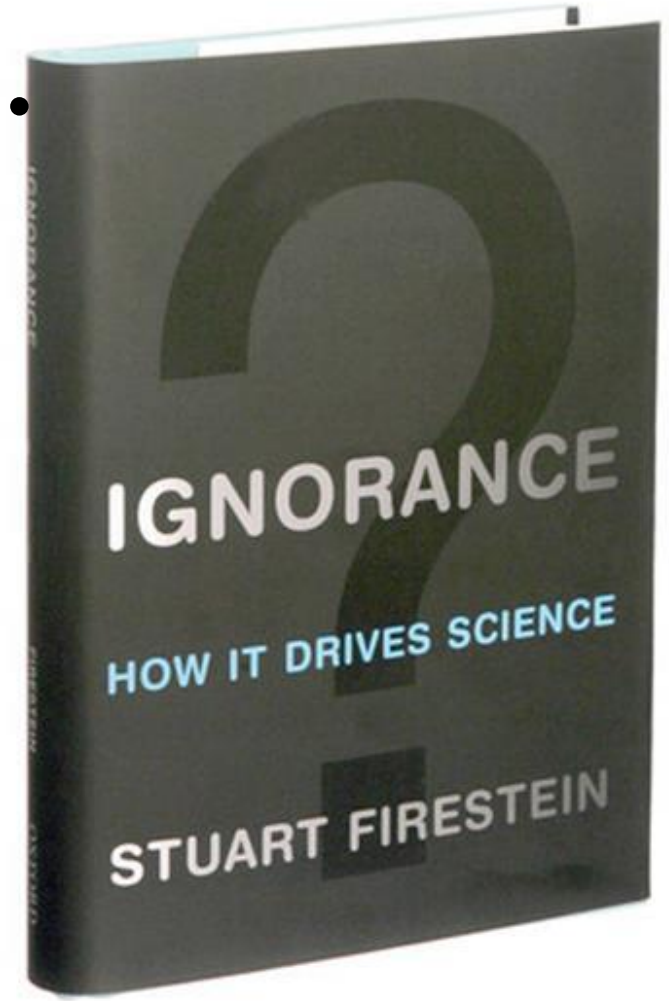
- G.K. Chesterton
- “In truth, there are only two kinds of people; those who accept dogma and know it, and those who accept dogma and don't know it.”

Wisdom

- Socrates
- “The only true wisdom is in knowing that you know nothing.”

- George Bernard Shaw
- “Beware of false knowledge it is more dangerous than ignorance.”

Ignorance



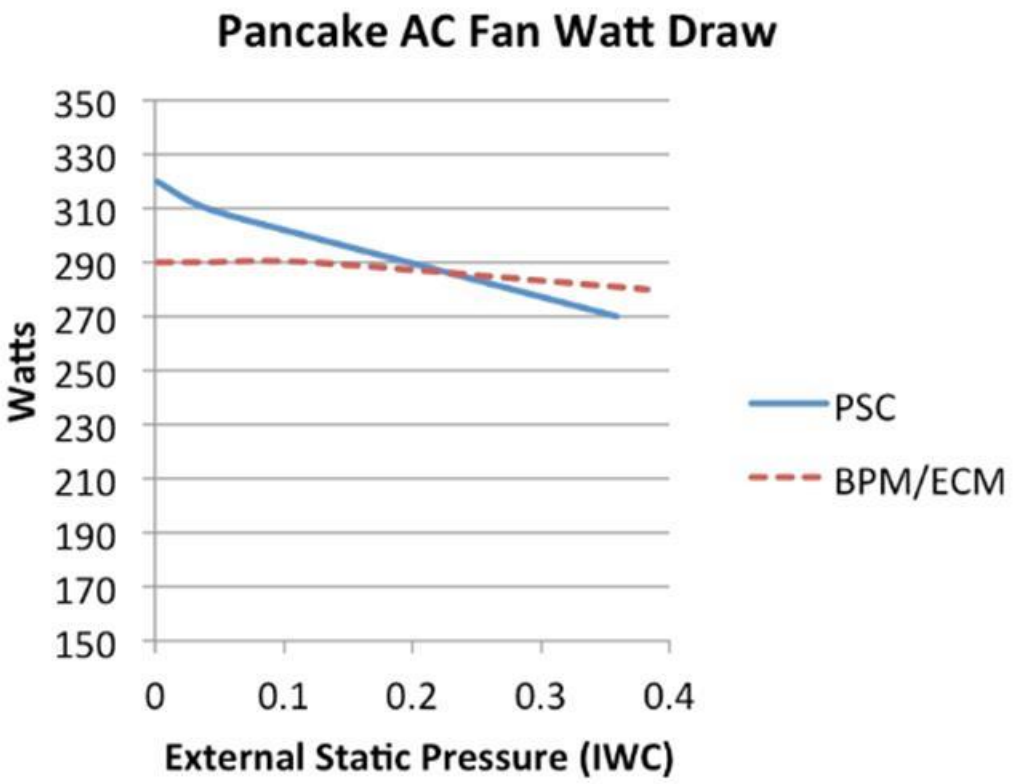
- Ignorance is not stupidity.
- Rather, it is a particular condition of knowledge: the absence of fact, understanding, insight.

ECM/BPM Motors

Dogma

- ECM/BPM Motors are more efficient than PSC Motors

Data

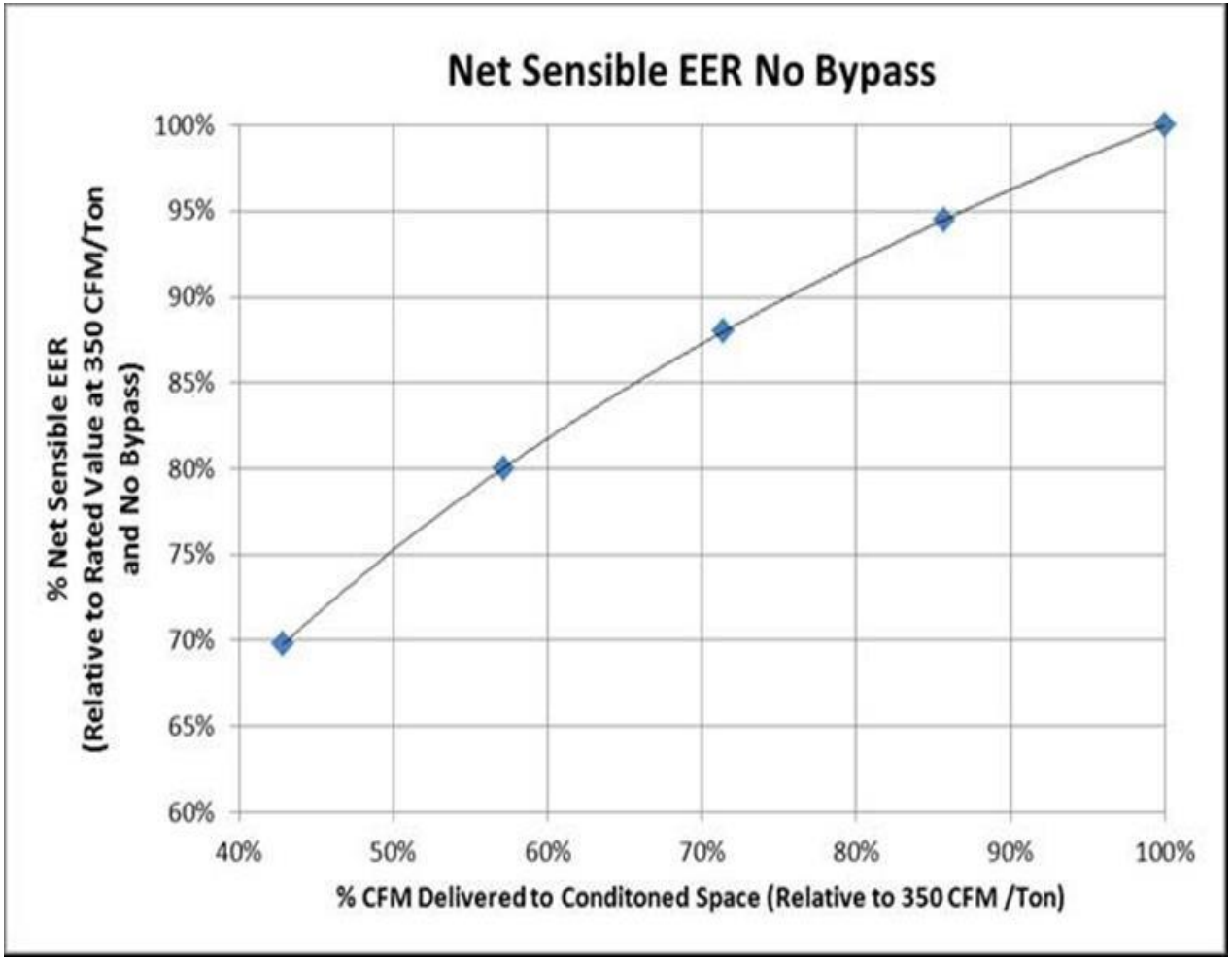


ECM/BPM Motors

Dogma

- Increasing airflow by cranking up a BPM motor is counter productive

Data



“The paradigms on which society's perception of reality are based are highly conservative. People invest heavily in these ideas, and so are heavily resistant to changing them.

They are only finally overturned by new ideas when new events occur which make the conventional wisdom appear so absurd as to be impalpable.”

The Affluent Society, John Kenneth Galbraith, 1969 (2nd ed)

Heat Pumps and Air Conditioners

Dogma

- Downsizing saves a ton of energy

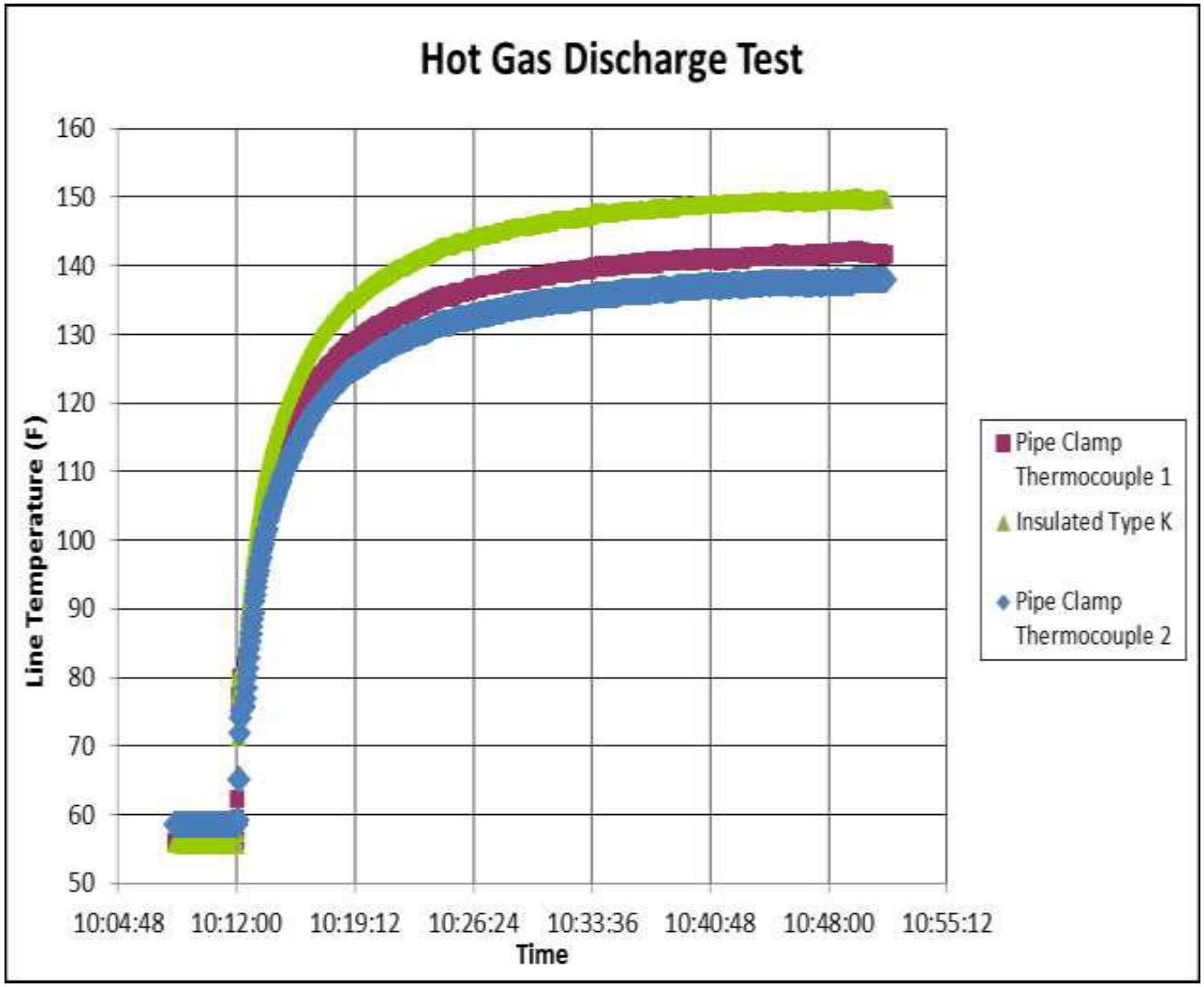
Data

- Except the existing field data do not support this

Measuring Refrigerant Line Temperatures

Dogma

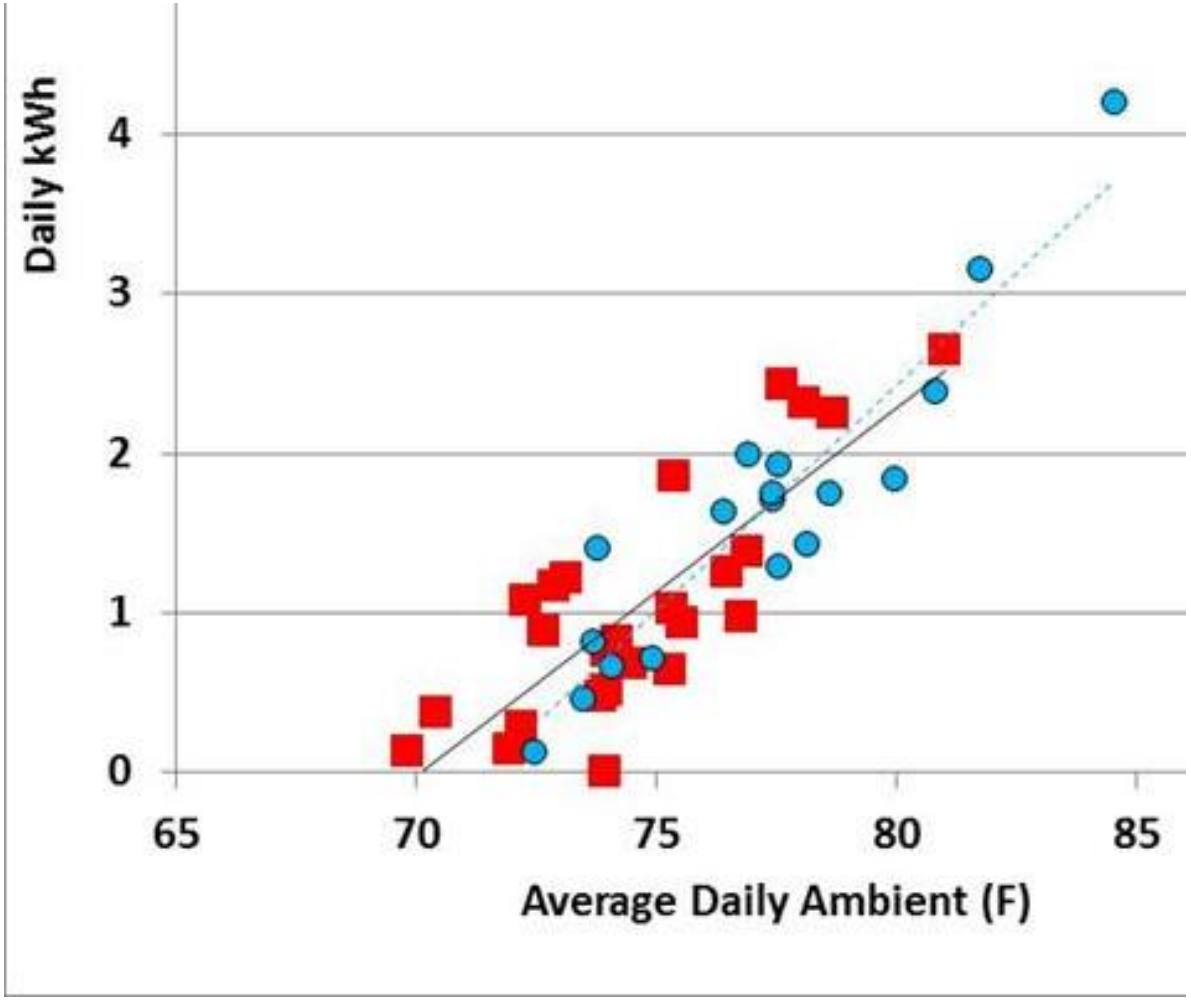
- Clamp on Sensors are the most accurate.



Efficiency from a Duct System

Dogma

- The only way to get efficiency out of a ducted system is to put it into the conditioned space!



Combustion Safety CO

Dogma

- The only legitimate test for CO an air-free CO test!

Data

Heating and Cooling

Dogma

- Zoning a ducted heating and cooling system saves a ton of money!

Data

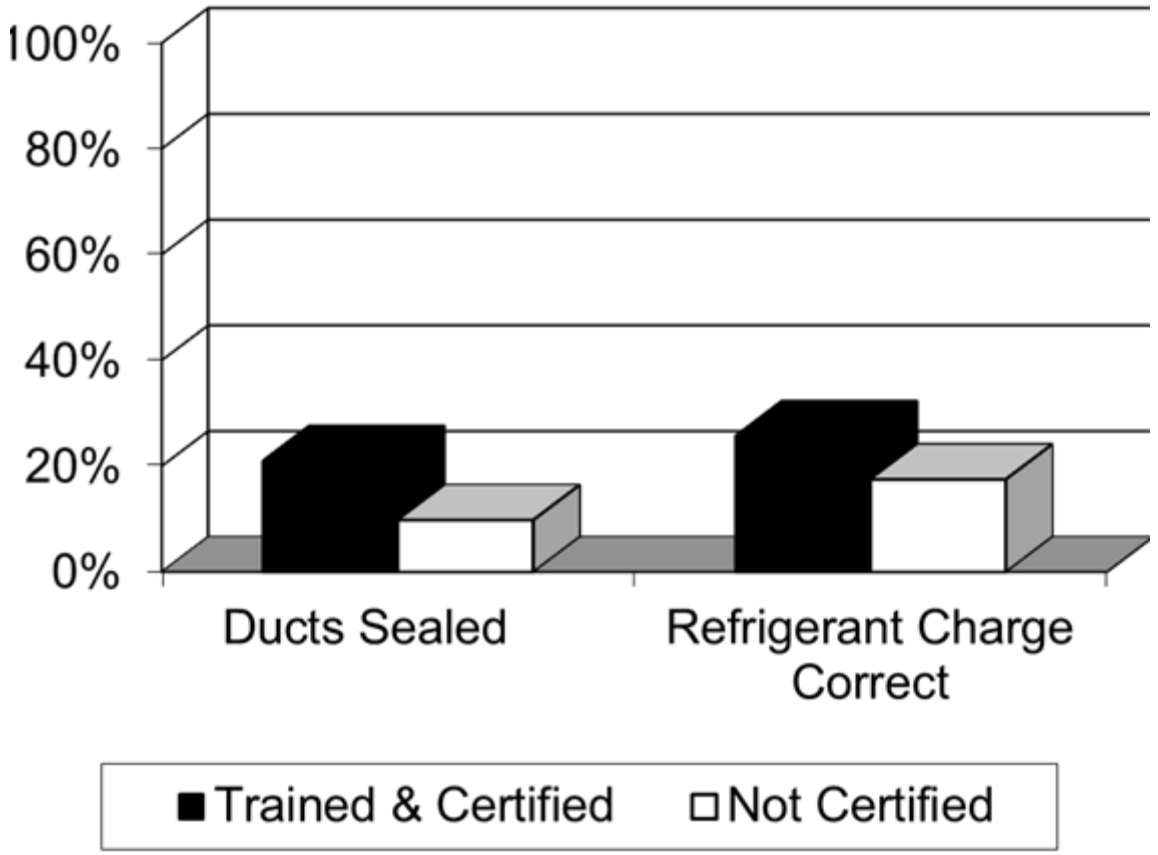
One of many reports:
"Zoning can improve thermal comfort, especially in areas that are underheated or ground coupled.

However, increased operating cost is required to achieve higher levels of thermal comfort."

Technician Performance

Dogma

- Training and Certification produces technicians that do their job right!



Standards

Dogma

- If technicians use the ACCA installation and maintenace standards, the units will work properly.

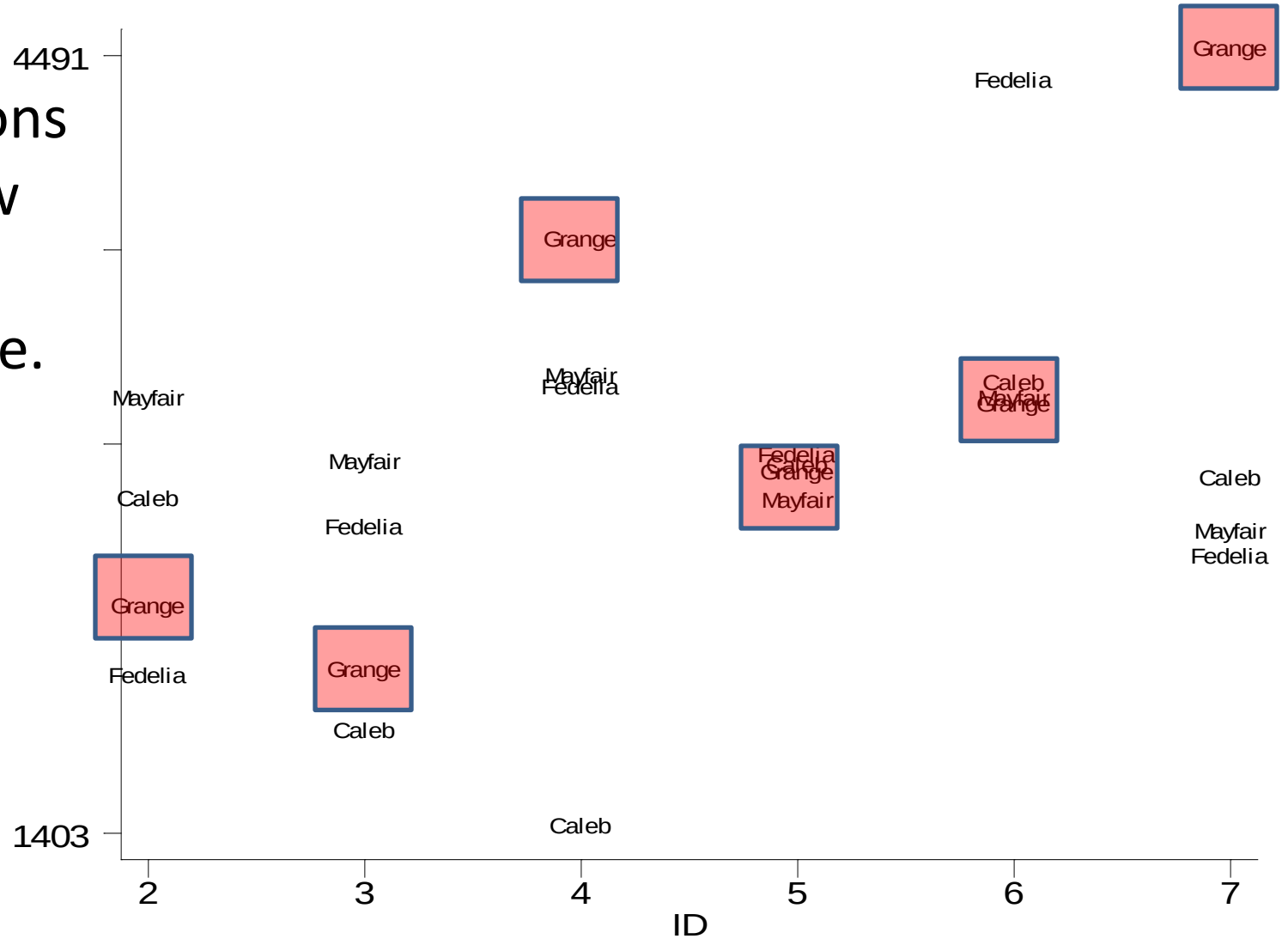
Data

- Evidence shows no change in procedures or outcomes

Dogma

Ratings

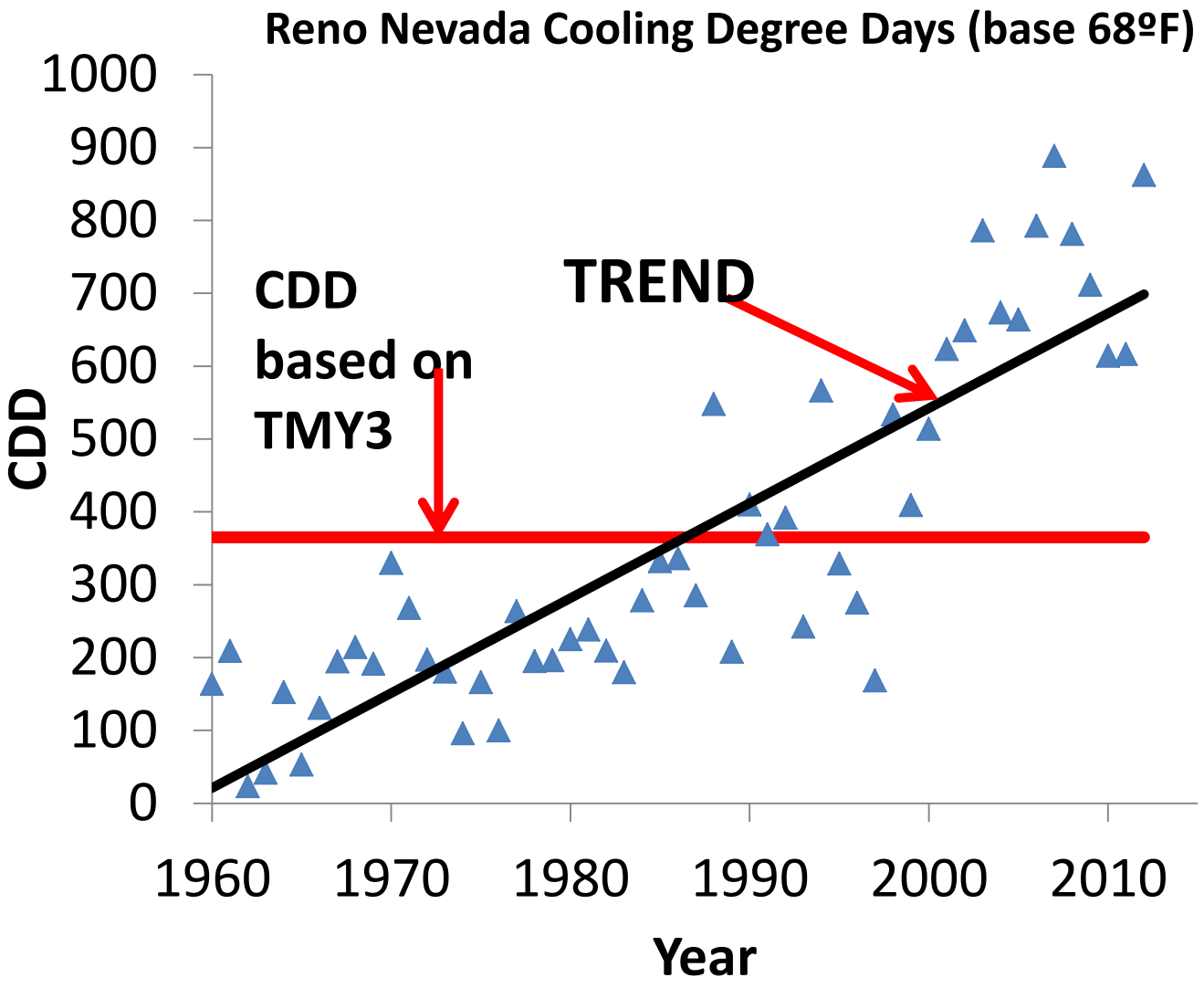
HERS Calculations show how efficient homes are.



Evaluations

Dogma

TMY3 allows you to "correct" measured data to what will happen in future years.



Program Evaluations

Dogma

- Program Evaluations determine the TRUE, REAL, ACTUAL savings from an energy efficiency measure.

Data

- They **ESTIMATE** what <u>that PROGRAM</u> saved, not the measure or its potential savings.

Cost Effectiveness TRC

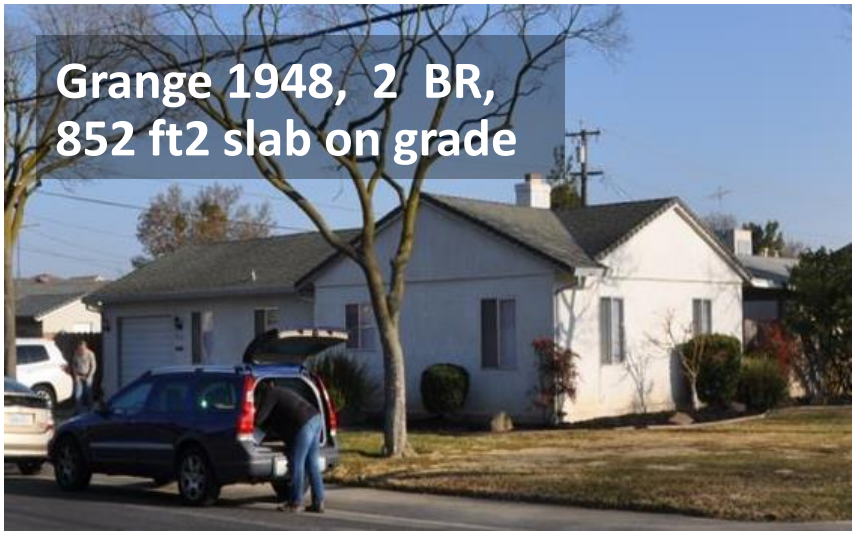
Dogma

- The consumer cost of an energy efficiency measure is what the average customer pays for "it".

Data

- The MEASURE COST is what the customer would pay **MINUS THE COST OF THE ADDITIONAL FEATURES THEY ARE BUYING**

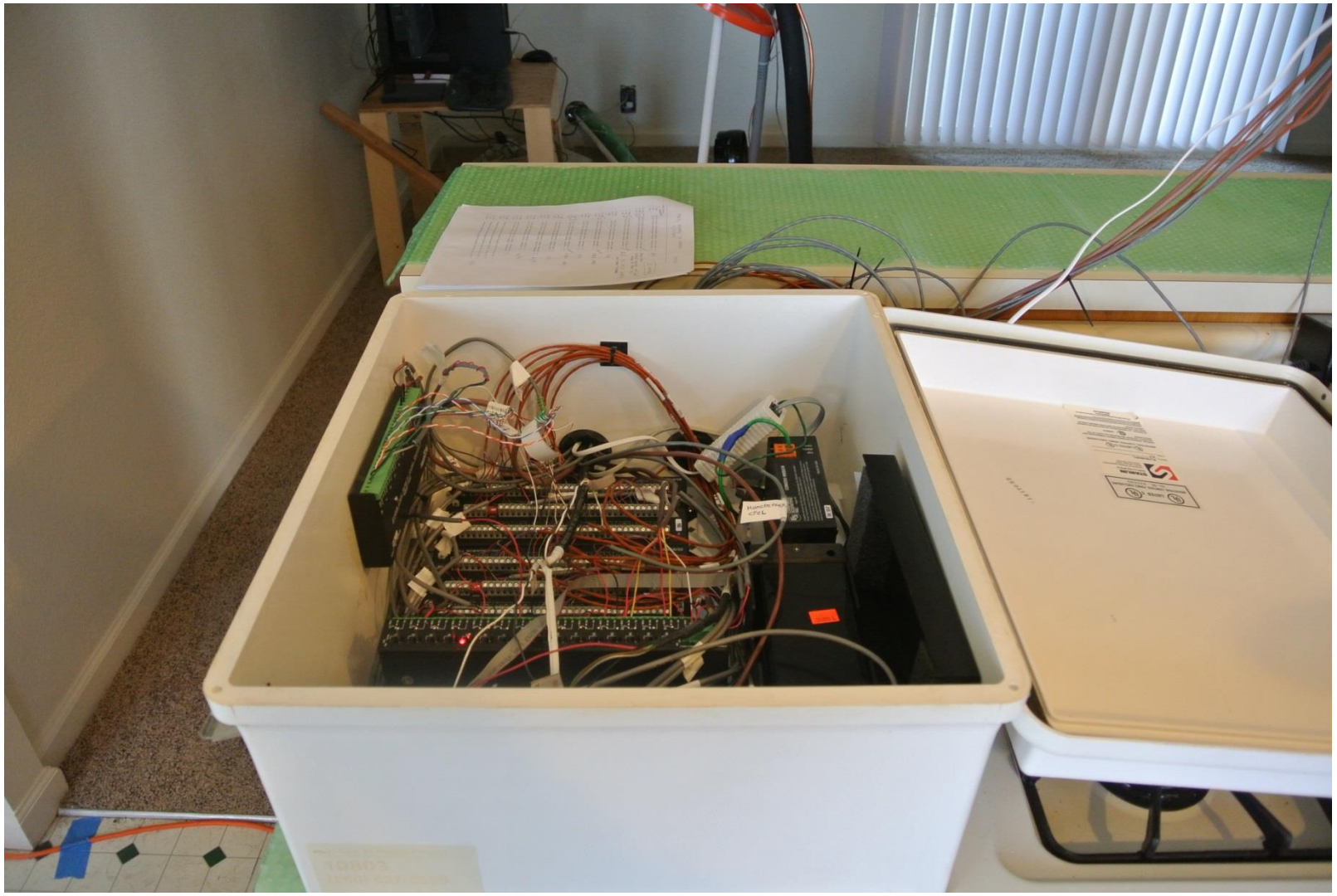
California Central Valley Four Houses



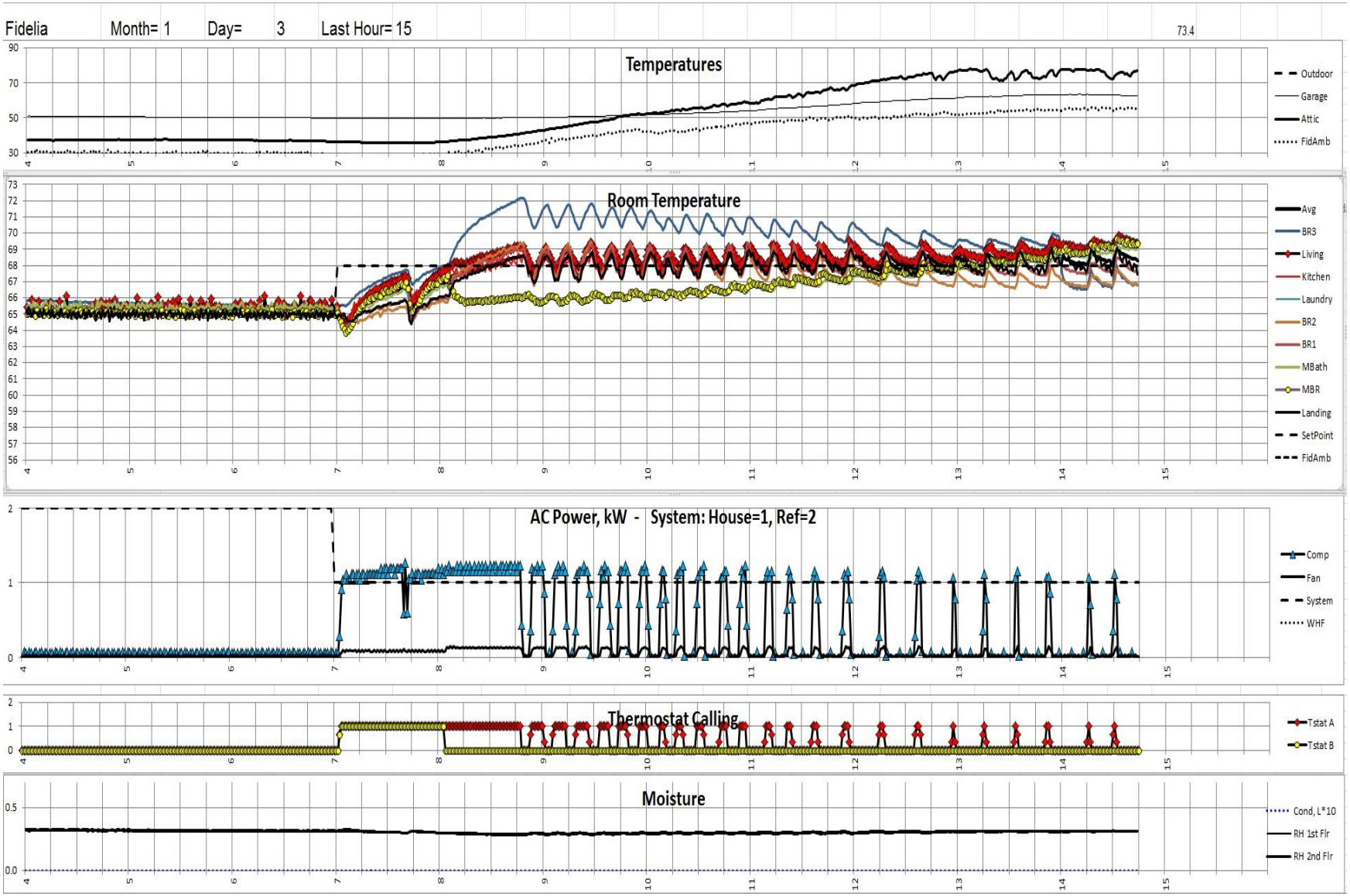
Four **Unoccupied** Houses

Simulated Occupants

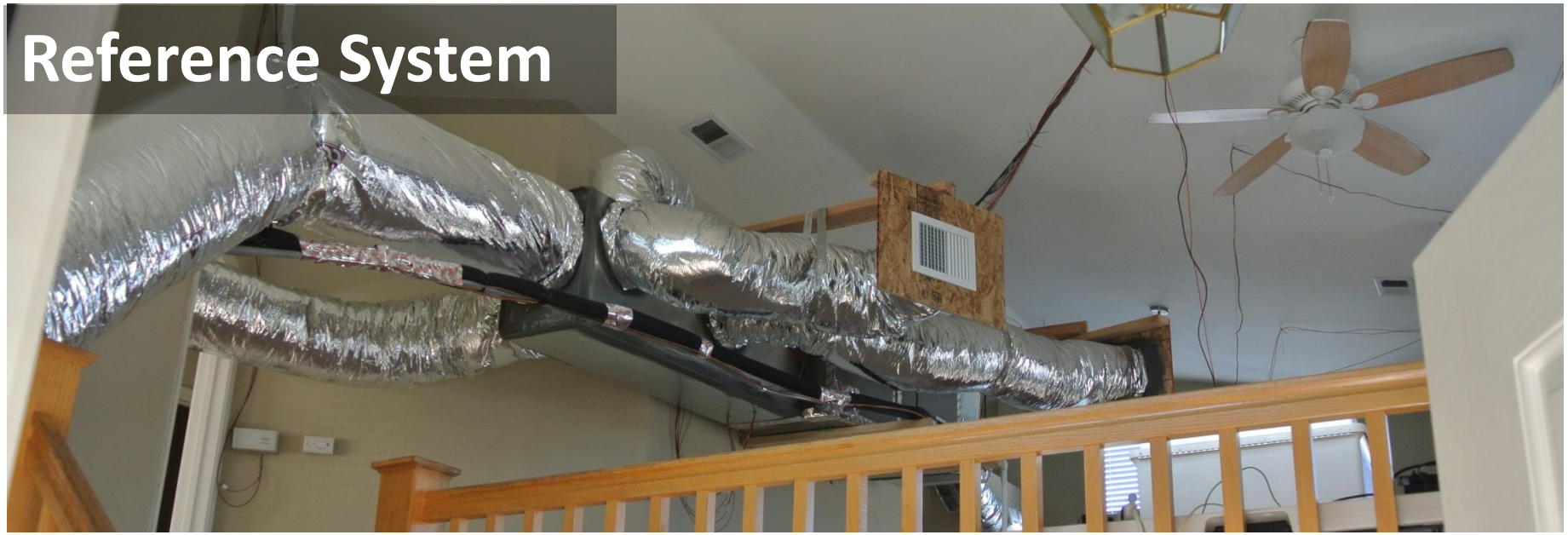
Four **Intensively Monitored** Houses



Four **Intensively Monitored** Houses


Fidelia
Month= 1
Day= 3
Last Hour= 15
73.4
Temperatures
Outdoor
Garage
Attic
FidAmb
Room Temperature
Avg
BR3
Living
Kitchen
Laundry
BR2
BR1
MBath
MBR
Landing
SetPoint
FidAmb
AC Power, kW - System: House=1, Ref=2
Comp
Fan
System
WHF
Thermostat Calling
Tstat A
Tstat B
Moisture
Cond, L*10
RH 1st Flr
RH 2nd Flr

Two Cooling Systems per House



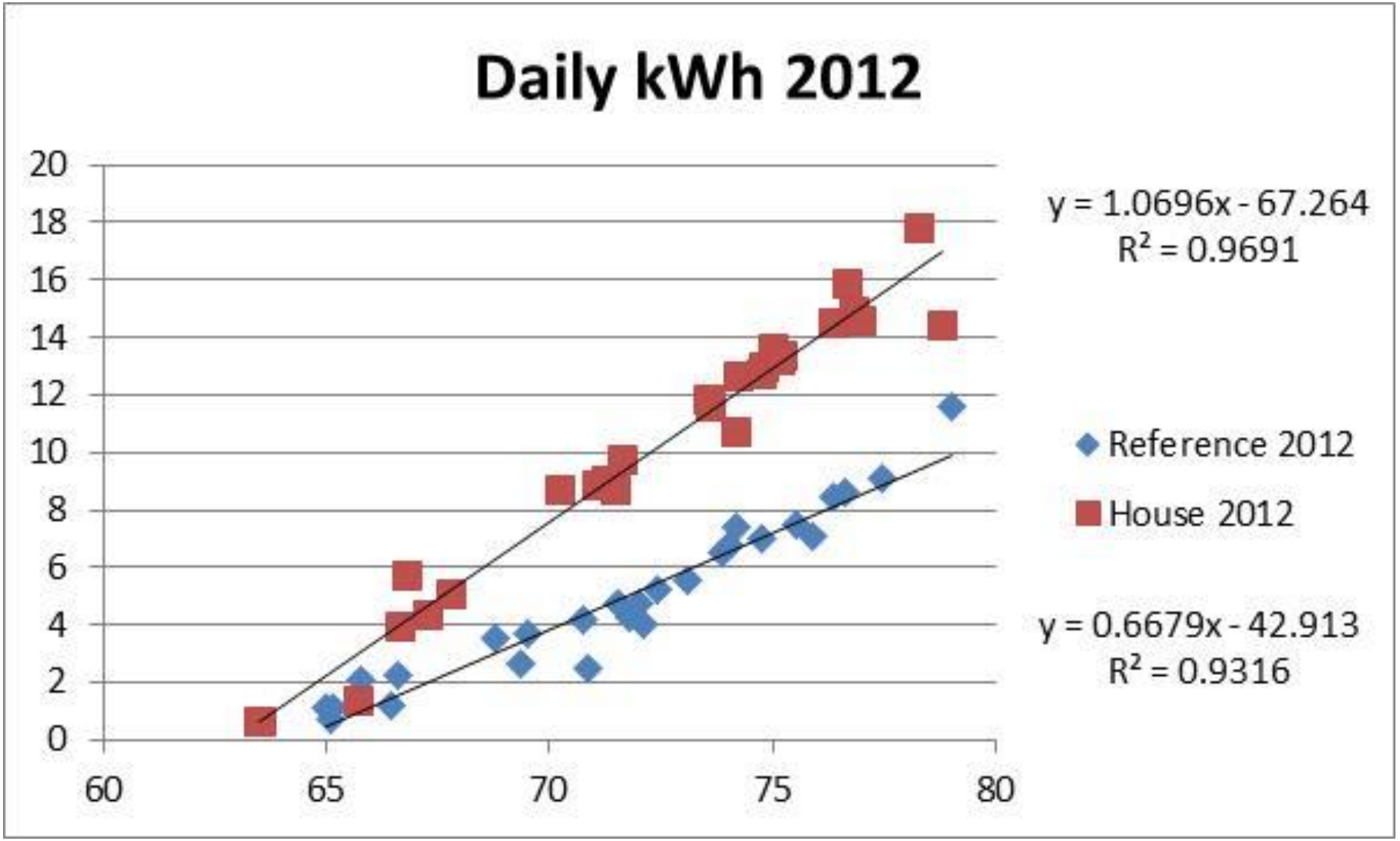
Step 1: Flip Flop Experiment

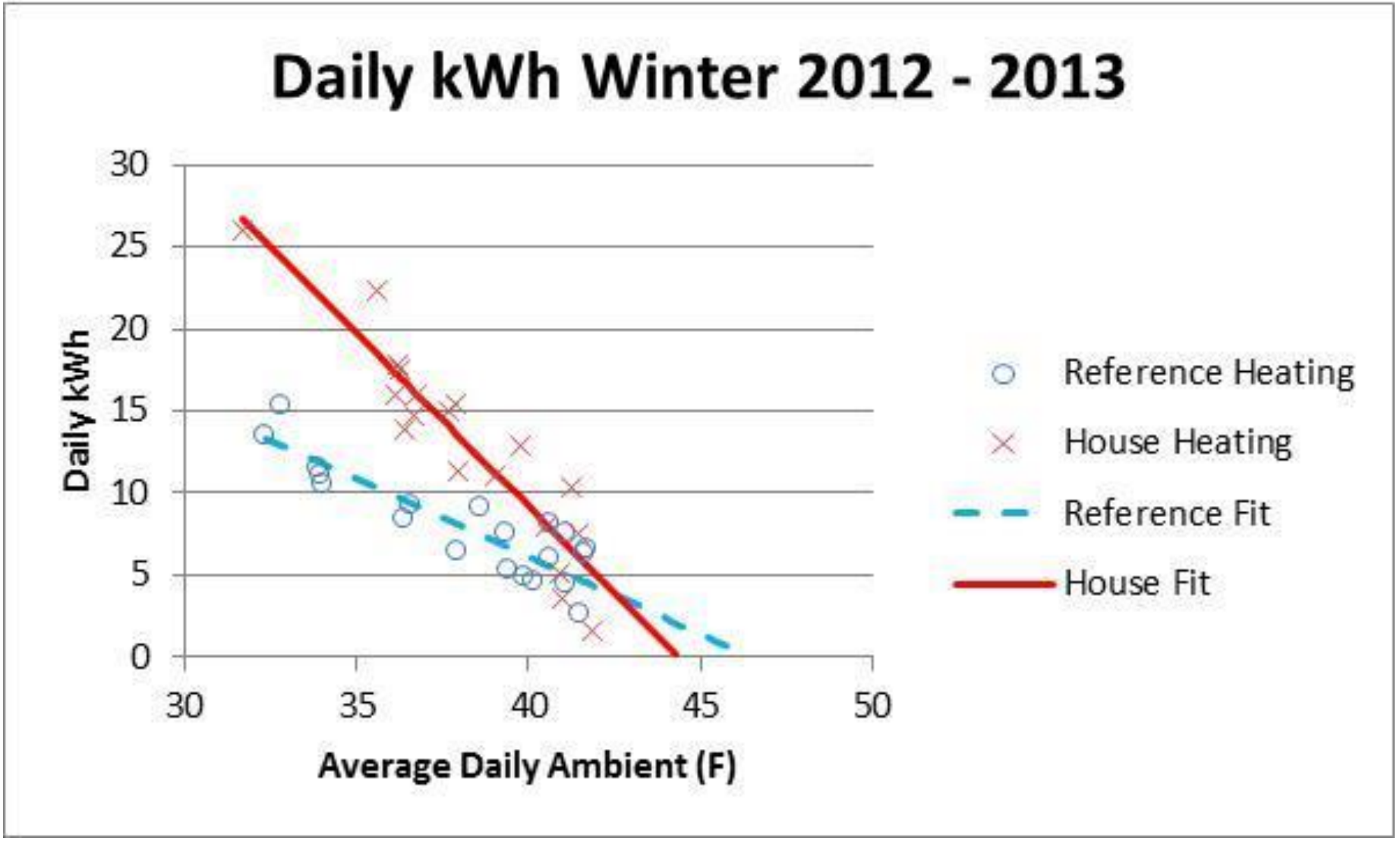
House System **Reference System**

- Switch every two days
- Simulated Occupants
- Simulated Occupant Thermostat Control
- Monitored Indoor and Outdoor Conditions (Incident Radiation, Wind, Temperature, Humidity)

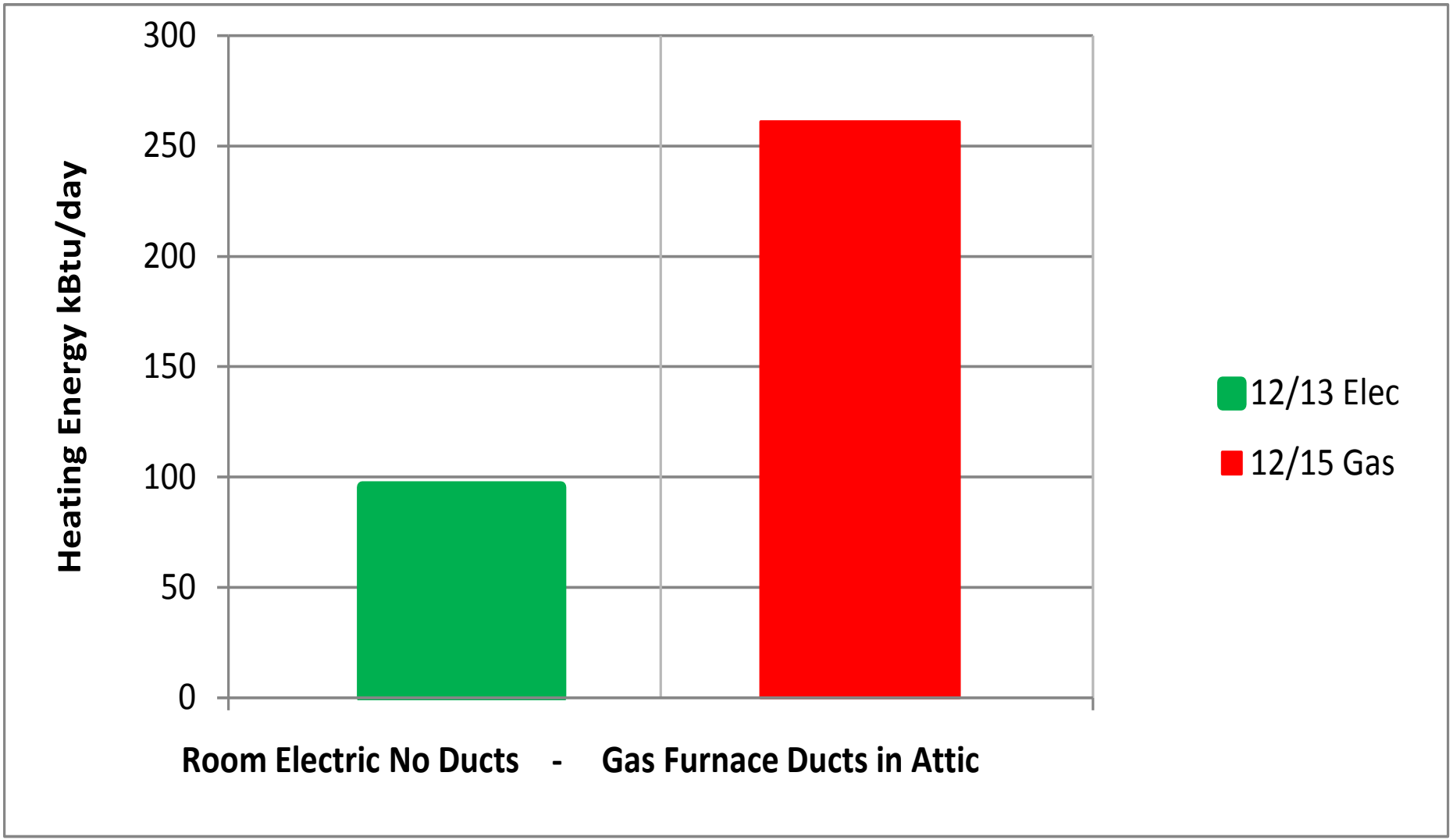
Caleb 2005, 4 BR, 2076 ft2, Approximately Current Code

HVAC & Ducts in Attic w Tile Roof


Daily kWh 2012
20
18
16
14
12
10
8
6
4
2
0
60
65
70
75
80
y = 1.0696x - 67.264
R² = 0.9691
Reference 2012
House 2012
y = 0.6679x - 42.913
R² = 0.9316


Daily kWh Winter 2012 - 2013
Daily kWh
30
25
20
15
10
5
0
30
35
40
45
50
Average Daily Ambient (F)
Reference Heating
House Heating
Reference Fit
House Fit

2012 Caleb Site Heating Energy
2 Similar days in December



Step 2 - Retrofits

House As Found (Yr 1)

- Forced Air Zoned Dampered System (2 Zones no Bypass)
- 9.25 EER 4 Ton AC
- Coil Airflow 215 CFM/ton
- 0.98 External Static Pressure
- ½ HP PSC Fan Motor (584W)
- No Nighttime Ventilation
- No Radiant Barrier or Roof Insulation

House After Retrofits

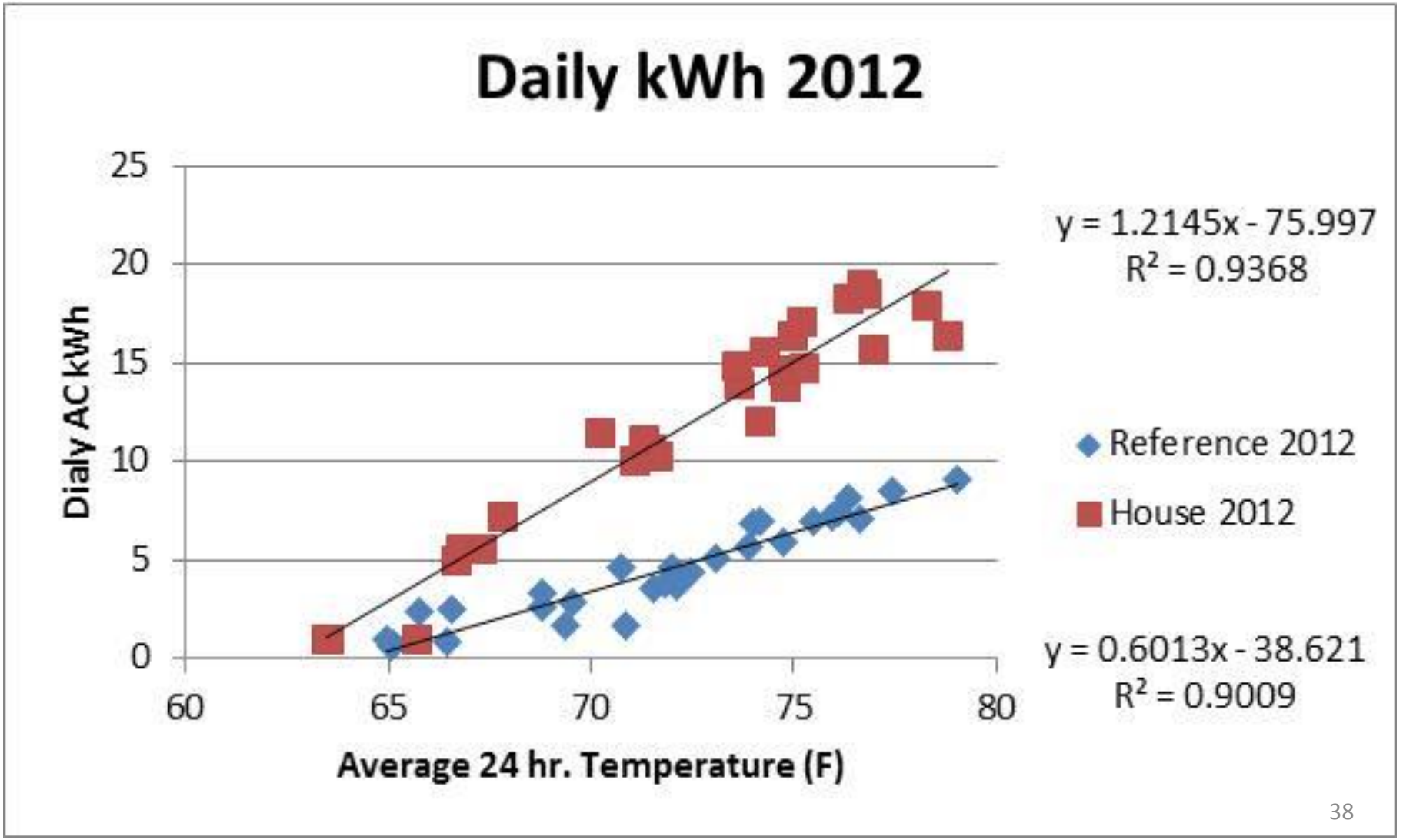
- Capacity Shift Zoning by use of Damper Stops
- Replaced Outside Unit only 11 EER 2.5 Ton AC
- Coil Airflow 443 CFM/ton
- 0.41 External Static Pressure
- ½ HP Concept3™ (293W)
- 2075 CFM Whole House Fans on Schedule
- Foam “Globs” Under Roof Tile

Caleb Annual Cooling Savings by Situation

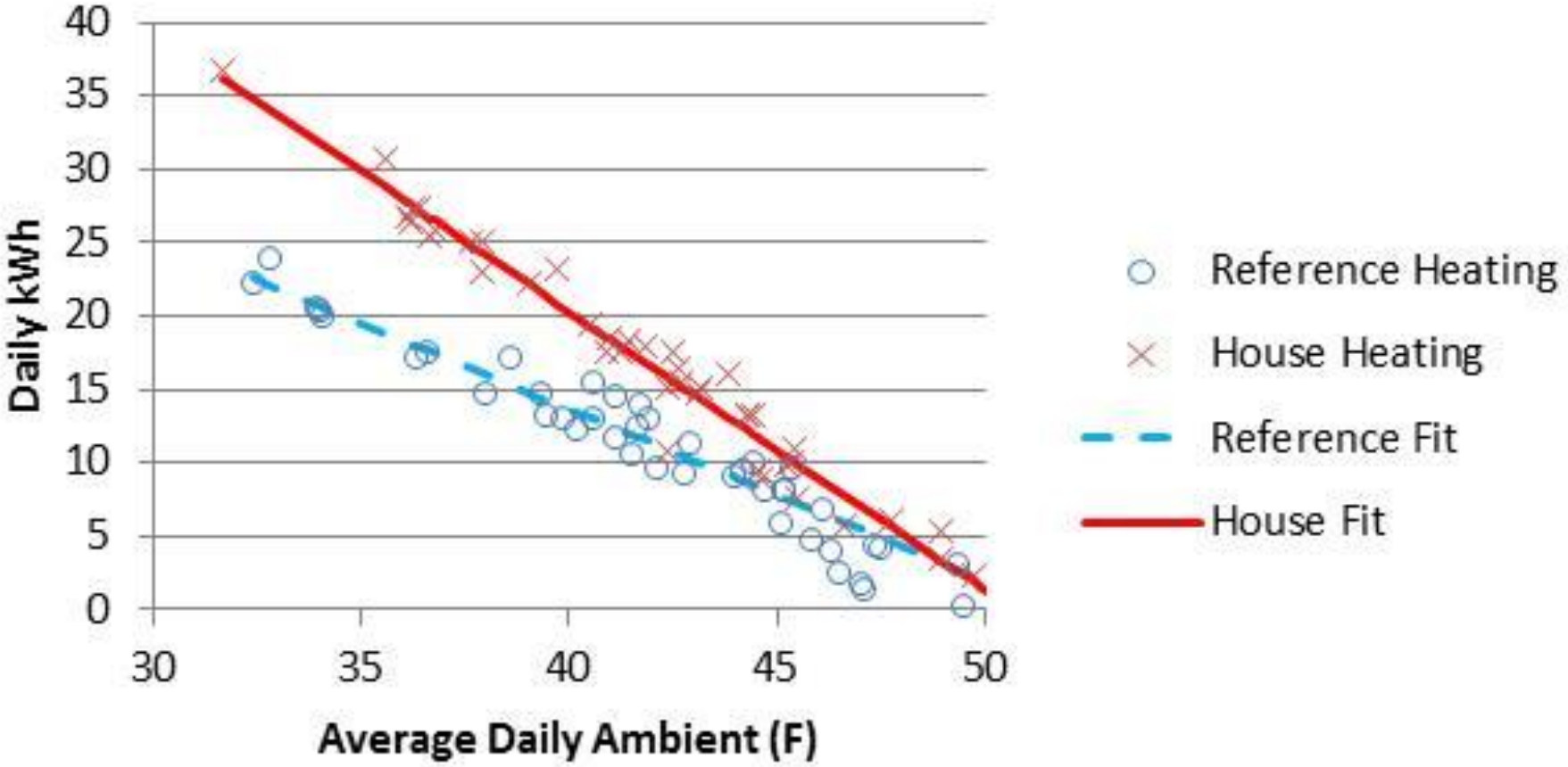
House Savings (Shell and System) between As Found and Retrofit Round Number 1	Shell Savings based on Reference System between As Found and Retrofit Round Number 1
35%	**12%**
HVAC System Savings between As Found and Retrofit Round Number 1	Retrofit Round 2 will further determine the effect of Whole House Fans, 62.2 Level Ventilation, and Roof Retrofit
27%	

Fidelia - Built 1996, 4 BR, 1690 ft2, slab on grade

Fidelia


Daily kWh 2012
Dialy AC kWh
25
20
15
10
5
0
60
65
70
75
80
Average 24 hr. Temperature (F)
y = 1.2145x - 75.997
R² = 0.9368
Reference 2012
House 2012
y = 0.6013x - 38.621
R² = 0.9009

Fidelia Daily kWh Winter 2012 - 2013



Step 2 - Retrofits

House As Found (Yr 1)

- 1625 CFM50
- R-30 Attic Insulation
- Double Pane Aluminum Windows 0.7 SHGC 0.65 U
- No Nighttime Ventilation
- No 62.2 Ventilation

House After Retrofits

- Air Sealing Top Plates and Penetrations 1168 CFM50
- Replaced with R-49
- Vinyl windows E3 glass SHGC-0.25 U-0.30
- 1593 CFM Whole House Fans on Schedule
- 62.2 Ventilation

Step 2 - Retrofits

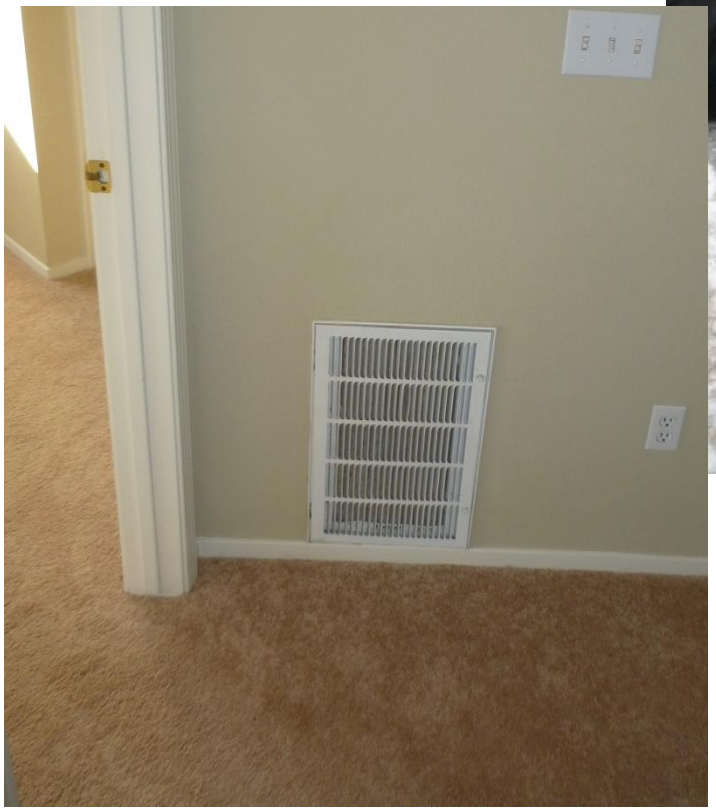
HVAC As Found (Yr 1)

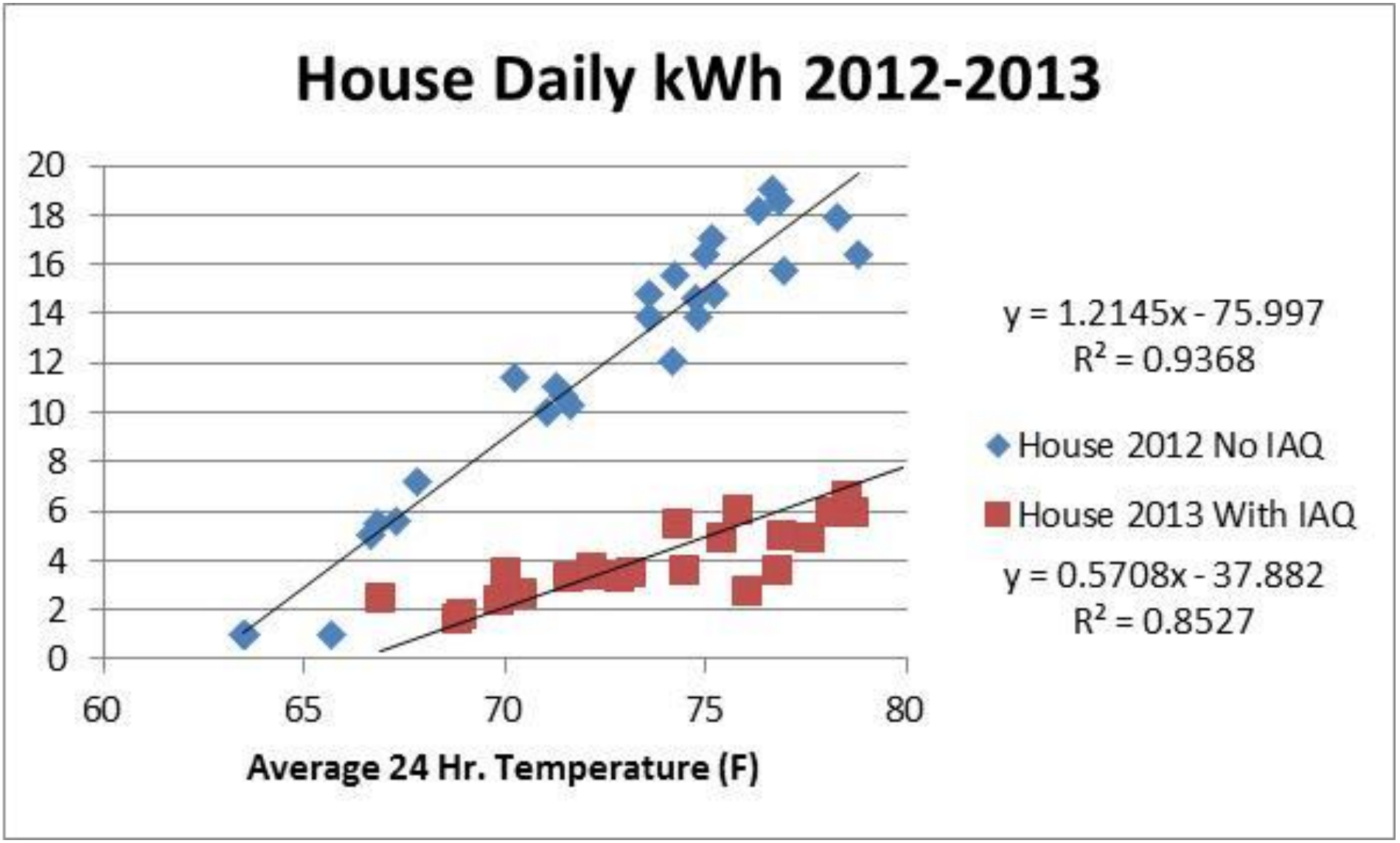
- Single Zone Ducts between floors and Spider system in Attic R-4.2
- 3.5 Ton 9 EER Split AC with 0.80 AFUE Furnace
- Coil Airflow 390 CFM/ton
- ½ HP PSC Fan Motor (554W)

HVAC After Retrofits

- Capacity Shift Zoning (damper stops) with upstairs ducts inside dropped ceiling R-8 Delivering to inside walls
- 1.4 (2) Ton 9.5 EER Heat Pump
- Coil Airflow 541 CFM/ton
- ECM/BPM Fan Motor (78W)

Original Duct System

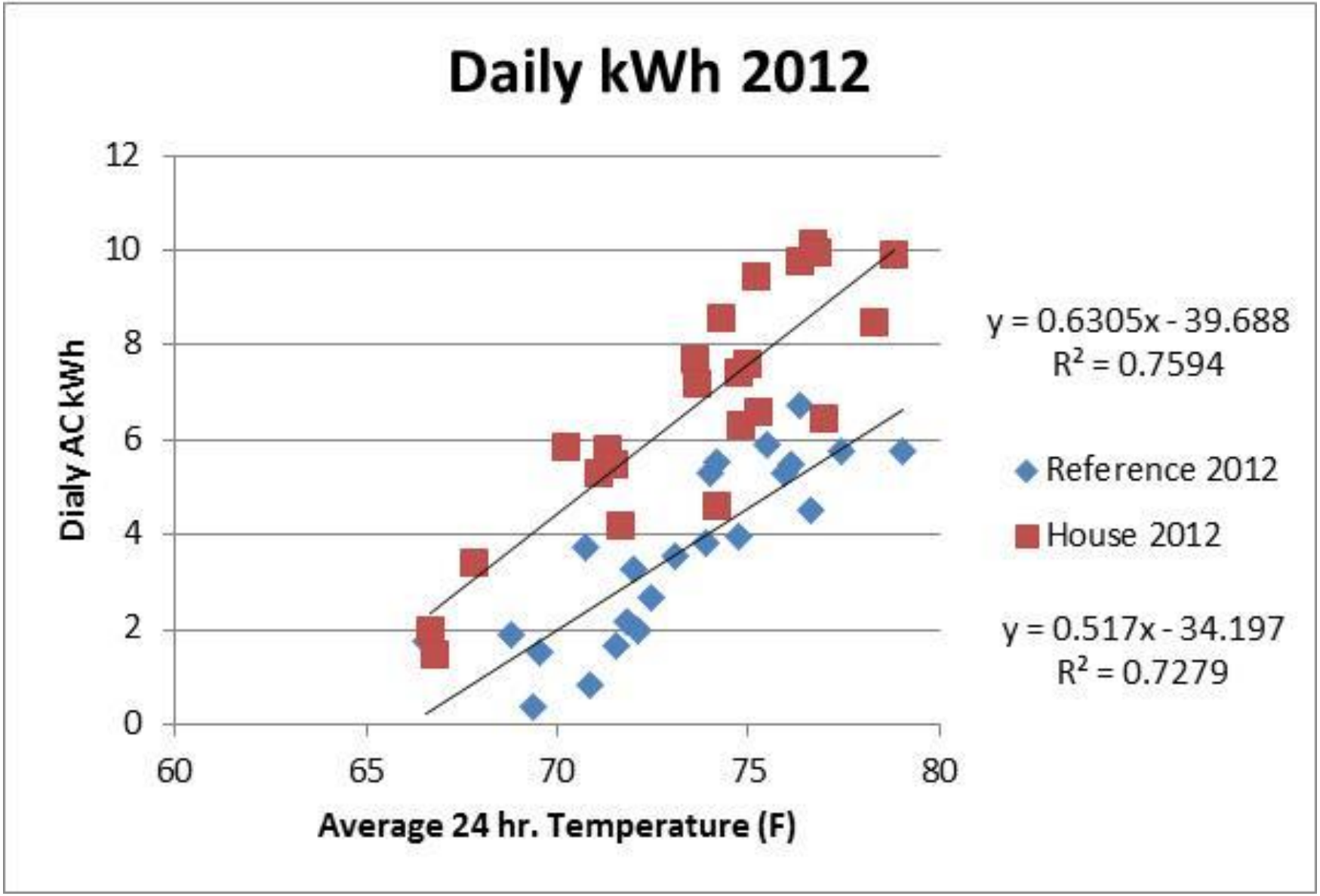


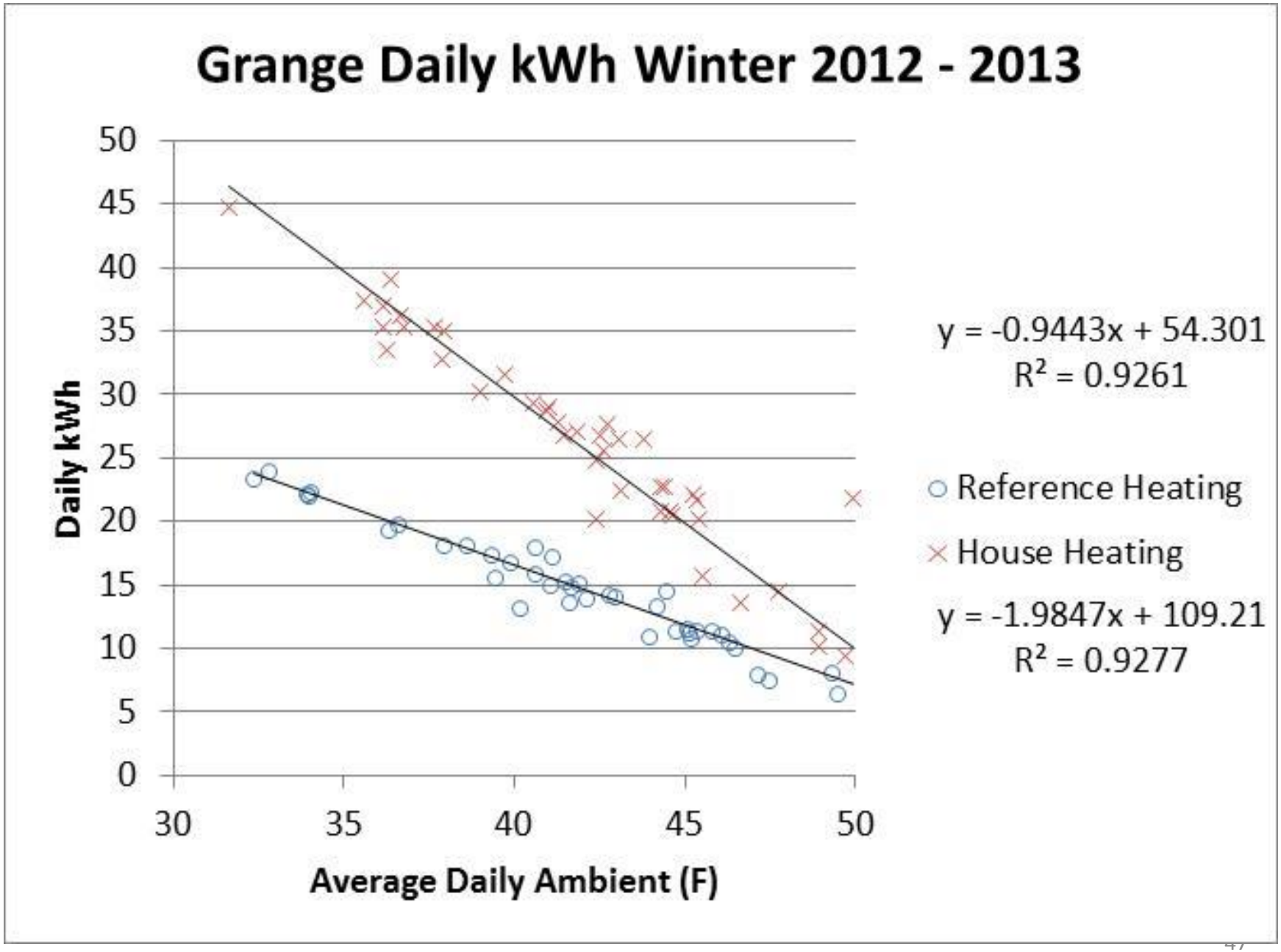

House Daily kWh 2012-2013
20
18
16
14
12
10
8
6
4
2
0
60
65
70
75
80
Average 24 Hr. Temperature (F)
y = 1.2145x - 75.997
R² = 0.9368
House 2012 No IAQ
House 2013 With IAQ
y = 0.5708x - 37.882
R² = 0.8527

Fidelia Annual Cooling Savings by Situation

As Found House HVAC System Efficiency vs. Ref System	Retrofitted House HVAC System Efficiency vs. Ref System
42%	**100%**
Savings from Shell & HVAC between As Found and Retrofit Round Number 1	Shell Savings between As Found and Retrofit Round Number 1
71%	**32%**
HVAC Savings between As Found and Retrofit Round Number 1	
57%	

Grange - Built 1948, 2 BR, 852 ft2, slab on grade


Daily kWh 2012
Dialy AC kWh
12
10
8
6
4
2
0
60
65
70
75
80
Average 24 hr. Temperature (F)
y = 0.6305x - 39.688
R² = 0.7594
Reference 2012
House 2012
y = 0.517x - 34.197
R² = 0.7279


Grange Daily kWh Winter 2012 - 2013
Daily kWh
50
45
40
35
30
25
20
15
10
5
0
30
35
40
45
50
Average Daily Ambient (F)
y = -0.9443x + 54.301
R² = 0.9261
Reference Heating
House Heating
y = -1.9847x + 109.21
R² = 0.9277

Foil insulated ceiling and walls

Single glazed aluminum sliders

Open Fireplace Cavity

Step 2 - Retrofits

House As Found (Yr 1)

- 762 CFM50
- R-5? Foil Attic Insulation
- R-5? Foil Wall Insulation
- Single Pane Aluminum Windows 1.1 U
- No Nighttime Ventilation
- No 62.2 Ventilation

House After Retrofits

- Air Sealing Fireplace Chase and Other Leaks 438 CFM50
- Replaced with R-49
- Replaced with R-10 Drill and Fill (2.5” Cavities)
- Vinyl windows E3 glass SHGC-0.25 U-0.30
- 1105 CFM Whole House Fans on Schedule
- 62.2 Ventilation

Step 2 - Retrofits

HVAC As Found (Yr 1)

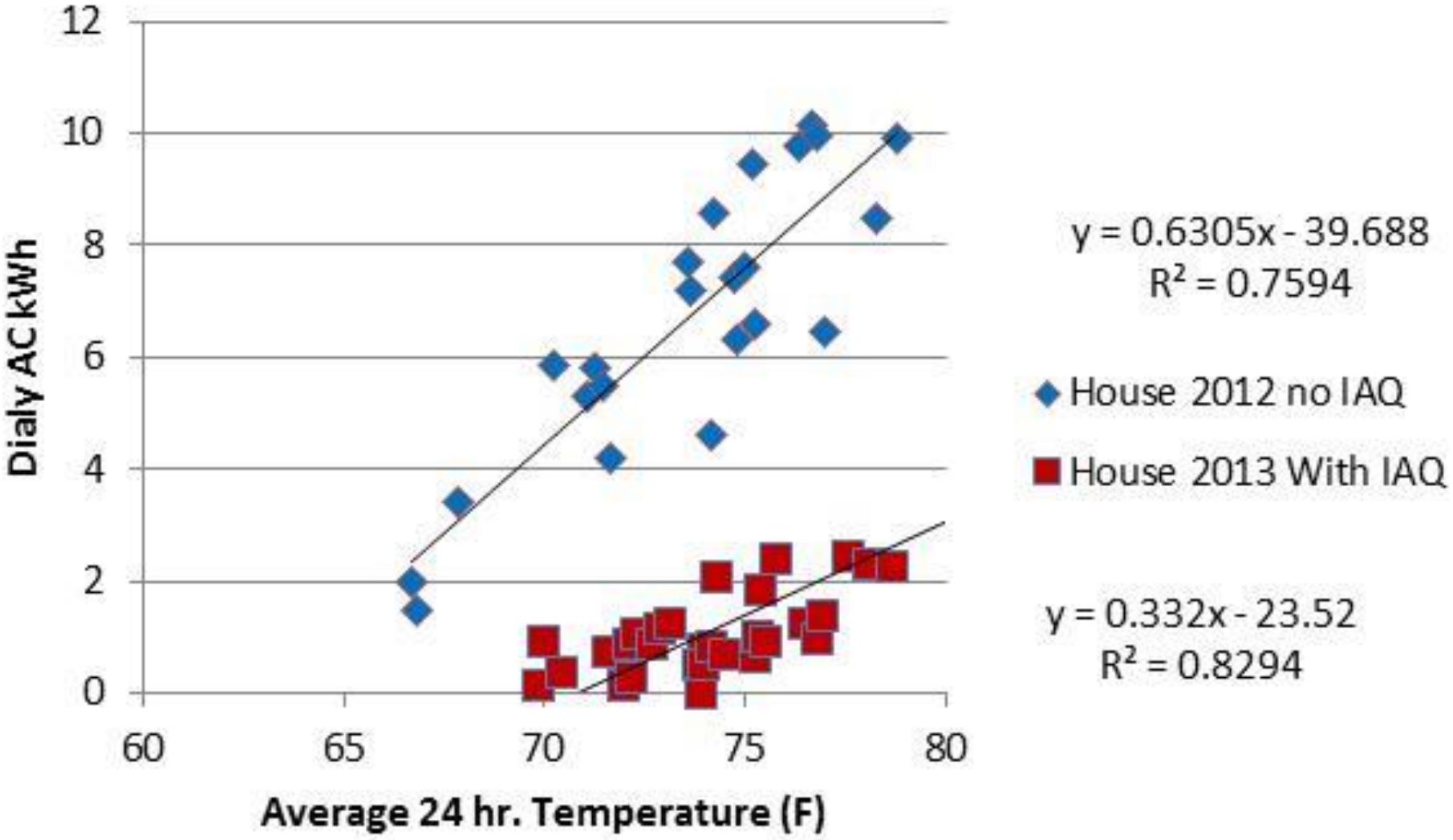
- Attic Ducts Branched Supply
  38’10” long 14” dia. return
  Surface Area 33% of Floor A
  95 CFM25 Leakage R-4.2
- 2.5 Ton 9.5 EER Split AC
  (2485 W) with 0.80 AFUE
  Furnace
- Coil Airflow 219 CFM/ton
- 1/3 HP PSC Fan Motor (361W)

HVAC After Retrofits

- Return Shortened to 5 ft.
  Single 14” dia. trunk duct
  system with delivery box in
  new dropped ceiling in hall.
  Delivering to inside walls
  9 CFM25 Leakage R-8 Buried
  (R-25?)
- 1 Ton (compressor 11 EER 980
  W) TXV to 6^{o} Superheat
  Reorificed Furnace
- Coil Airflow 540 CFM/ton
- Concept3™ BPM Fan Motor
  (80W)

Attic Air Sealing

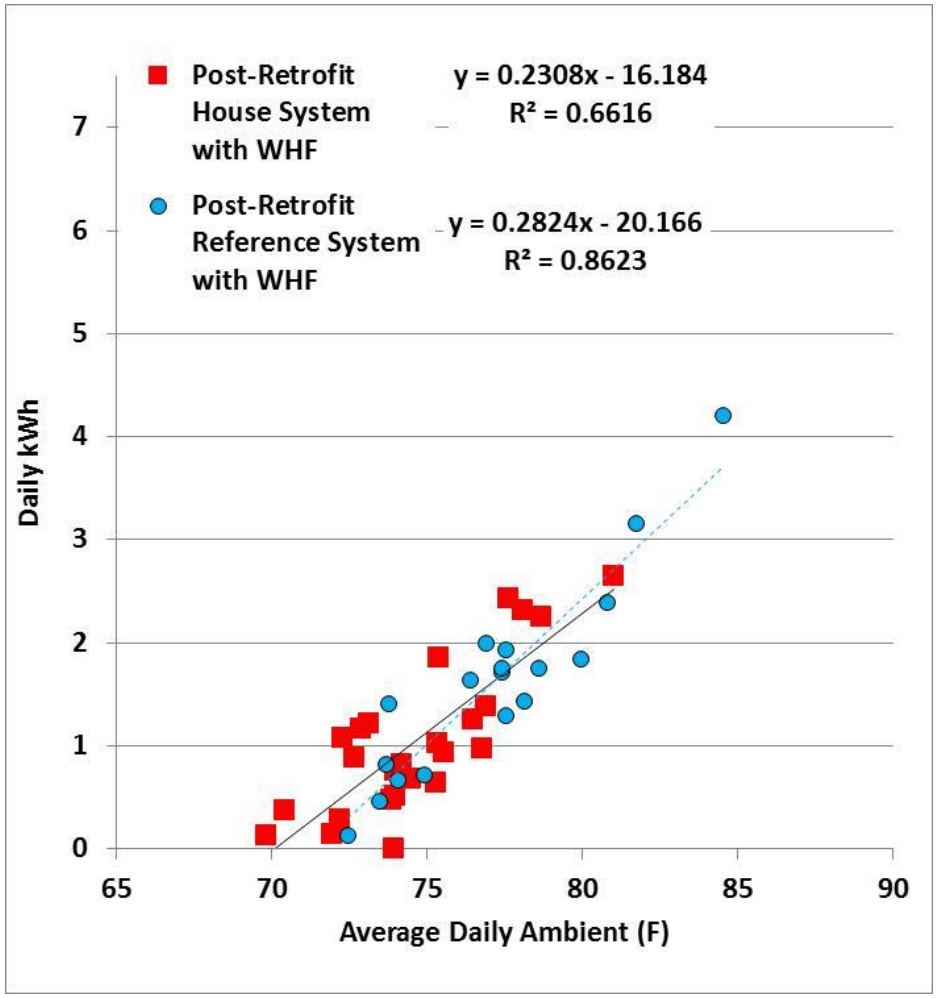
House Daily kWh 2012-2013

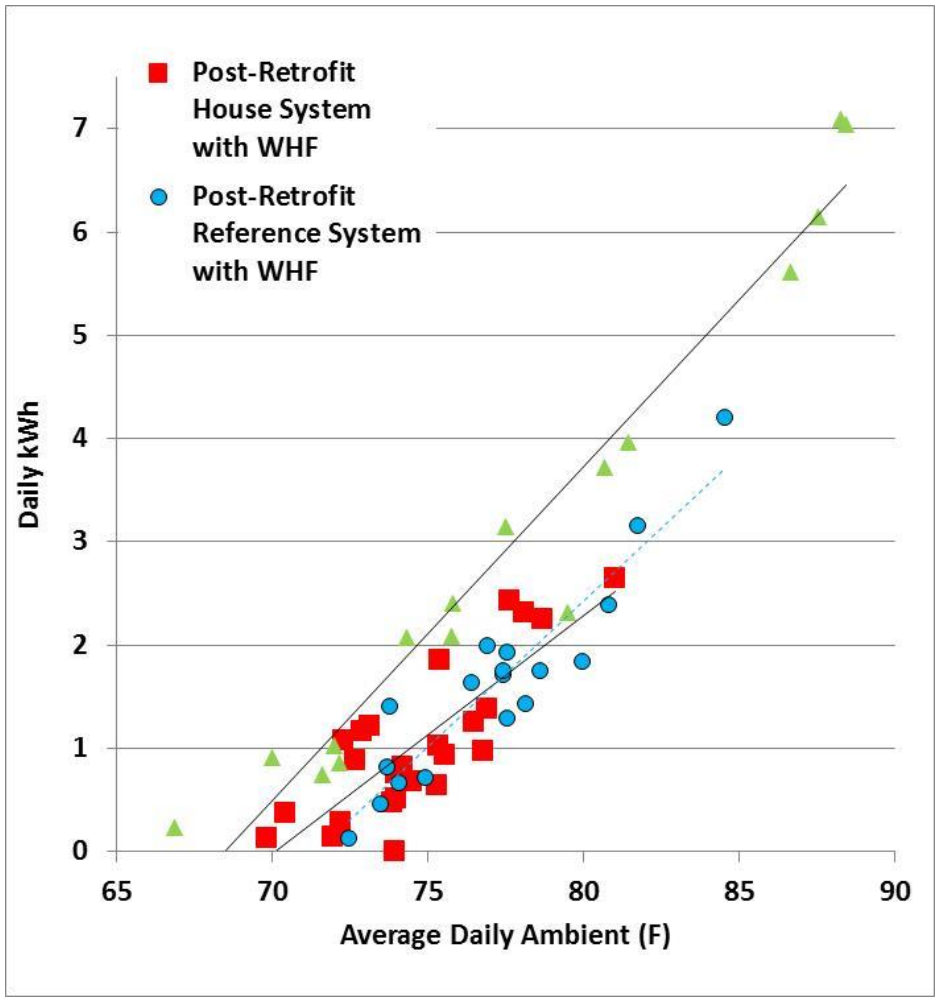


Grange Annual Cooling Savings by Situation

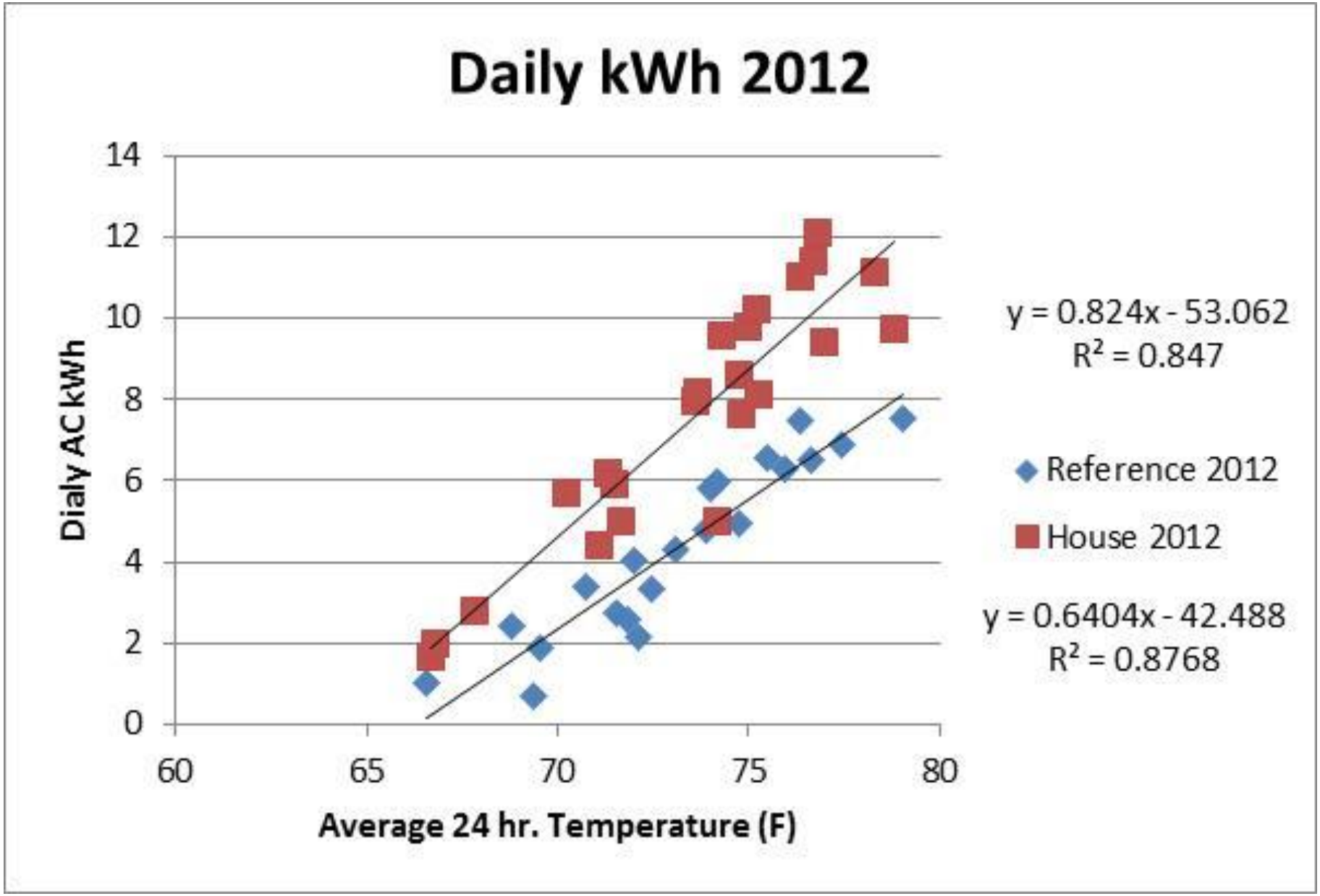
As Found House HVAC System Efficiency vs. Ref System	Retrofitted House HVAC System Efficiency vs. Ref System
65%	**95%**
Savings from Shell & HVAC between As Found and Retrofit Round Number 1	Shell Savings between As Found and Retrofit Round Number 1
73%	**61%**
HVAC Savings between As Found and Retrofit Round Number 1	
31%	

Grange

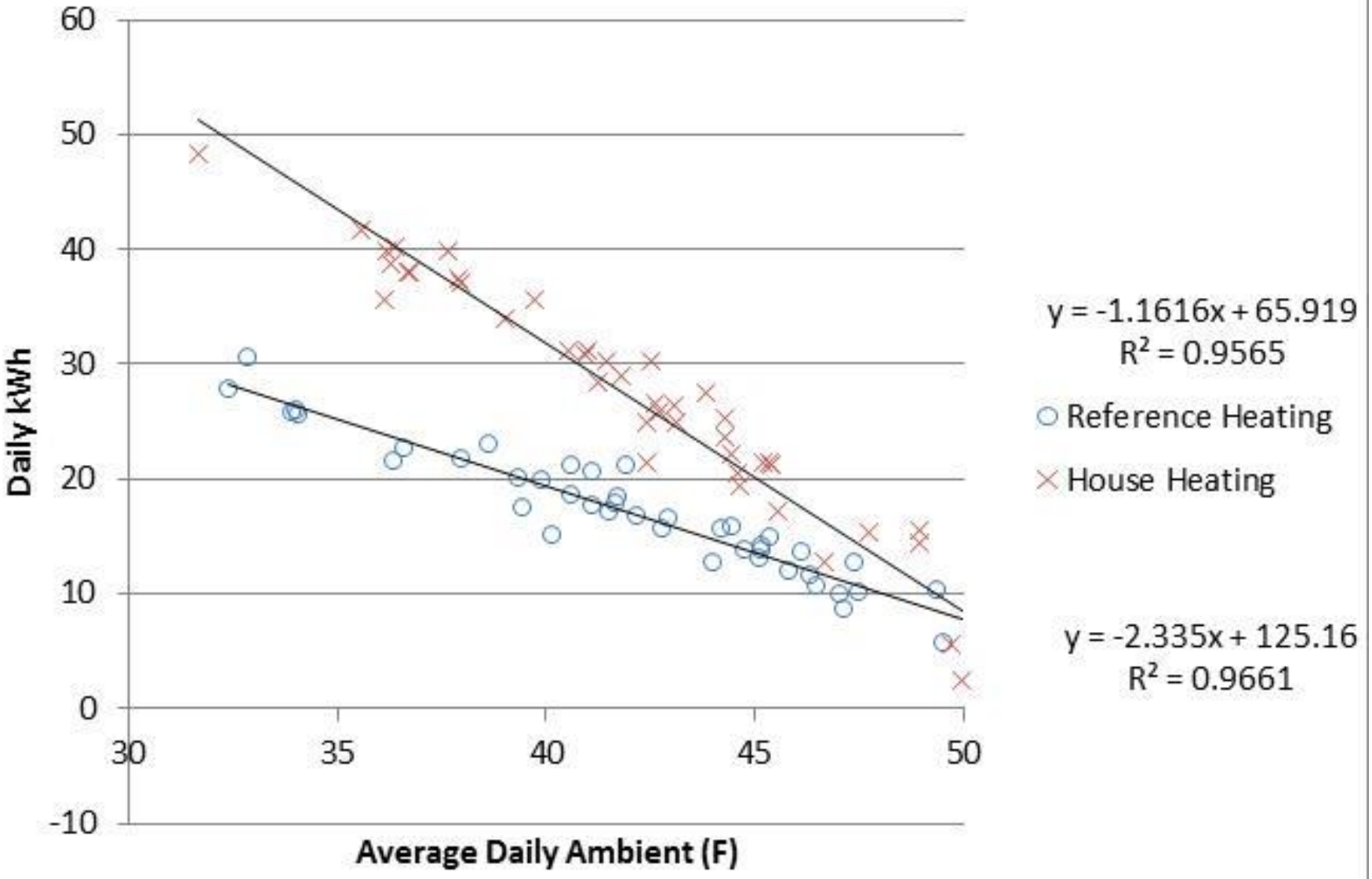

Post-Retrofit House System with WHF
y = 0.2308x - 16.184
R² = 0.6616
Post-Retrofit Reference System with WHF
y = 0.2824x - 20.166
R² = 0.8623
Daily kWh
Average Daily Ambient (F)
0
1
2
3
4
5
6
7
65
70
75
80
85
90


Post-Retrofit House System with WHF
Post-Retrofit Reference System with WHF
Daily kWh
Average Daily Ambient (F)
0
1
2
3
4
5
6
7
65
70
75
80
85
90

Mayfair - Built 1953, 3 BR, 1104 ft2, crawl space


Daily kWh 2012
Dialy AC kWh
14
12
10
8
6
4
2
0
60
65
70
75
80
Average 24 hr. Temperature (F)
y = 0.824x - 53.062
R² = 0.847
Reference 2012
House 2012
y = 0.6404x - 42.488
R² = 0.8768

Mayfair Daily kWh Winter 2012 - 2013



Insulation Ceiling Minimal Wall & Floor None New HVAC

Only 3 Months Old

Steel Casement Single Glazed

Step 2 - Retrofits

House As Found (Yr 1)

- 1437 CFM50
- R-11 Attic Insulation
- No Wall Insulation
- Single Pane Steel Casement Windows 1.1 U
- No Nighttime Ventilation
- No 62.2 Ventilation

House After Retrofits

- 212 CFM50 Reduction
- Replaced with R-49
- Drill and Fill to R-13
- Vinyl windows E3 glass SHGC-0.25 U-0.30
- 1520 CFM Whole House Fans on Schedule
- 62.2 Ventilation

Step 2 - Retrofits

HVAC As Found (Yr 1)

- Attic Ducts Branched Supply with long return
  107 CFM25 Leakage R-6
- 2.5 Ton 11.5 EER Package AC
- Coil Airflow 362 CFM/ton
- X13 Fan Motor (320W)

HVAC After Retrofits

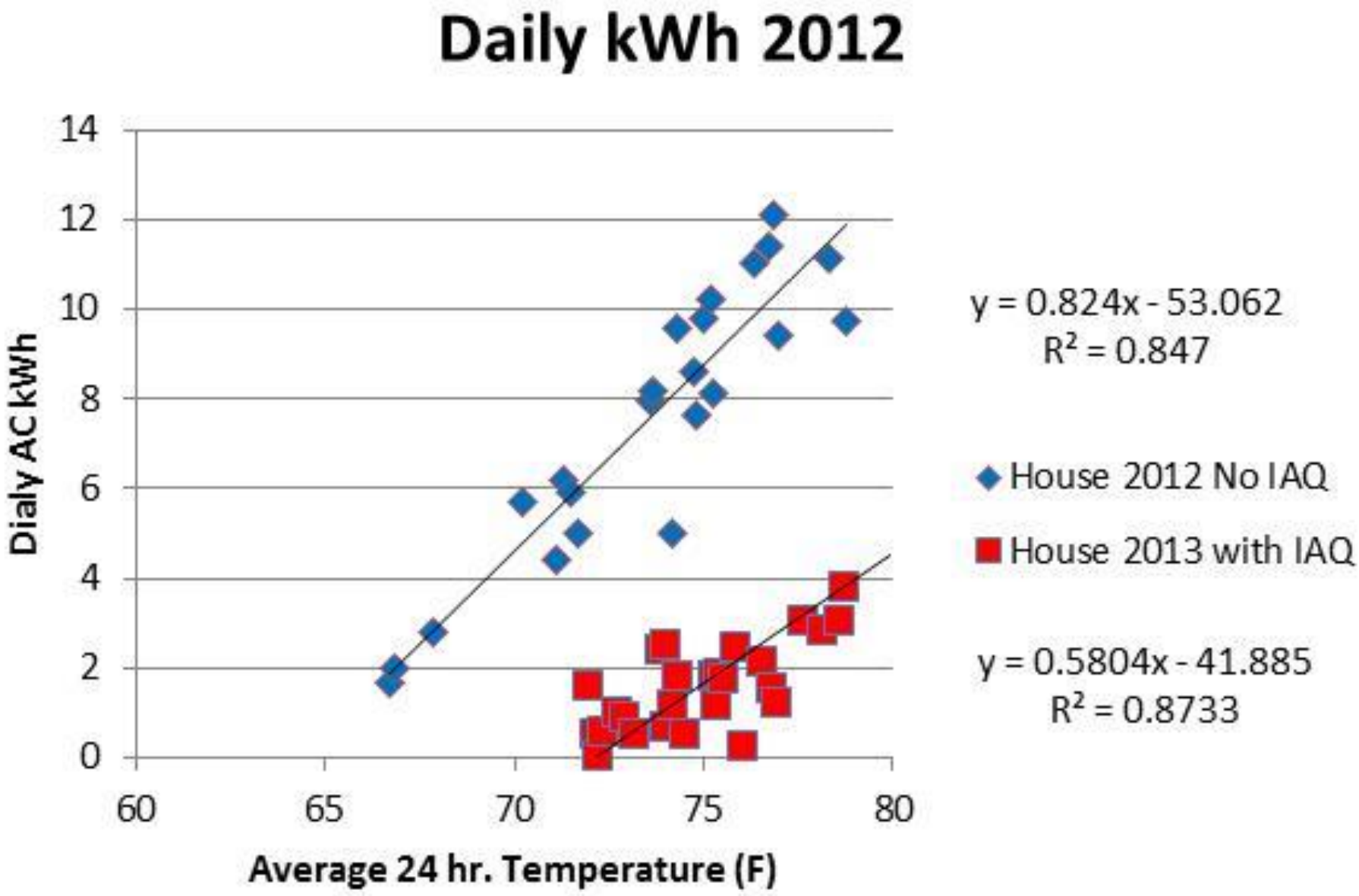
- Extended supply plenum to rafters and did low tapins double insulated plenum, 27 CFM25 Leakage R-8 Buried (R-25?)
- 1.5 Ton (compressor 9.3 EER) TXV to 6^{o} Superheat
- Coil Airflow 612 CFM/ton
- X13 Fan Motor (140W)

New Ducts

Air Sealing

R-49 Attic Insulation

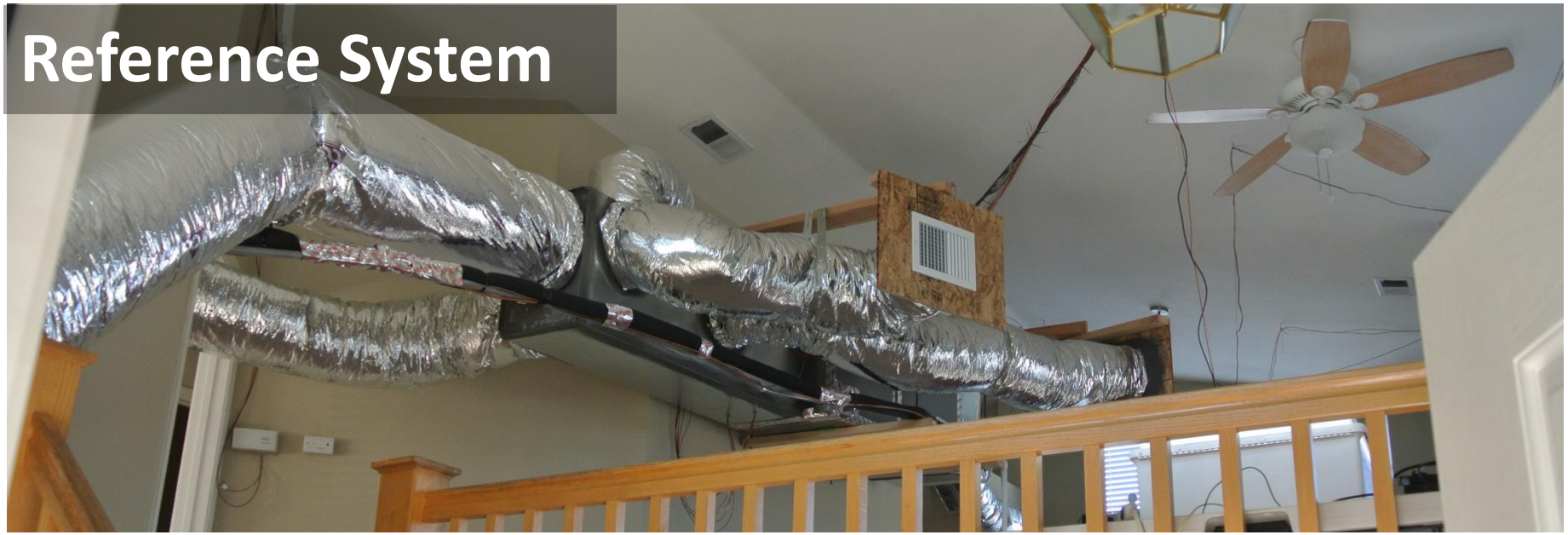
Drill and Fill


Daily kWh 2012
Dialy AC kWh
14
12
10
8
6
4
2
0
60
65
70
75
80
Average 24 hr. Temperature (F)
y = 0.824x - 53.062
R² = 0.847
House 2012 No IAQ
House 2013 with IAQ
y = 0.5804x - 41.885
R² = 0.8733

Mayfair Annual Cooling Savings by Situation

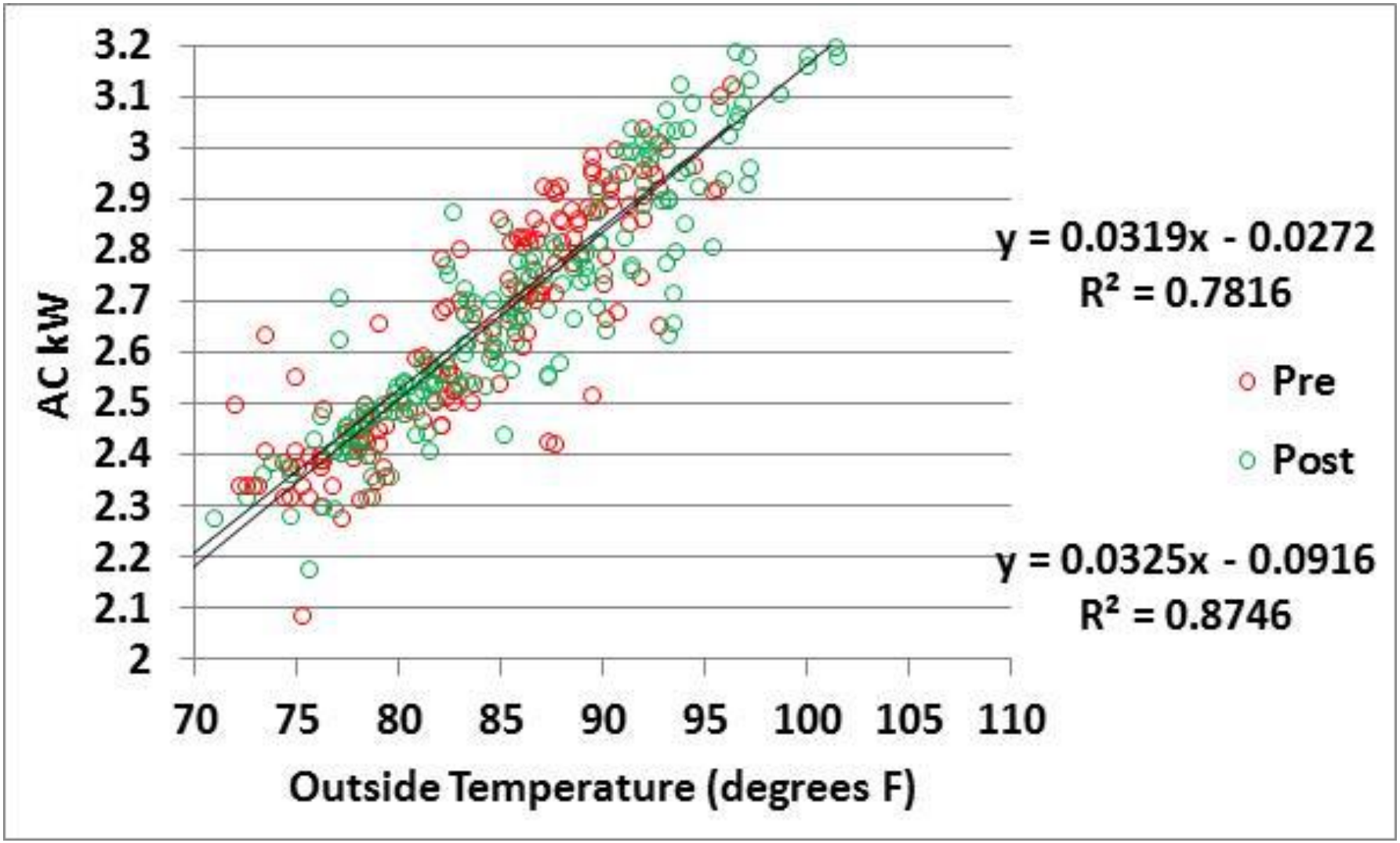
As Found House HVAC System Efficiency vs. Ref System	Retrofitted House HVAC System Efficiency vs. Ref System
62%	**89%**
Savings from Shell & HVAC between As Found and Retrofit Round Number 1	Shell Savings between As Found and Retrofit Round Number 1
74%	**60%**
HVAC Savings between As Found and Retrofit Round Number 1	
30%	

The Case of the Flexible Yardstick

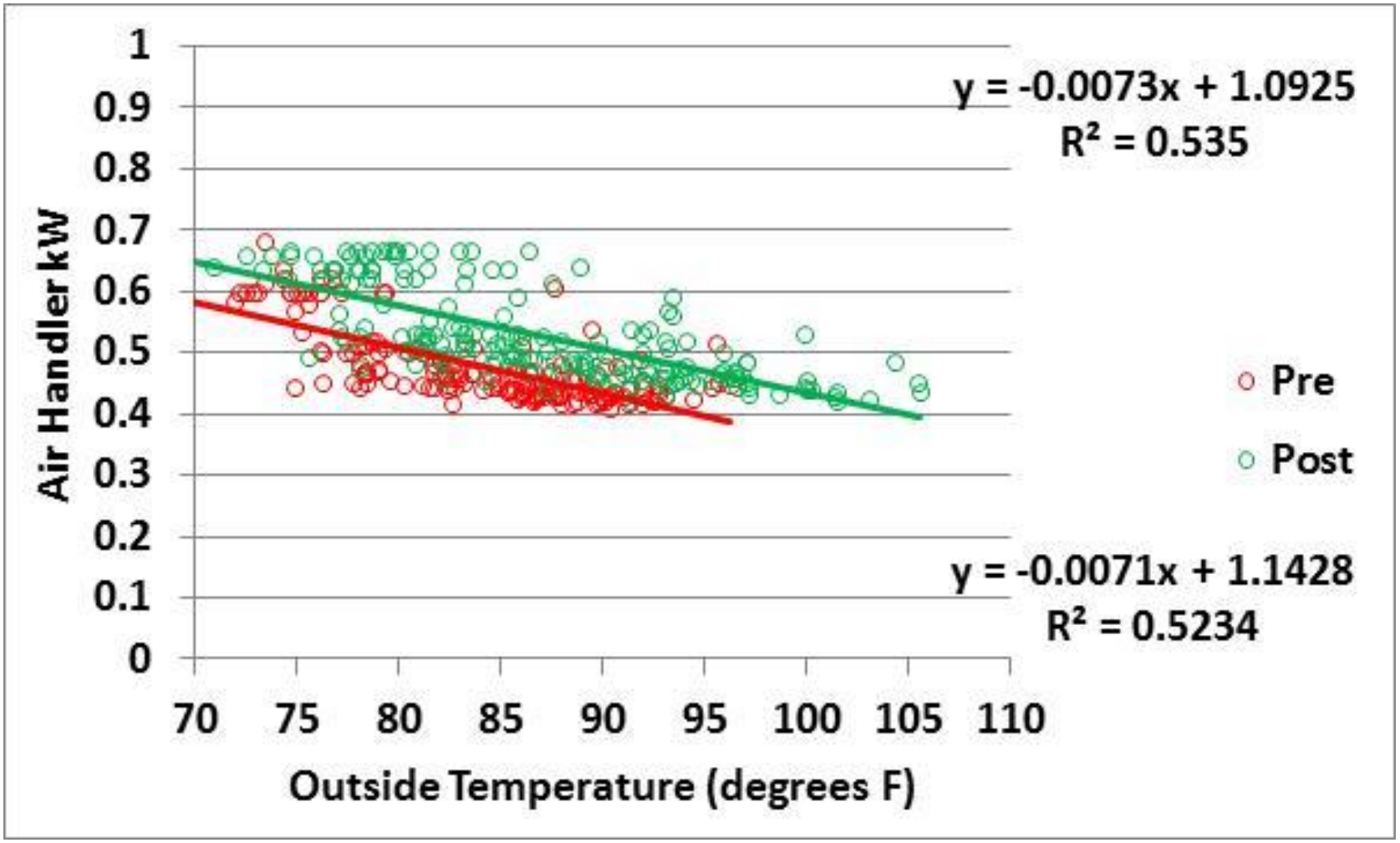


Mayfair Example

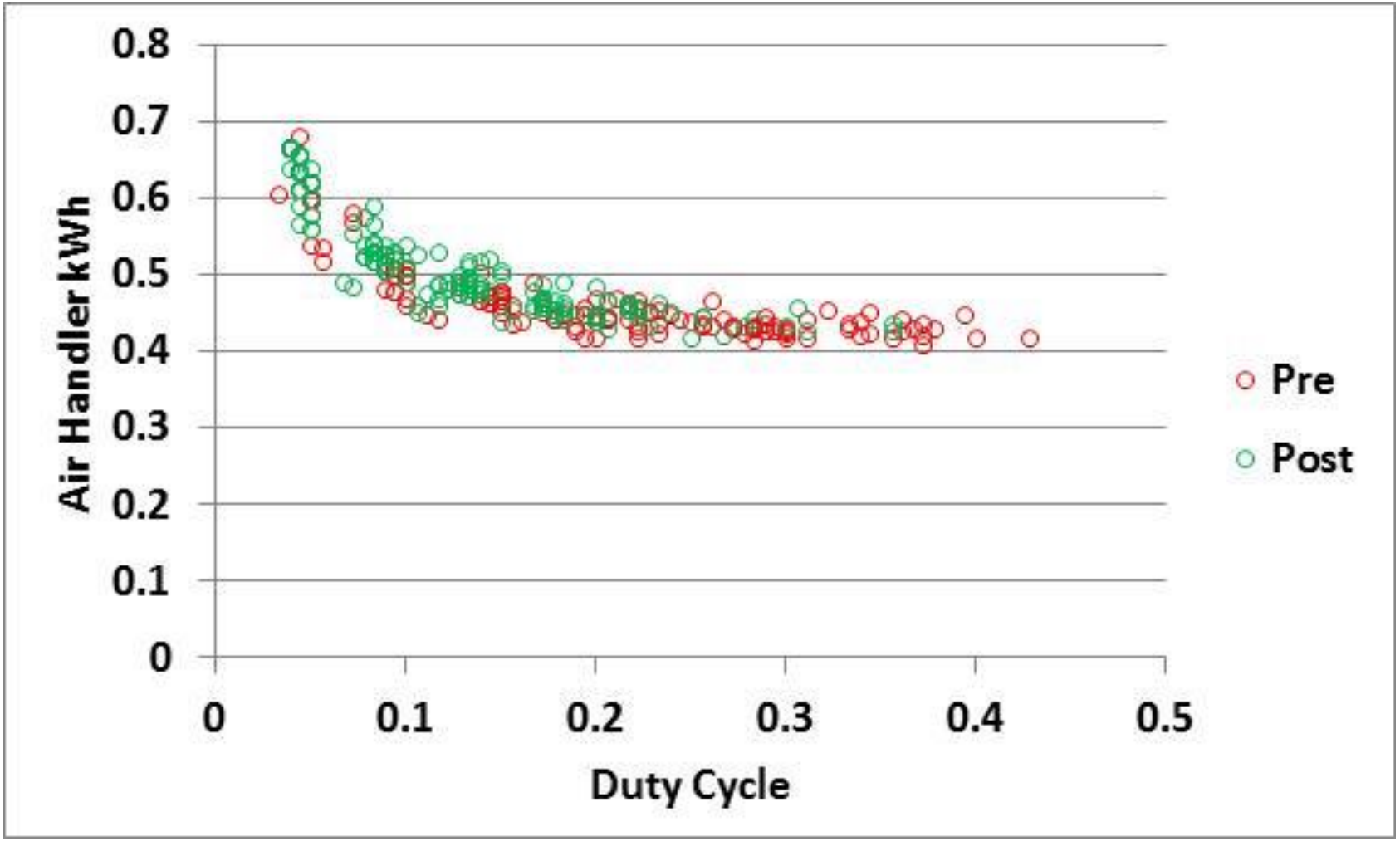
Reference Outdoor Watt Draw
No Change



Reference Air Handler Watt Draw Changed Relative to Outdoor Temp



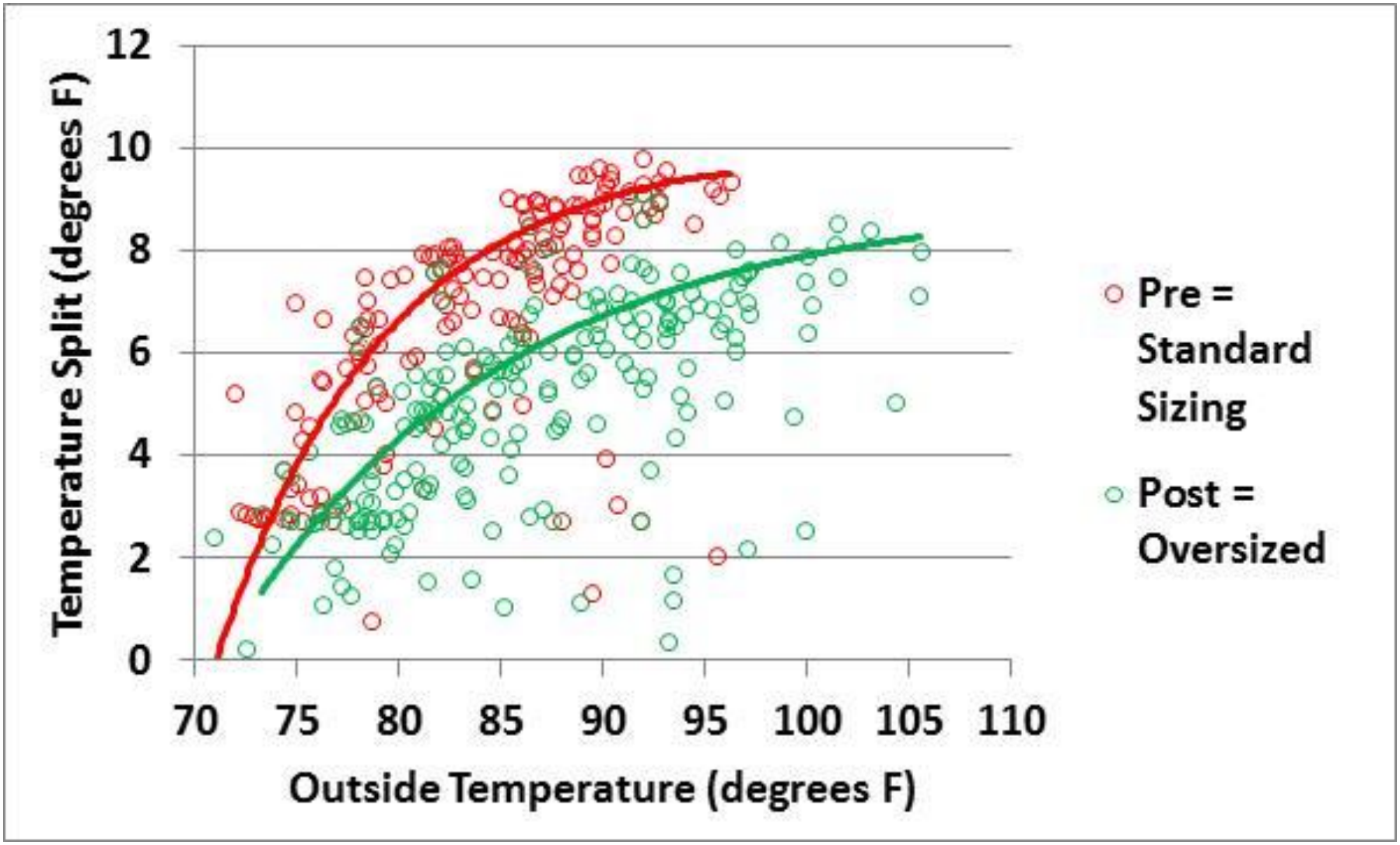
Reference Air Handler Watt Draw
No Change Relative to Duty Cycle



So the Input (Watt Draw) of the Air Conditioner
Remained the Same

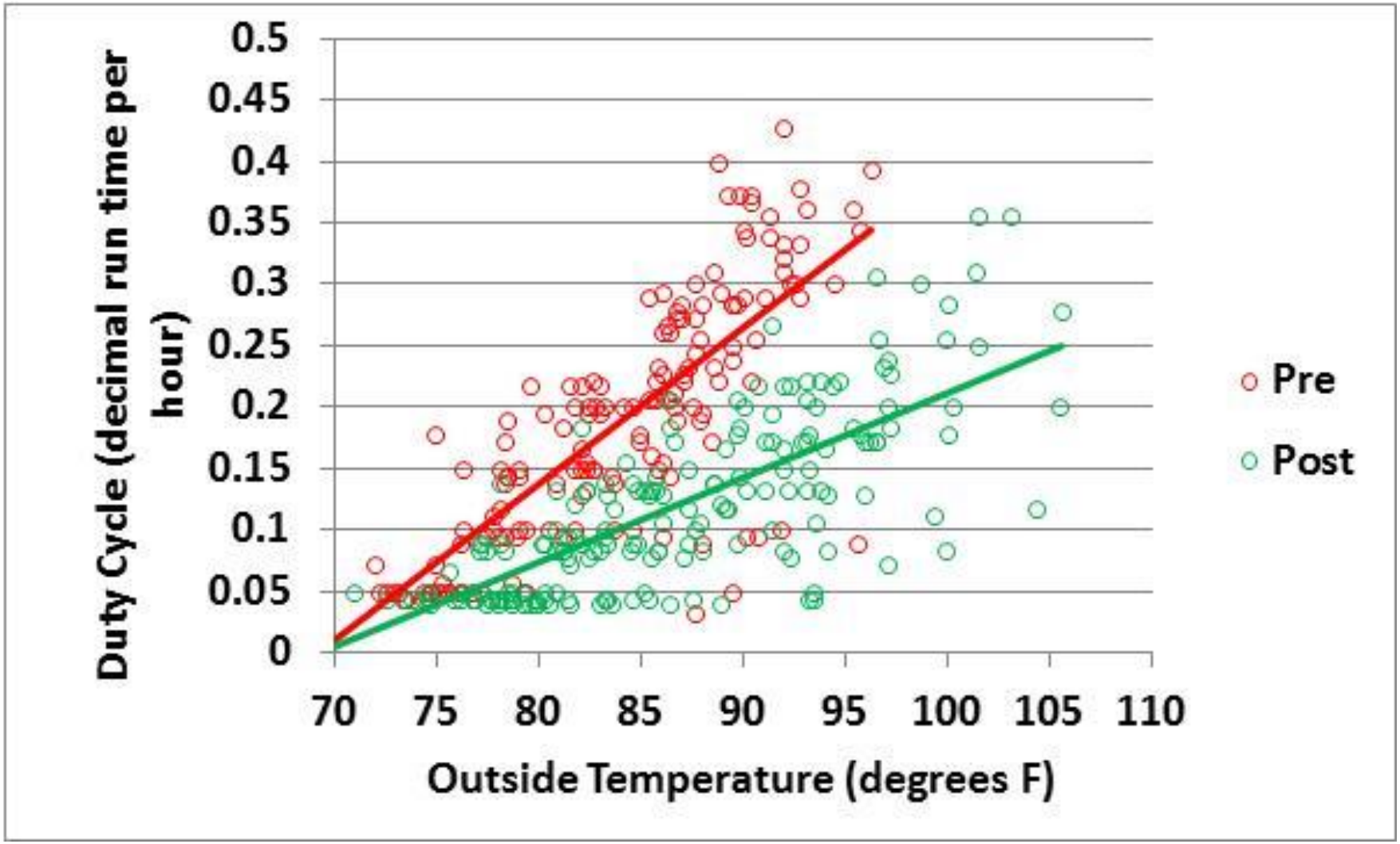
Now All We Need is for the Capacity to Remain the Same

Capacity (Output) Changed



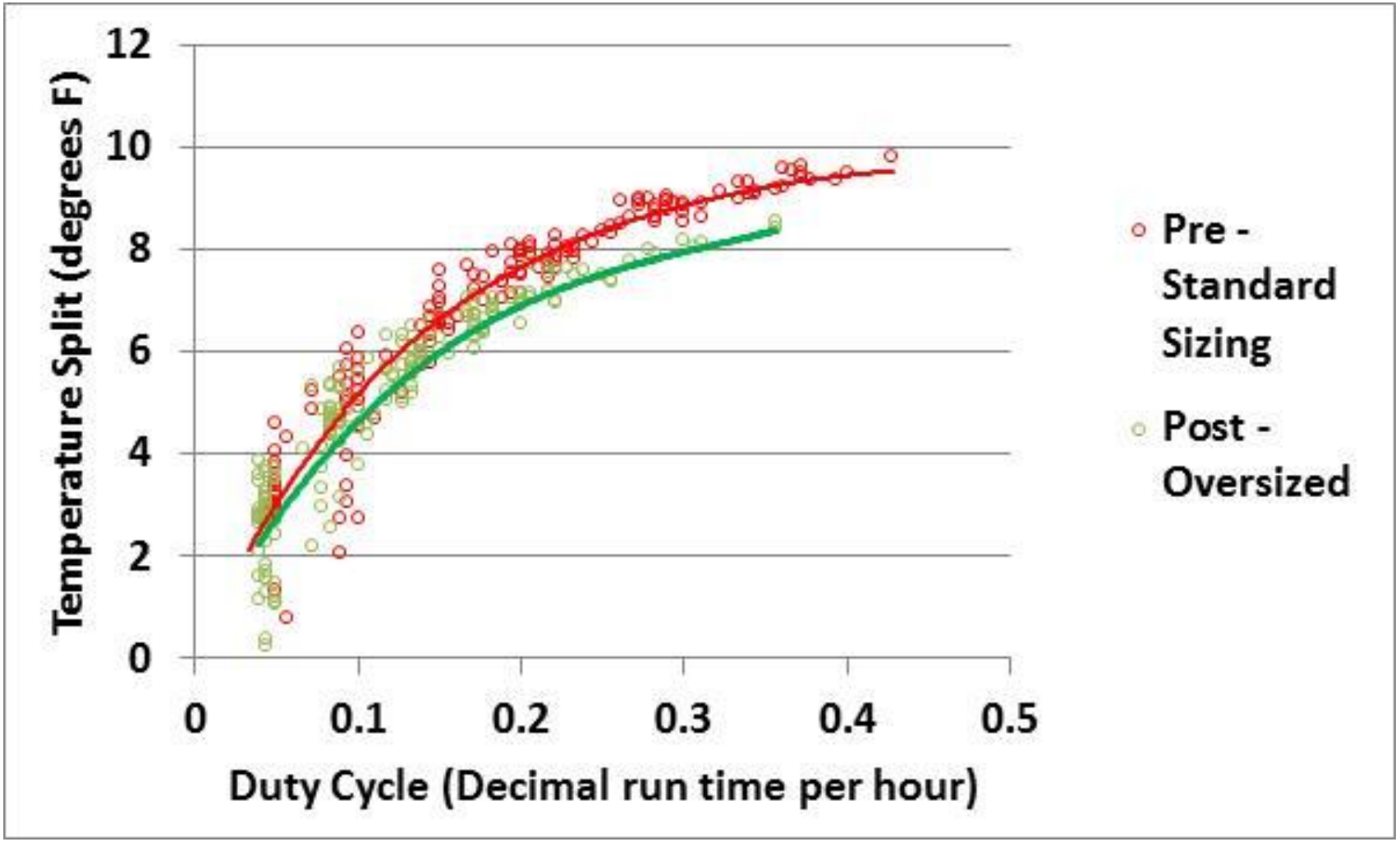
Hypothesis – Of Course
That is Because the Duty Cycle at a Given Temperature Changed
Reference Air Conditioner
“became” More Oversized

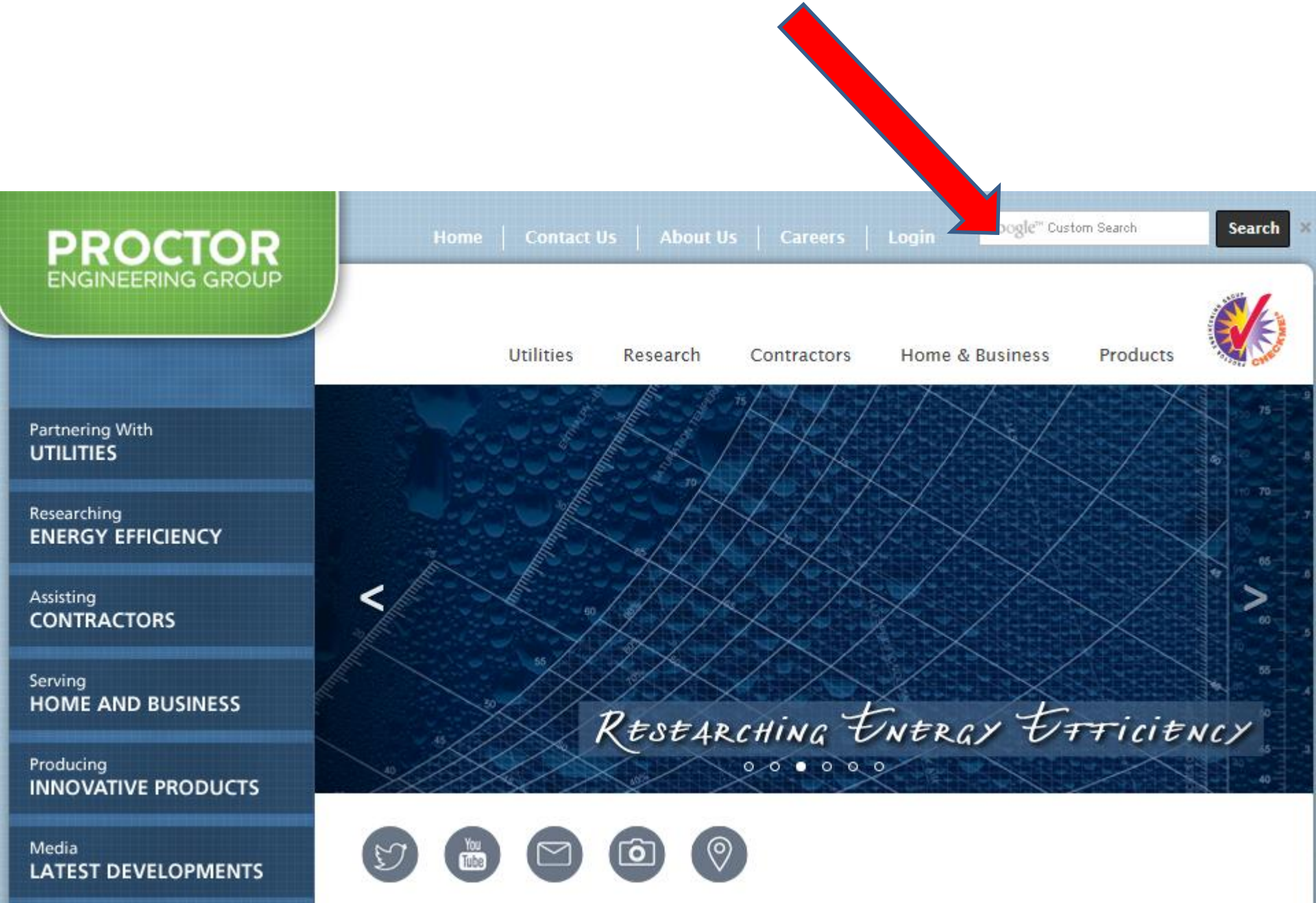
Duty Cycle Did Change (a lot!)



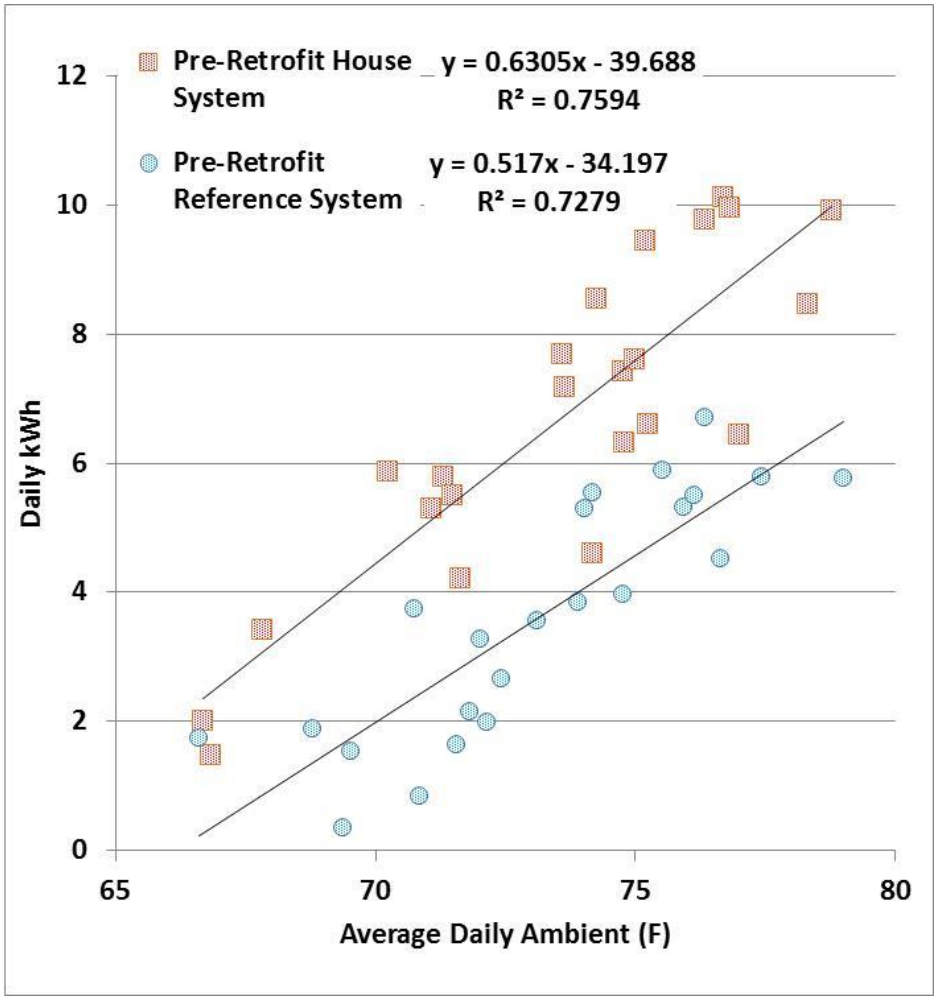
Is that the Whole Explanation?

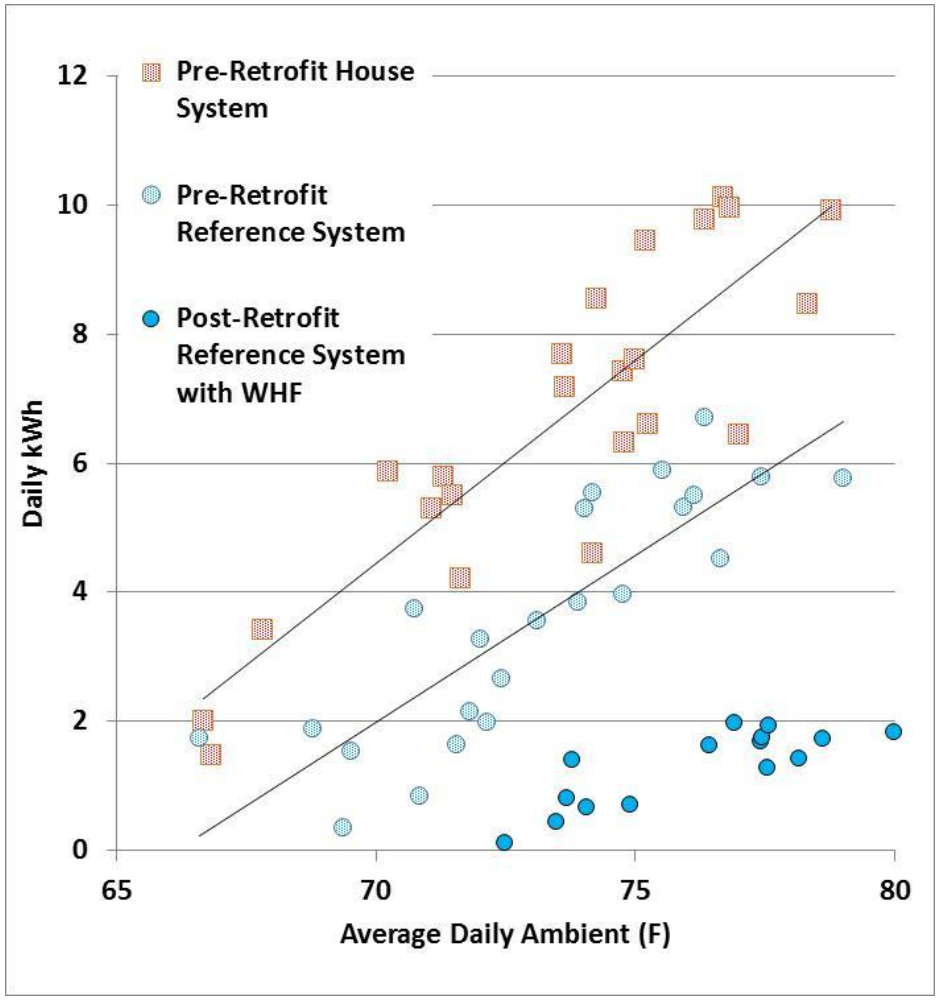
Only Part of it
The Output also changed for the same duty cycle



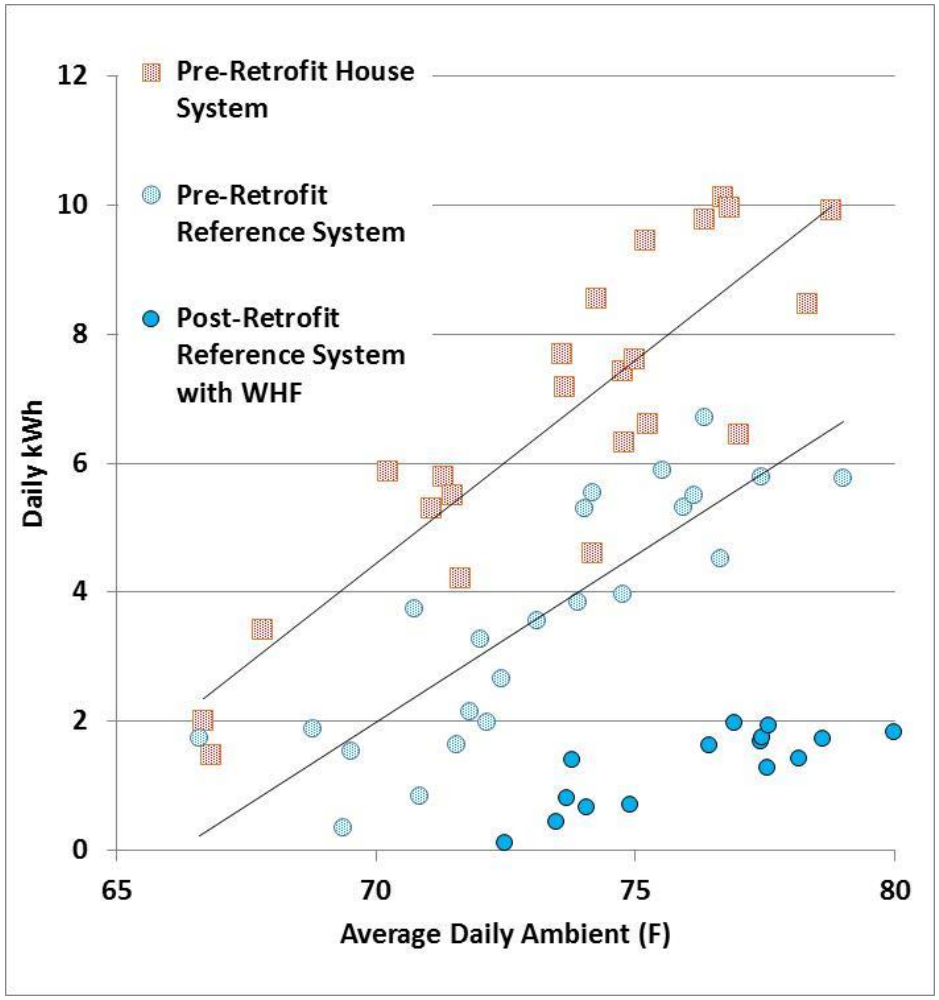

PROCTOR
ENGINEERING GROUP
Home
Contact Us
About Us
Careers
Login
Search
Utilities
Research
Contractors
Home & Business
Products
Partnering With
UTILITIES
Researching
ENERGY EFFICIENCY
Assisting
CONTRACTORS
Serving
HOME AND BUSINESS
Producing
INNOVATIVE PRODUCTS
Media
LATEST DEVELOPMENTS
RESEARCHING ENERGY EFFICIENCY

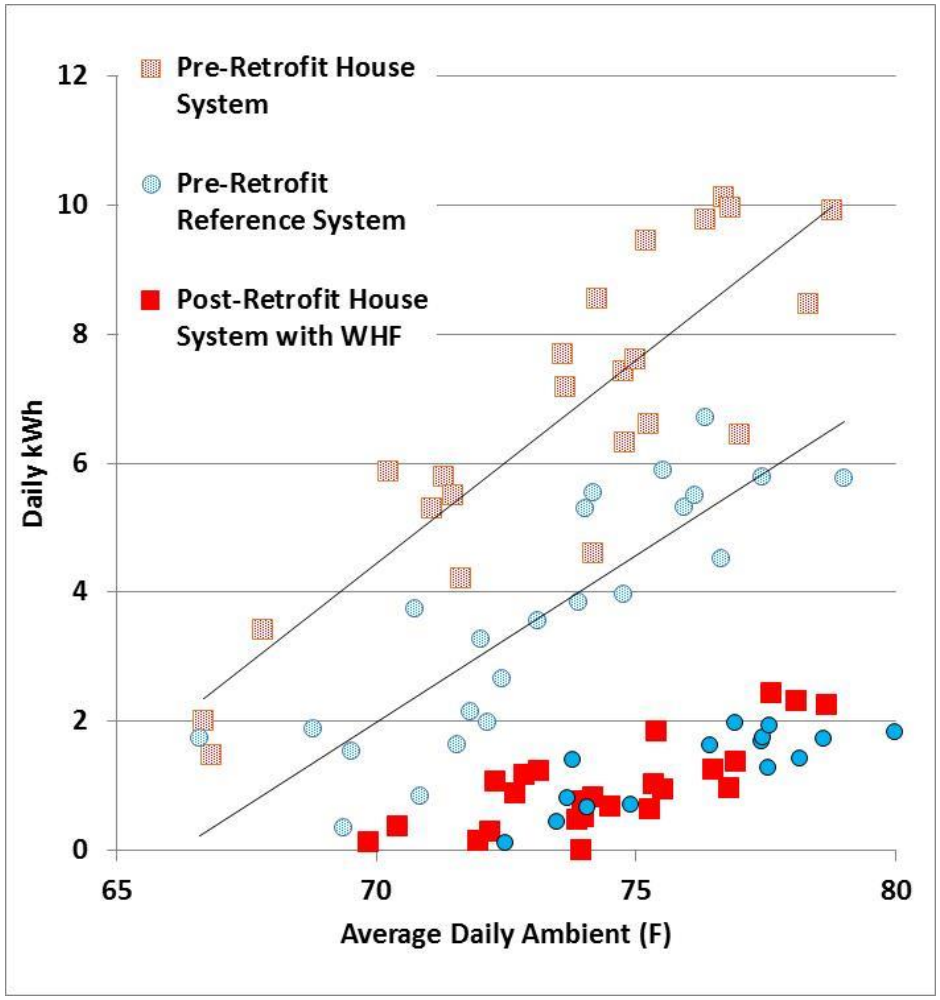
Grange


Pre-Retrofit House System
y = 0.6305x - 39.688
R² = 0.7594
Pre-Retrofit Reference System
y = 0.517x - 34.197
R² = 0.7279
Daily kWh
Average Daily Ambient (F)
0
2
4
6
8
10
12
65
70
75
80

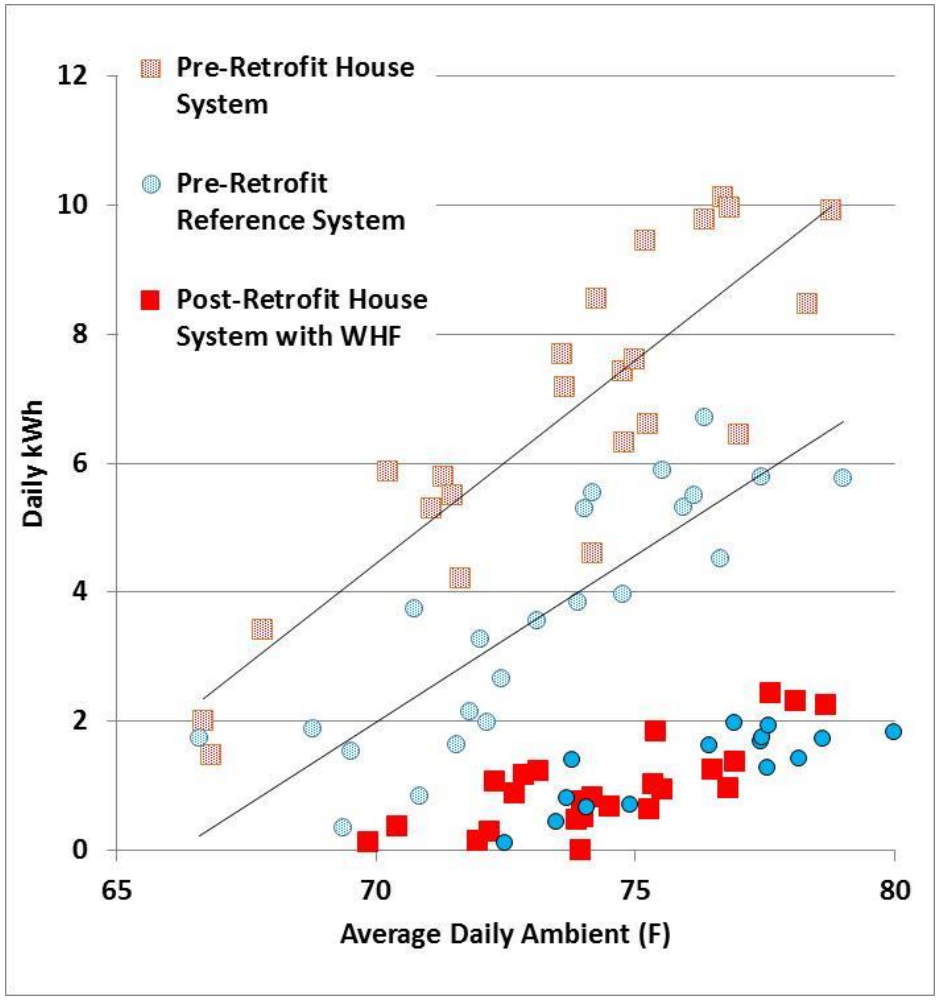

Pre-Retrofit House System
Pre-Retrofit Reference System
Post-Retrofit Reference System with WHF
Daily kWh
Average Daily Ambient (F)
0
2
4
6
8
10
12
65
70
75
80

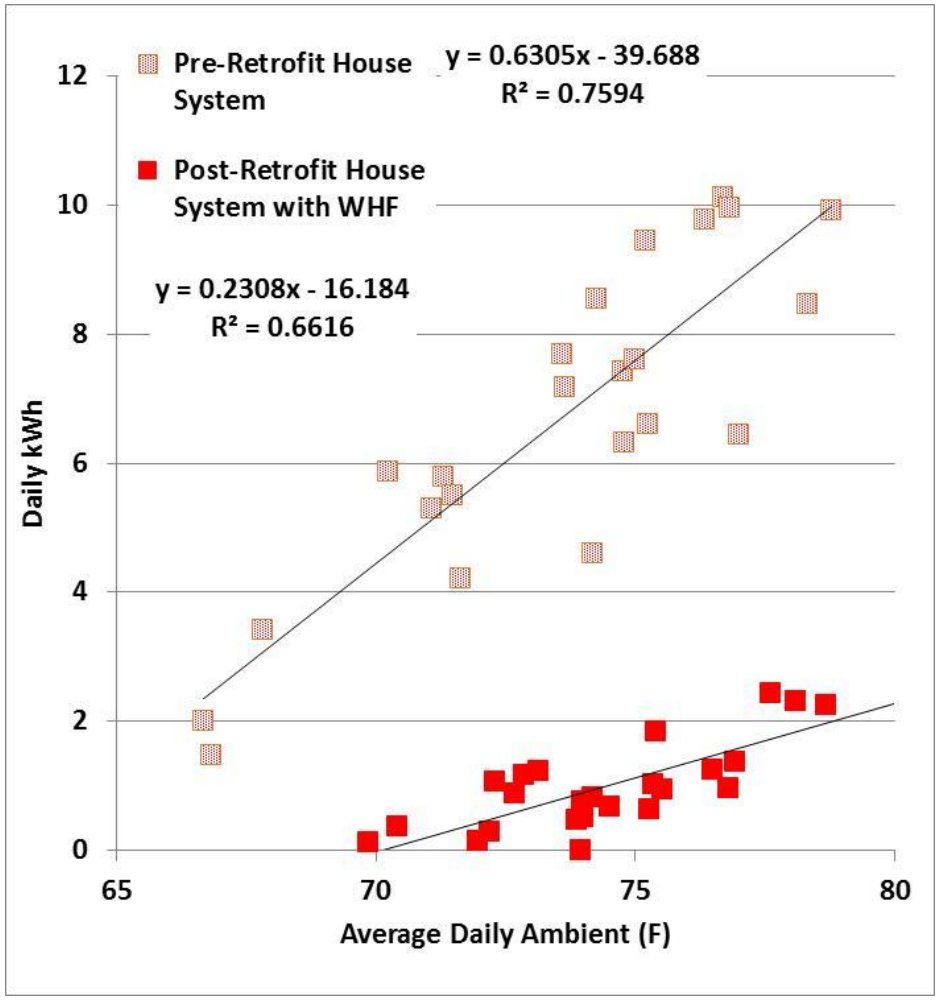
Grange


Pre-Retrofit House System
Pre-Retrofit Reference System
Post-Retrofit Reference System with WHF
Daily kWh
Average Daily Ambient (F)
0
2
4
6
8
10
12
65
70
75
80

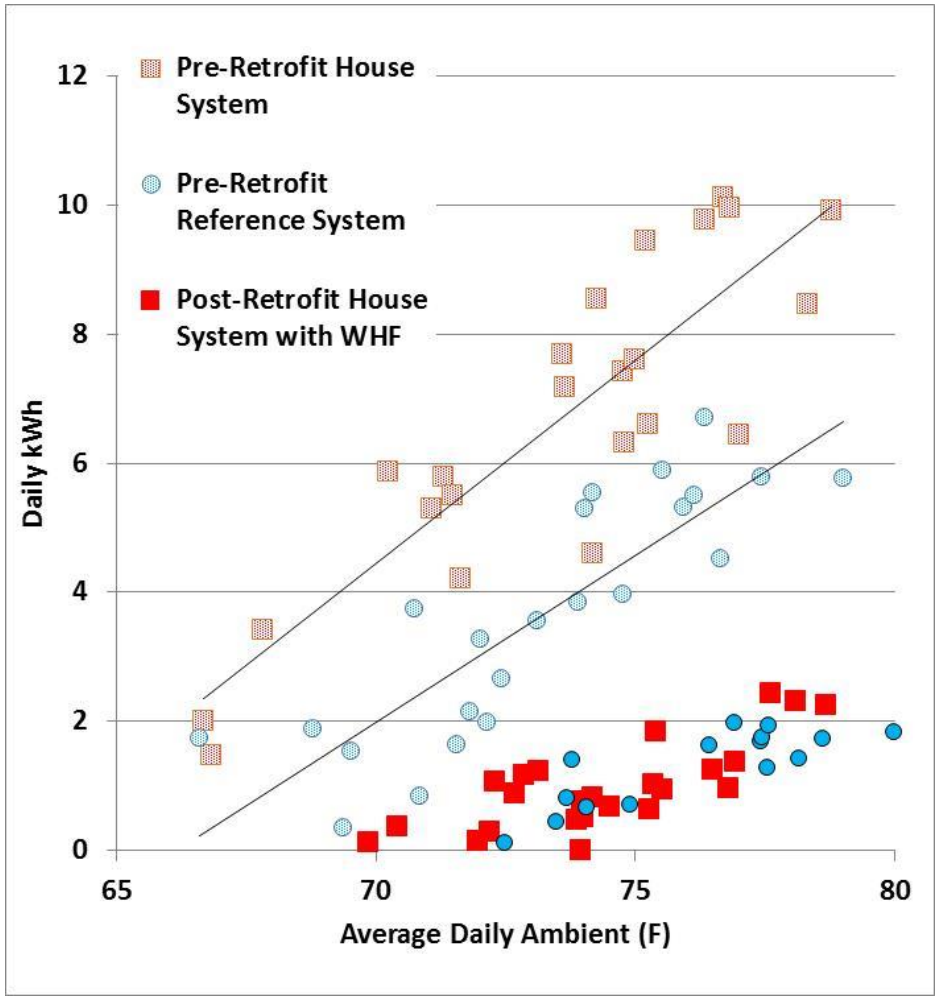

Pre-Retrofit House System
Pre-Retrofit Reference System
Post-Retrofit House System with WHF
Daily kWh
Average Daily Ambient (F)
0
2
4
6
8
10
12
65
70
75
80

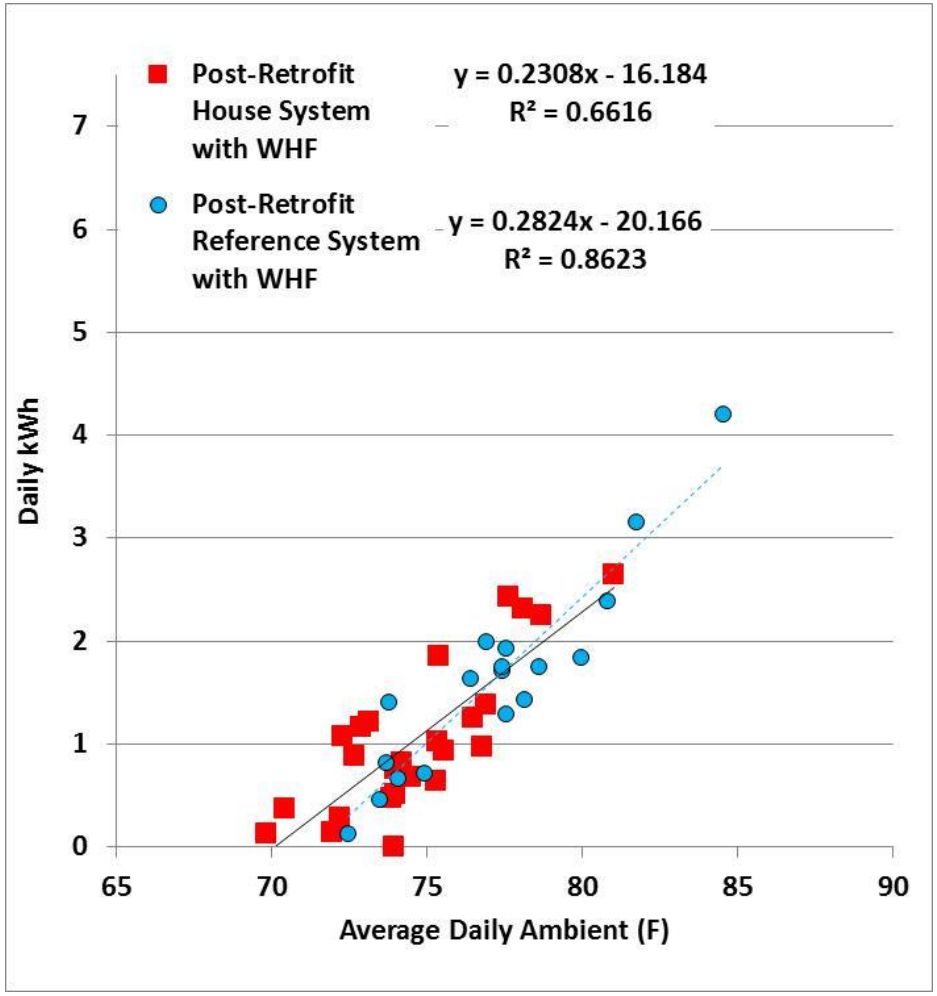
Grange


Pre-Retrofit House System
Pre-Retrofit Reference System
Post-Retrofit House System with WHF
Daily kWh
Average Daily Ambient (F)
0
2
4
6
8
10
12
65
70
75
80


Pre-Retrofit House System
y = 0.6305x - 39.688
R² = 0.7594
Post-Retrofit House System with WHF
y = 0.2308x - 16.184
R² = 0.6616
Daily kWh
Average Daily Ambient (F)
0
2
4
6
8
10
12
65
70
75
80

Grange


Pre-Retrofit House System
Pre-Retrofit Reference System
Post-Retrofit House System with WHF
Daily kWh
Average Daily Ambient (F)
0
2
4
6
8
10
12
65
70
75
80


Post-Retrofit House System with WHF
y = 0.2308x - 16.184
R² = 0.6616
Post-Retrofit Reference System with WHF
y = 0.2824x - 20.166
R² = 0.8623
Daily kWh
Average Daily Ambient (F)
0
1
2
3
4
5
6
7
65
70
75
80
85
90