Central Valley Research Houses

John Proctor (channeling Chitwood & Wilcox)

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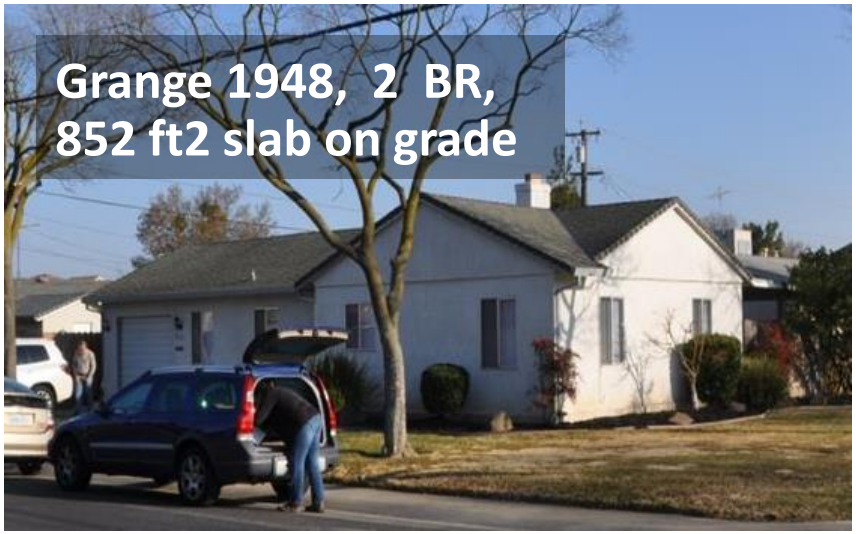
http://www.proctoreng.com/energy-efficiency/climate-specific-ac.html

Four Houses


Grange 1948, 2 BR,
852 ft2 slab on grade


Mayfair 1953, 3 BR,
1104 ft2, crawl space


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

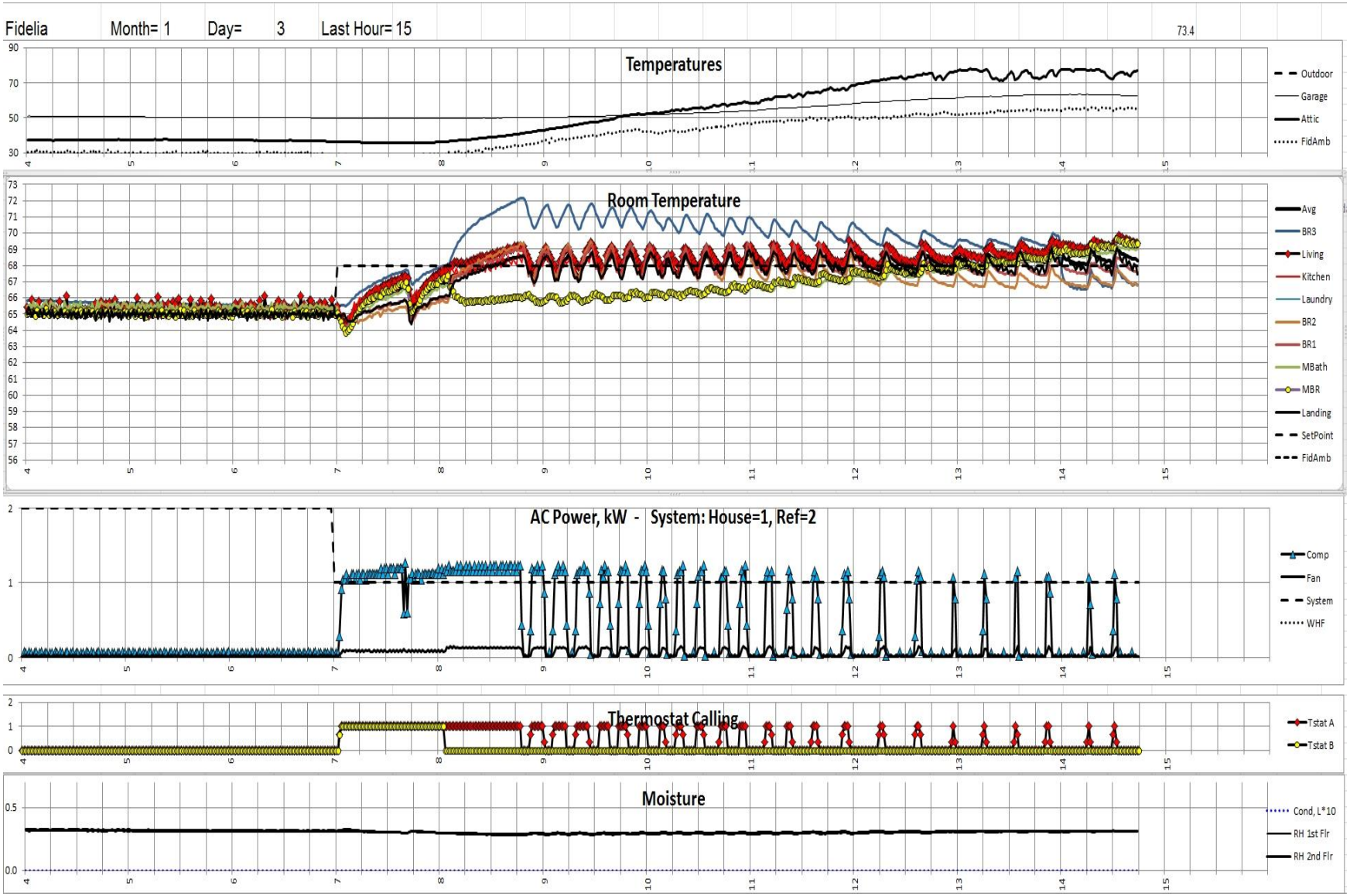

Caleb 2005, 4 BR,
2076 ft2 slab on grade

Four **Unoccupied** Houses

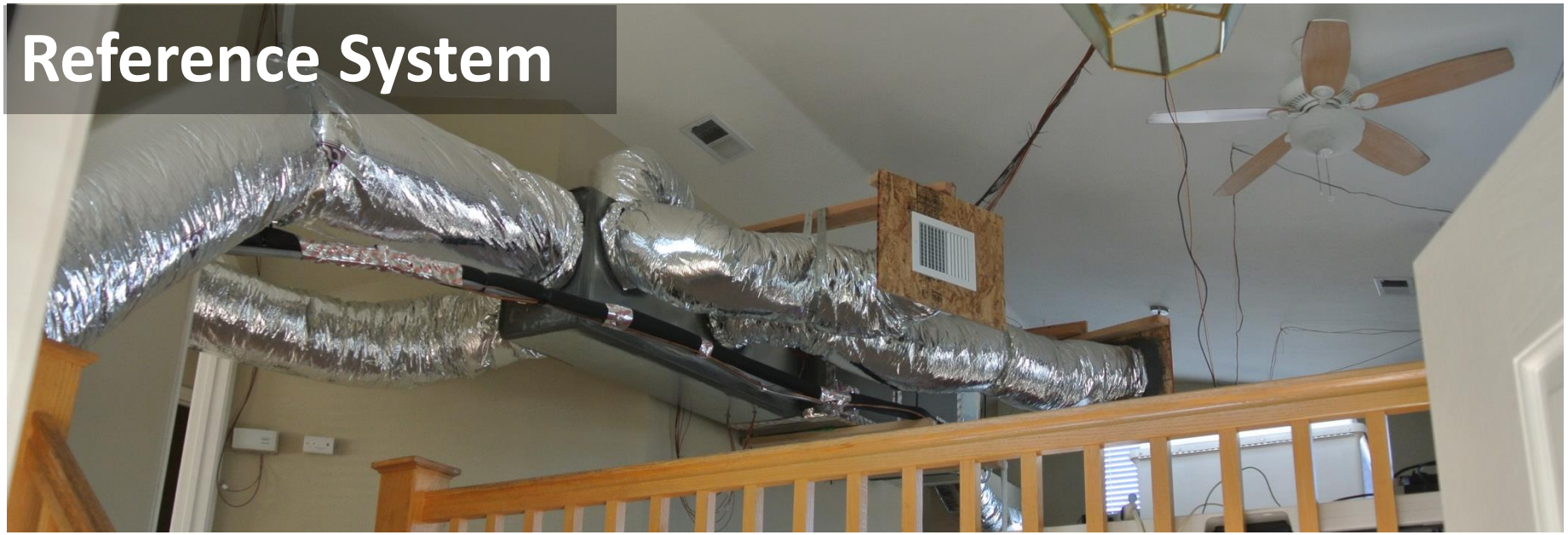
Simulated Occupants

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



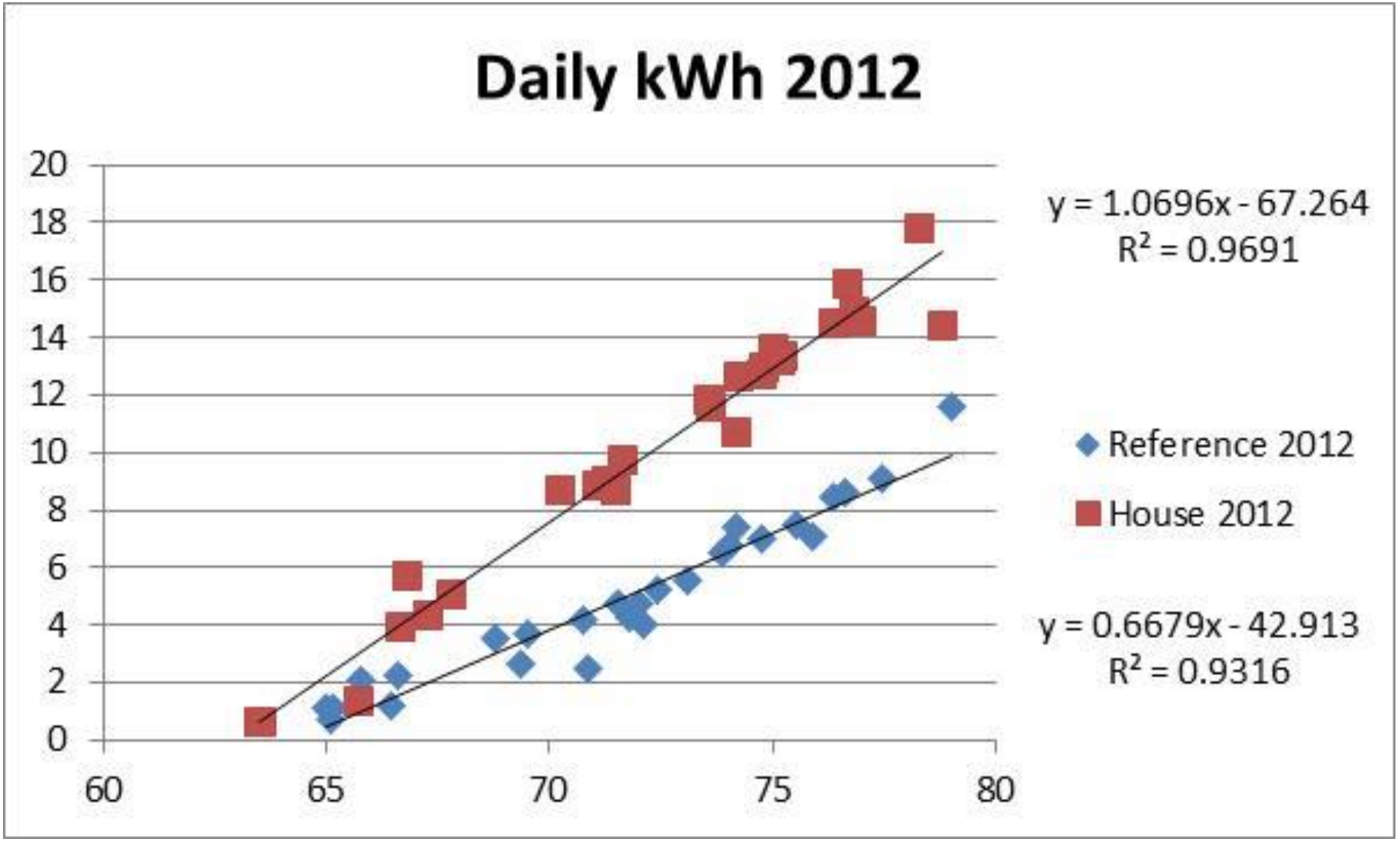
Step 1: Flip Flop Experiment

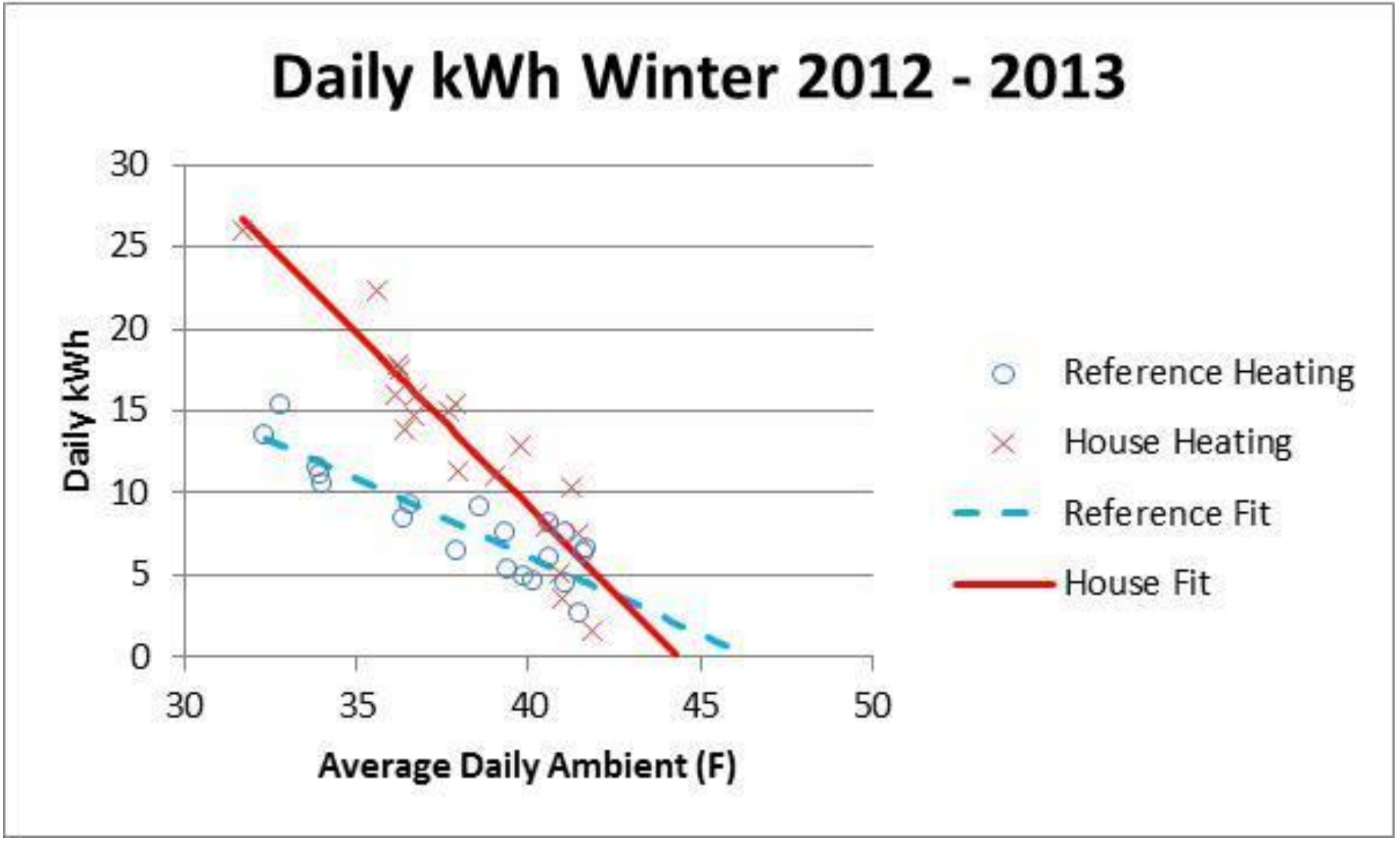
House System **Reference System**

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

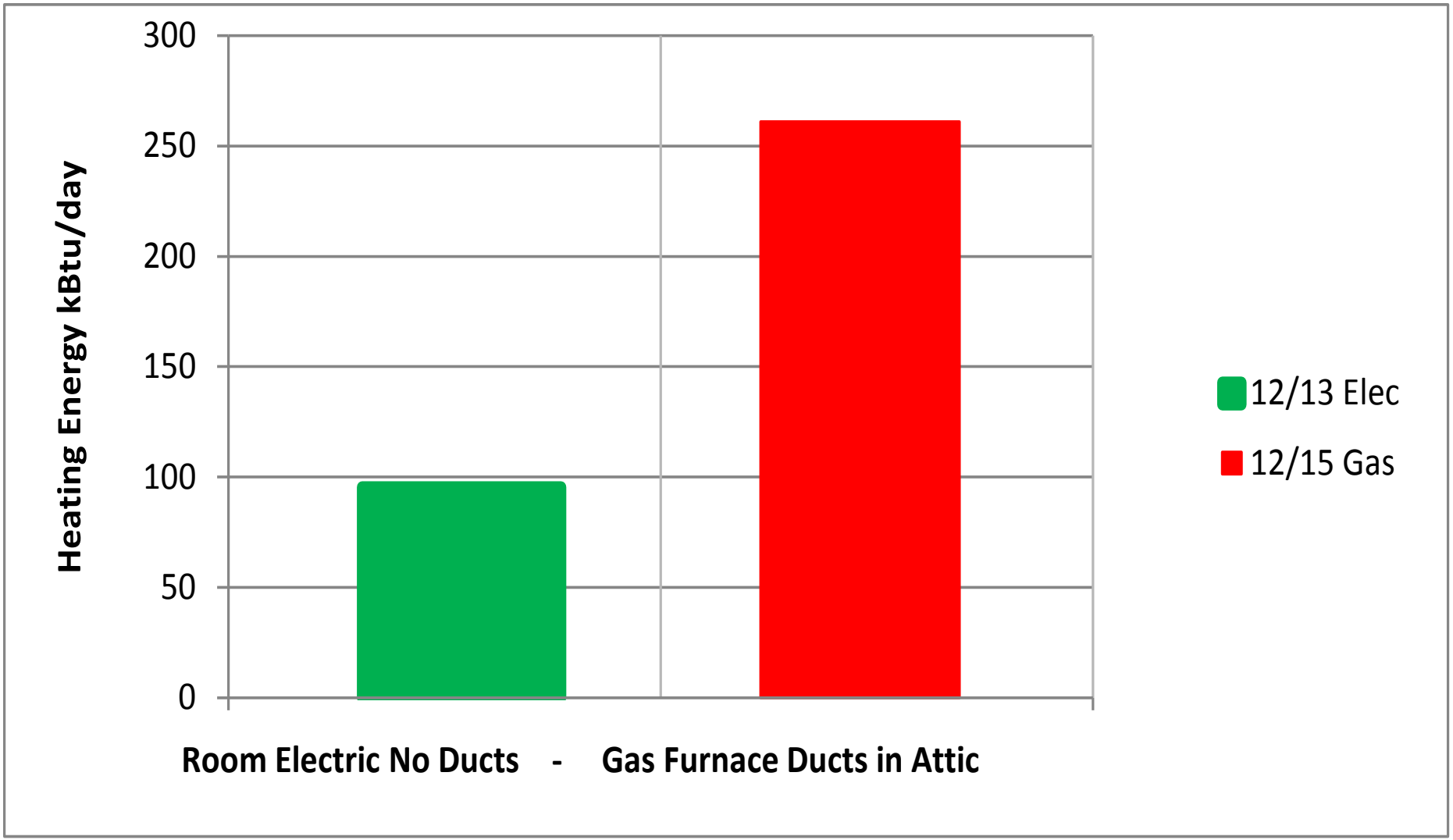
Caleb 2005, 4 BR, 2076 ft2, Approximately Current Code

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

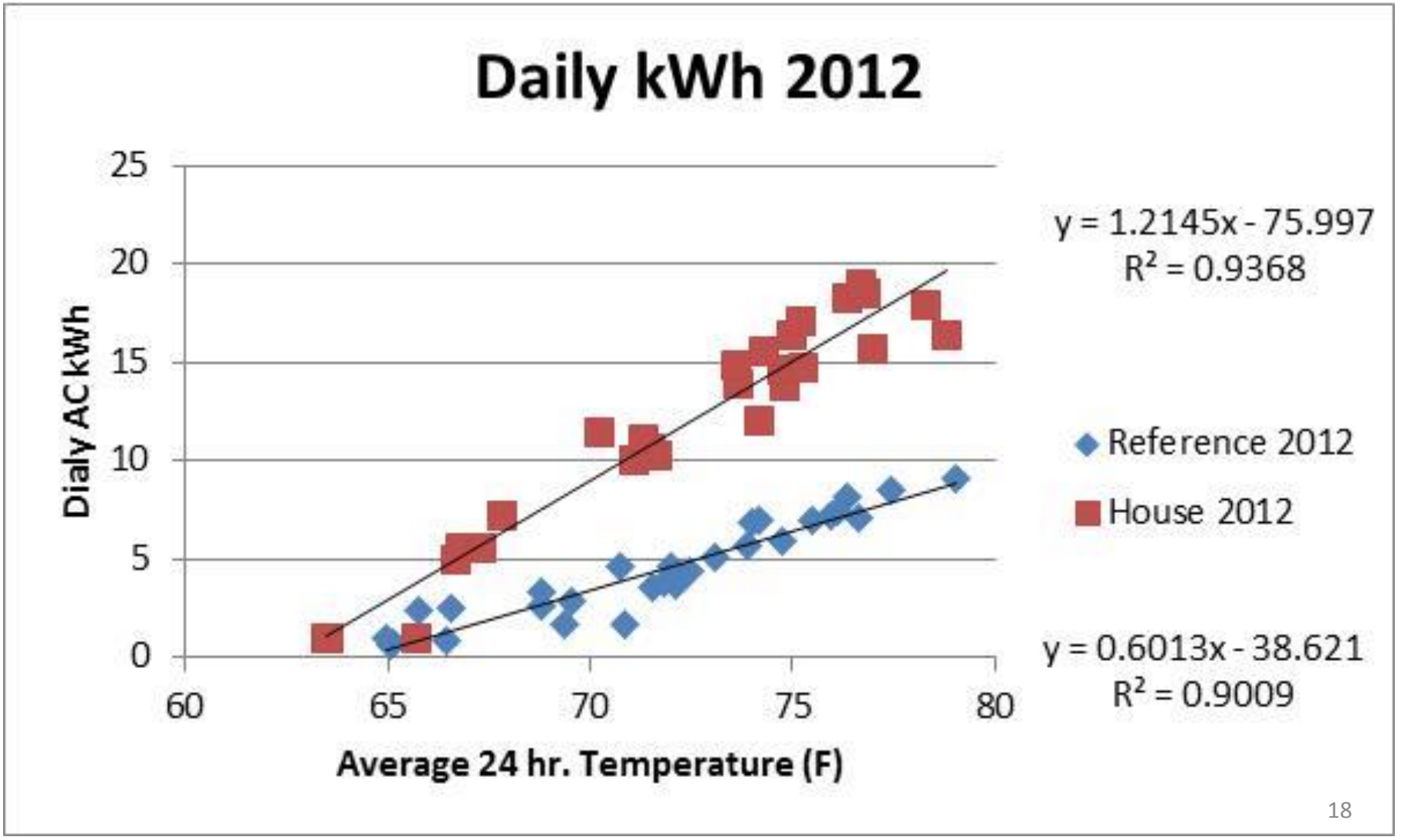
- Capacity Shift Zoning by use of Damper Stops
- Replaced Outside Unit only 11 EER 2.5 Ton AC
- Coil Airflow 443 CFM/ton
- 0.41 External Static Pressure
- ½ HP Concept3™ (293W)
- 2075 CFM Whole House Fans on Schedule
- Foam “Globs” Under Roof Tile

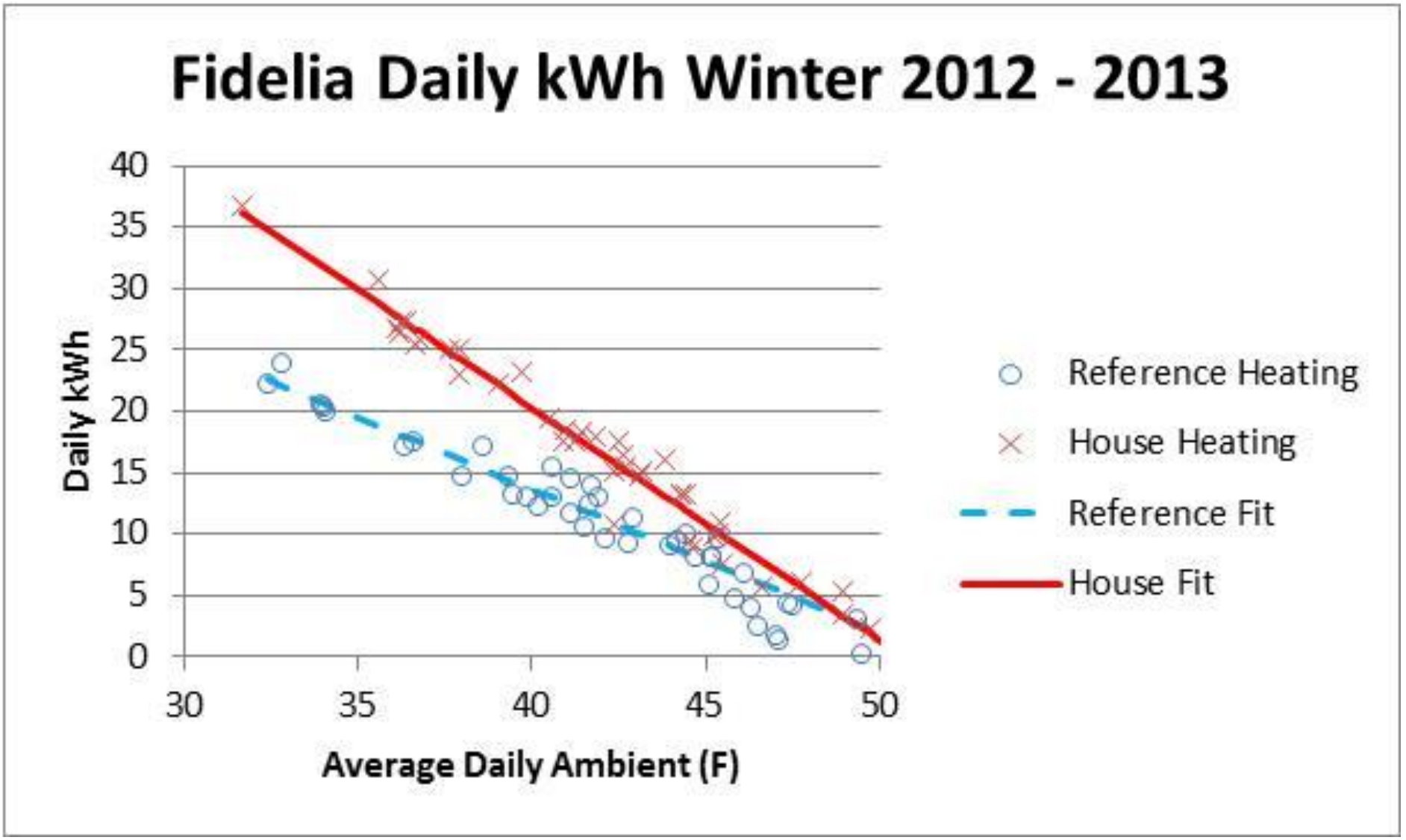
Caleb Annual Cooling Savings by Situation

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

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

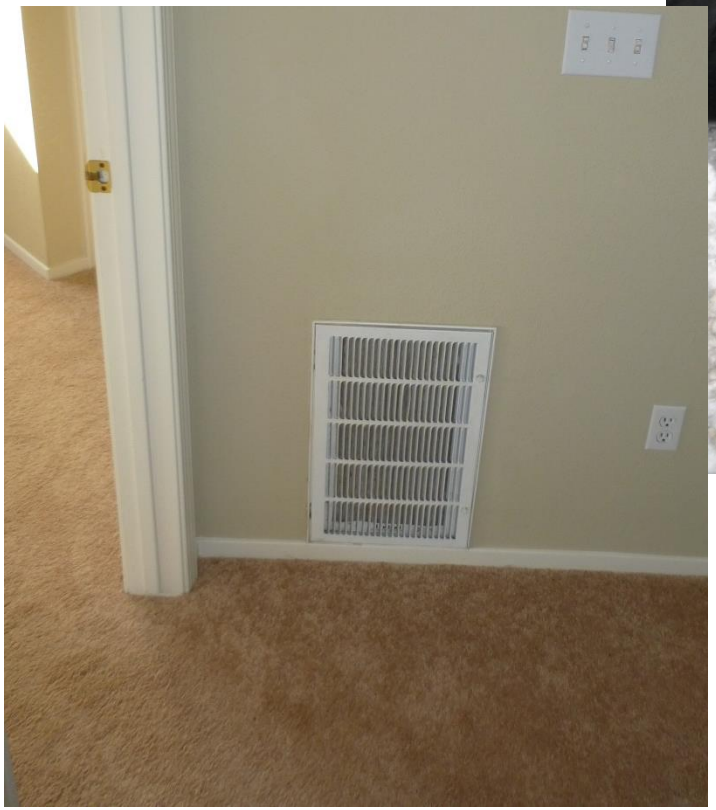
HVAC As Found (Yr 1)

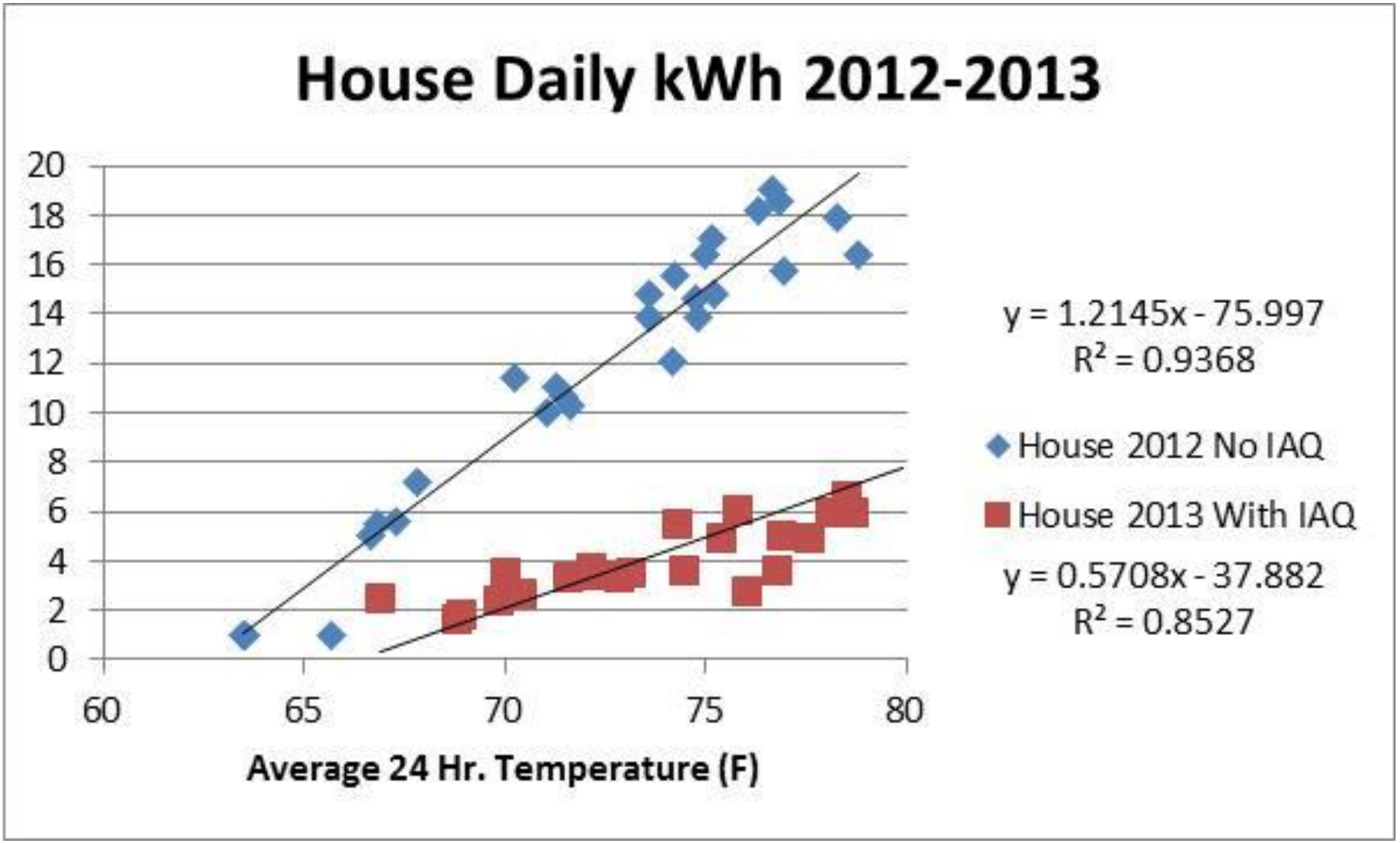
- Single Zone Ducts between floors and Spider system in Attic R-4.2
- 3.5 Ton 9 EER Split AC with 0.80 AFUE Furnace
- Coil Airflow 390 CFM/ton
- ½ HP PSC Fan Motor (554W)

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

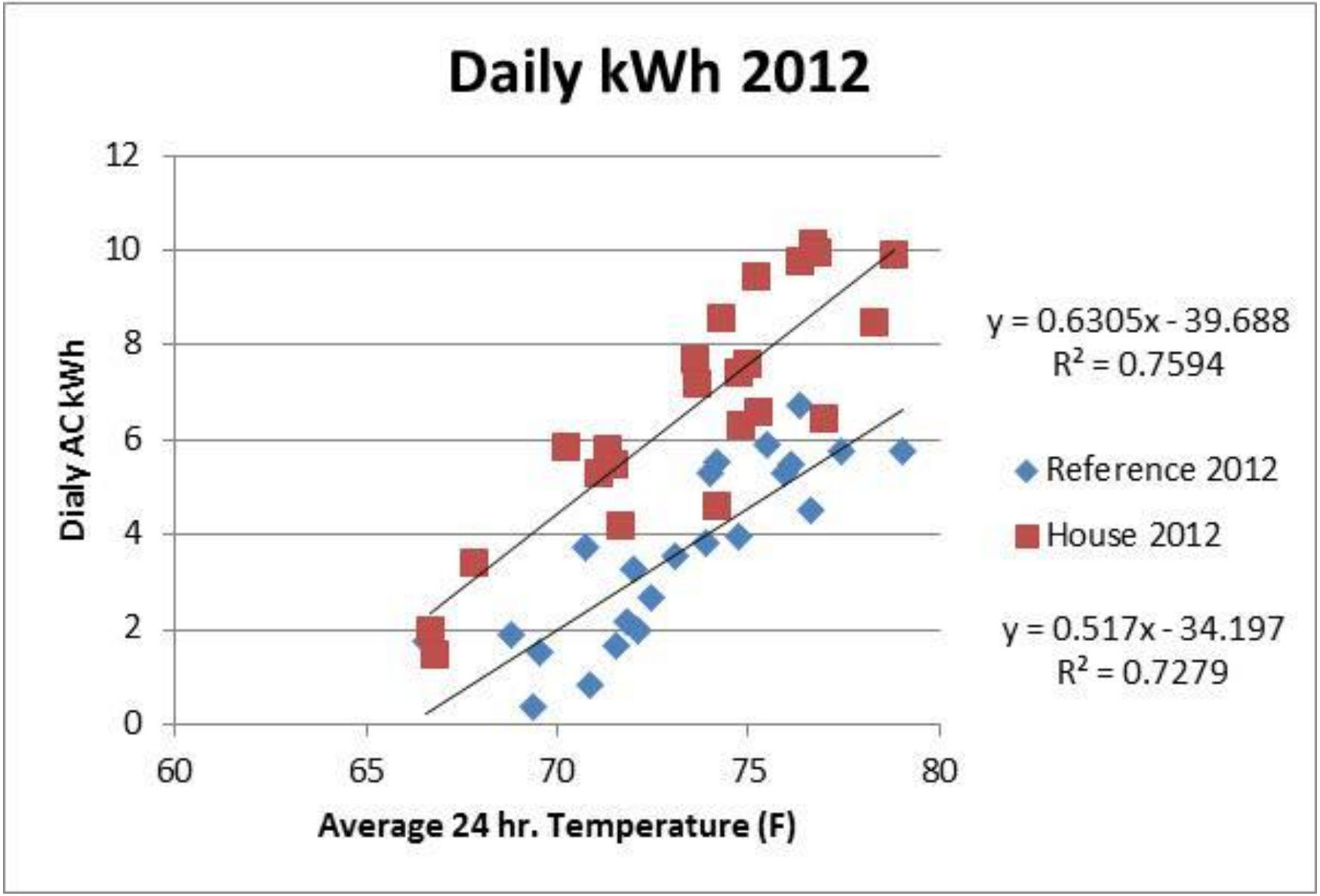


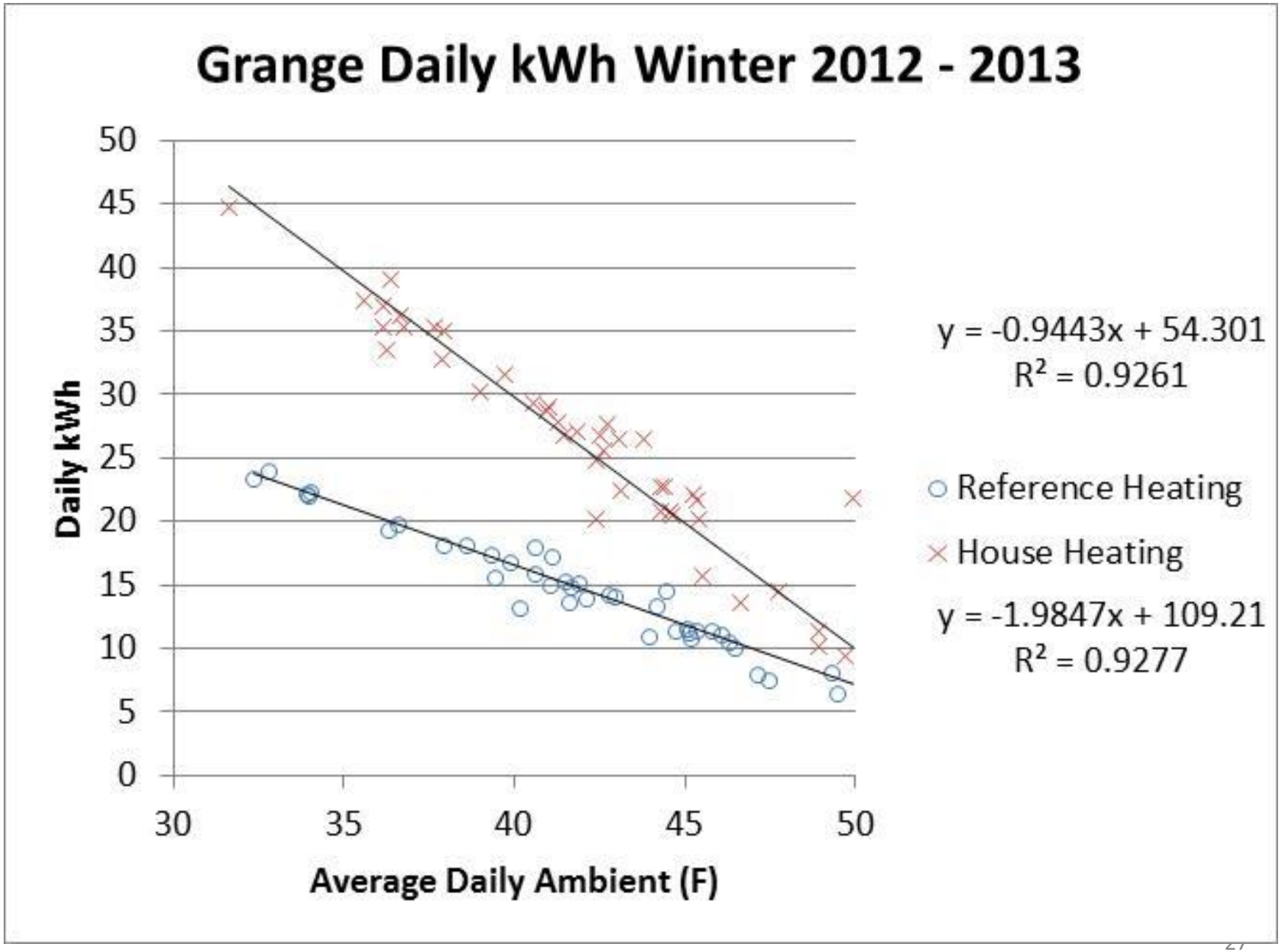

House Daily kWh 2012-2013
20
18
16
14
12
10
8
6
4
2
0
60
65
70
75
80
Average 24 Hr. Temperature (F)
y = 1.2145x - 75.997
R² = 0.9368
House 2012 No IAQ
House 2013 With IAQ
y = 0.5708x - 37.882
R² = 0.8527

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)

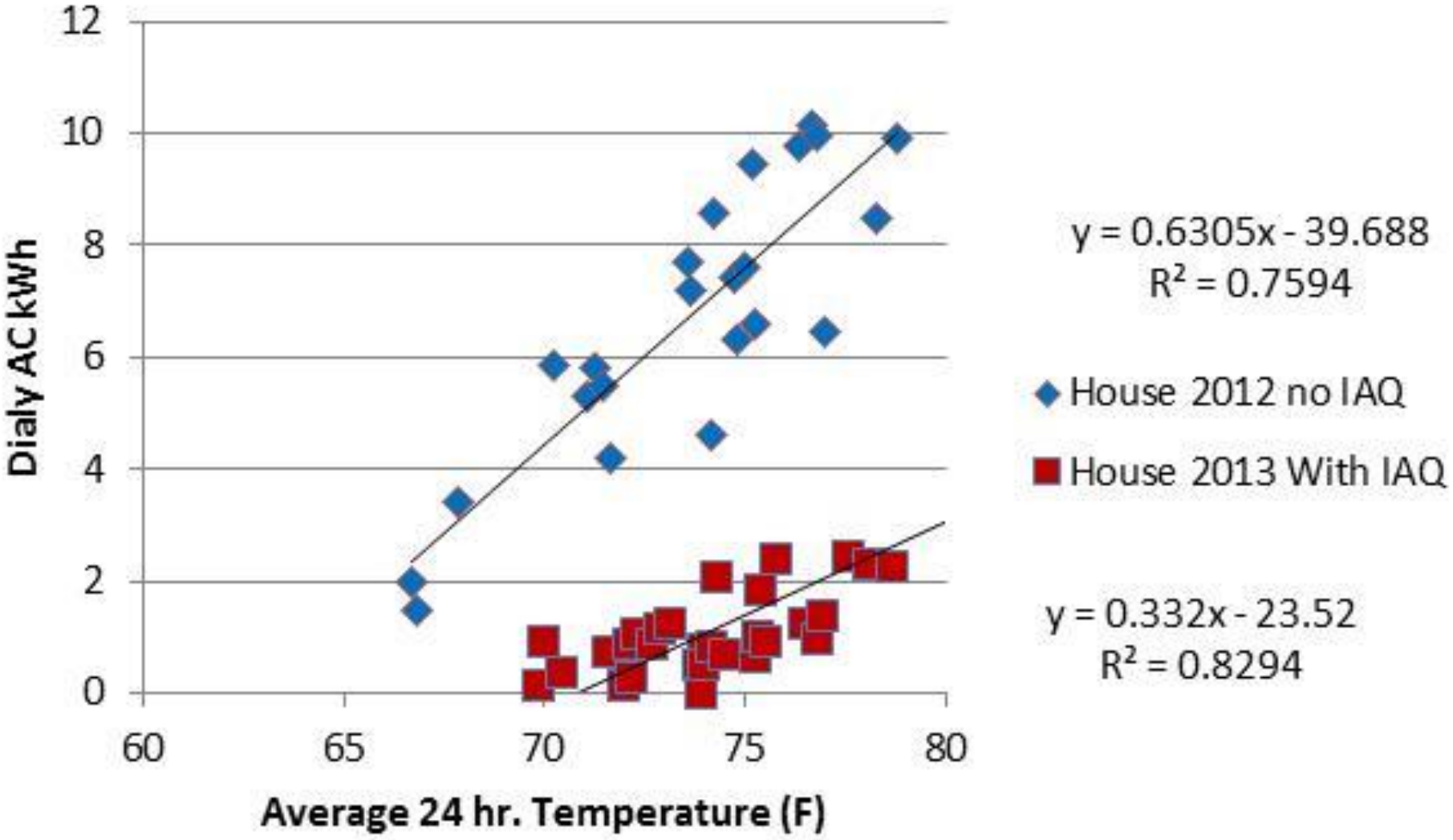
- Attic Ducts Branched Supply
  38”10” long 14” dia. return
  Surface Area 33% of Floor A
  95 CFM25 Leakage R-4.2
- 2.5 Ton 9.5 EER Split AC
  (2485 W) with 0.80 AFUE
  Furnace
- Coil Airflow 219 CFM/ton
- 1/3 HP PSC Fan Motor (361W)

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

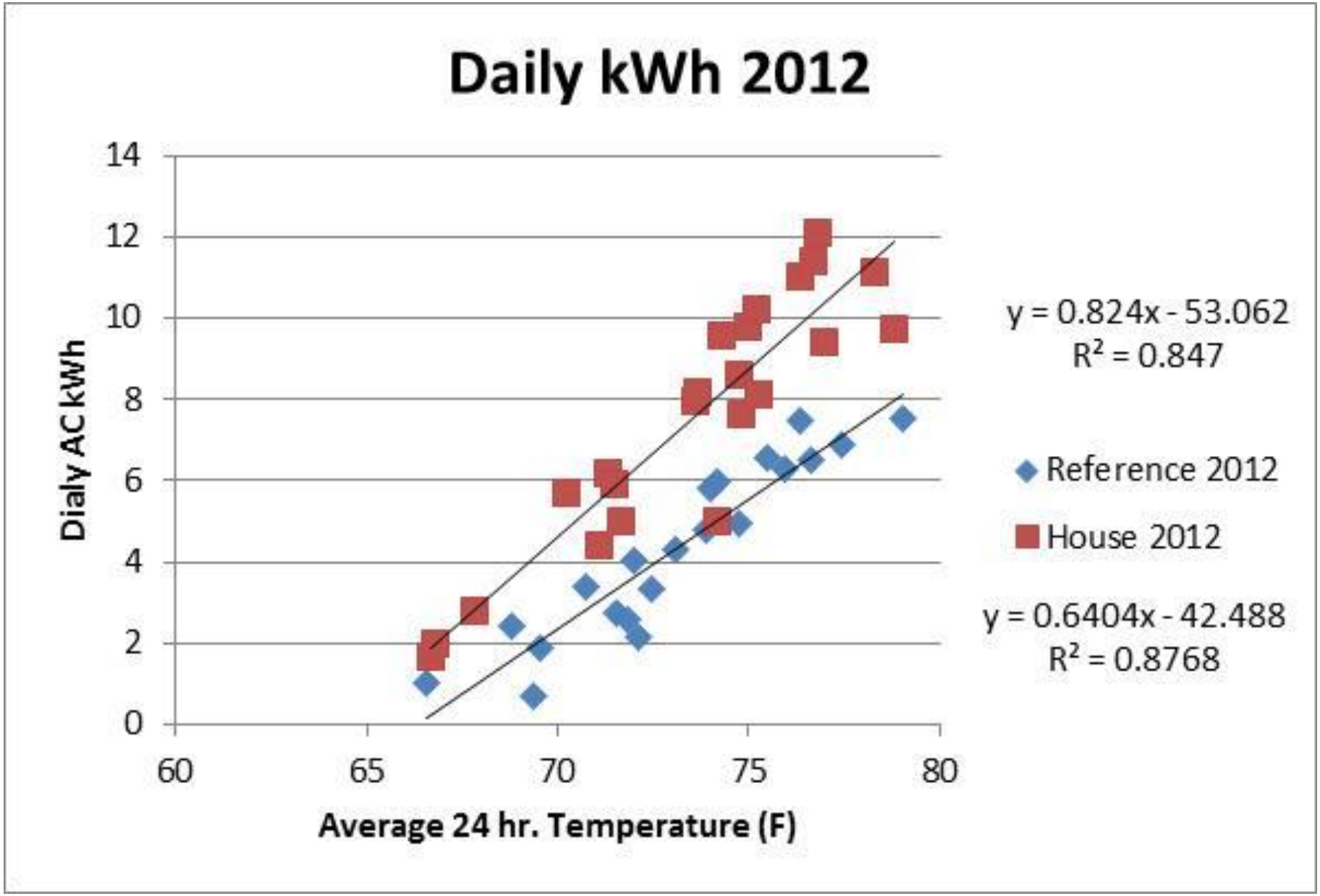
House Daily kWh 2012-2013



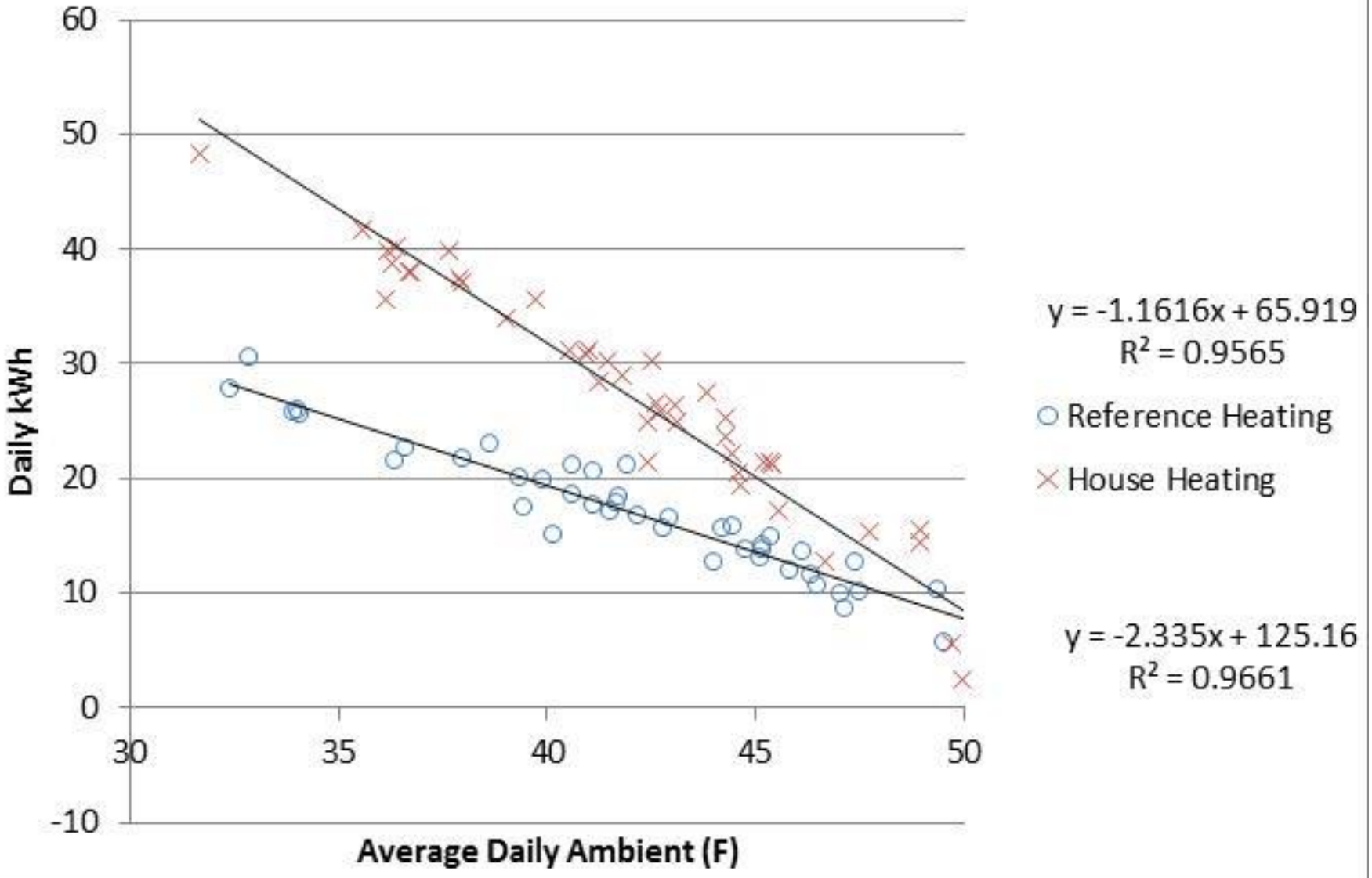
Grange Annual Cooling Savings by Situation

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%	

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

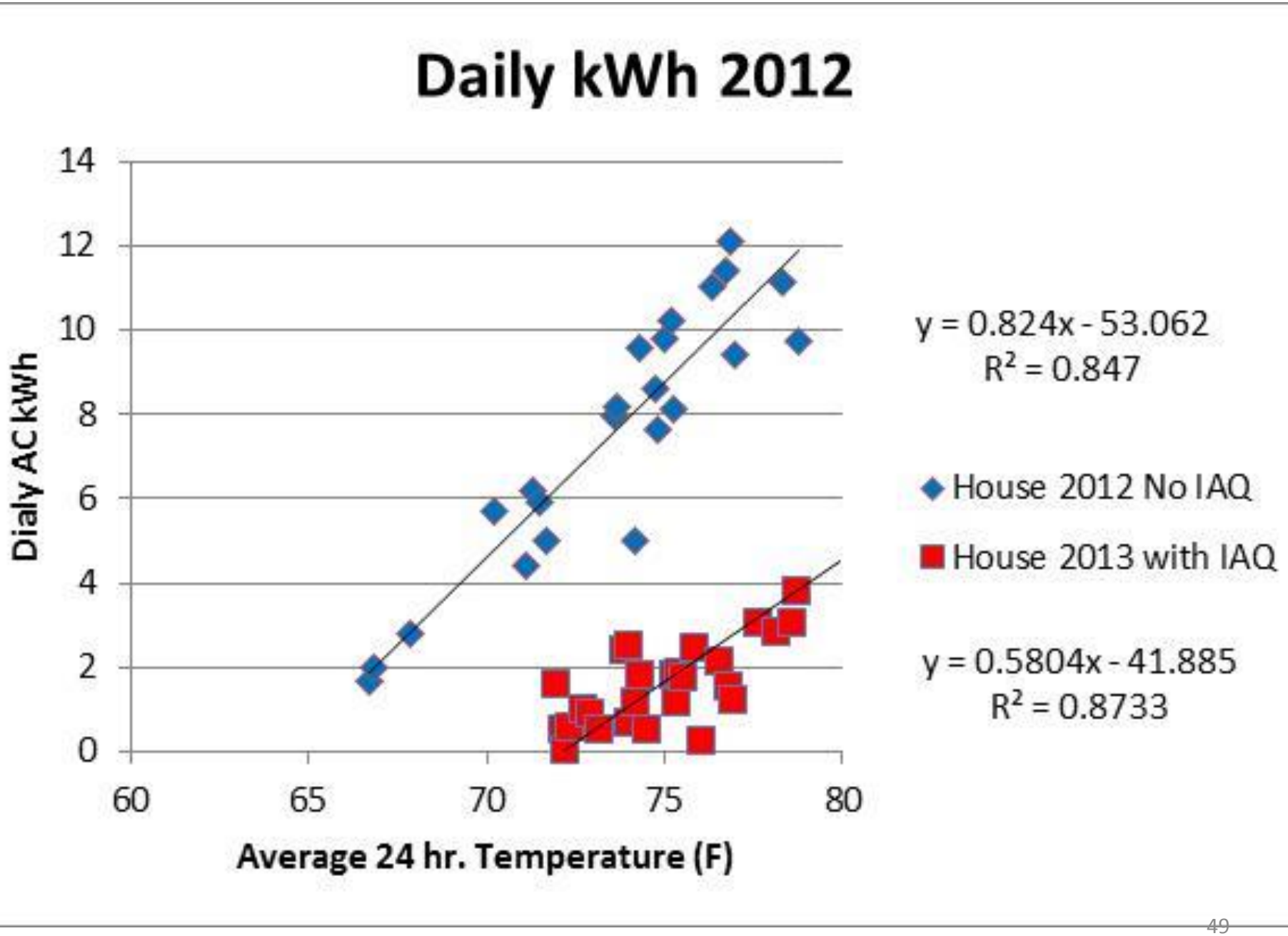
- Extended supply plenum to rafters and did low tapins double insulated plenum, 27 CFM25 Leakage R-8 Buried (R-25?)
- 1.5 Ton (compressor 9.3 EER) TXV to 6^{o} Superheat
- Coil Airflow 612 CFM/ton
- X13 Fan Motor (140W)

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%	