Data not Dogma

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July 30, 2014

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Randomness Happens
Data not Dogma

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 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

[Graph showing comparison of Watts vs. External Static Pressure (IWC) between PSC and BPM/ECM motors.]
ECM/BPM Motors

Dogma

- Increasing airflow by cranking up a BPM motor is counter productive
“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!
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 maintenance standards, the units will work properly.

Data

• Evidence shows no change in procedures or outcomes
Ratings

HERS Calculations show how efficient homes are.
Evaluations

Dogma

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

Reno Nevada Cooling Degree Days (base 68ºF)

TREND

CDD based on TMY3
Program Evaluations

**Dogma**

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

**Data**

- They **ESTIMATE** what that PROGRAM 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

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

OMG Where Do All These Wires Go !!!
Two Cooling Systems per House

Reference System

House System
Step 1: Flip Flop Experiment

<table>
<thead>
<tr>
<th>House System</th>
<th>Reference System</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Switch every two days</td>
<td>• Simulated Occupants</td>
</tr>
<tr>
<td>• Simulated Occupants</td>
<td>• Simulated Occupant Thermostat Control</td>
</tr>
<tr>
<td>• Monitored Indoor and Outdoor Conditions (Incident Radiation, Wind, Temperature, Humidity)</td>
<td></td>
</tr>
</tbody>
</table>
Caleb 2005, 4 BR, 2076 ft², Approximately Current Code
HVAC & Ducts in Attic w Tile Roof
Daily kWh 2012

\[ y = 1.0696x - 67.264 \]
\[ R^2 = 0.9691 \]

\[ y = 0.6679x - 42.913 \]
\[ R^2 = 0.9316 \]
2012 Caleb Site Heating Energy
2 Similar days in December

<table>
<thead>
<tr>
<th>Heating Energy kBtu/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Electric No Ducts</td>
</tr>
<tr>
<td>Gas Furnace Ducts in Attic</td>
</tr>
</tbody>
</table>

- 12/13 Elec
- 12/15 Gas
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
<table>
<thead>
<tr>
<th>Situation</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Savings (Shell and System) between As Found and Retrofit Round Number 1</td>
<td><strong>35%</strong></td>
</tr>
<tr>
<td>Shell Savings based on Reference System between As Found and Retrofit Round Number 1</td>
<td><strong>12%</strong></td>
</tr>
<tr>
<td>HVAC System Savings between As Found and Retrofit Round Number 1</td>
<td><strong>27%</strong></td>
</tr>
<tr>
<td>Retrofit Round 2 will further determine the effect of Whole House Fans, 62.2 Level Ventilation, and Roof Retrofit</td>
<td></td>
</tr>
</tbody>
</table>
Fidelia - Built 1996, 4 BR, 1690 ft², slab on grade
Fidelia Daily kWh Winter 2012 - 2013

- 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

- House 2012 No IAQ:
  \[ y = 1.2145x - 75.997 \]
  \[ R^2 = 0.9368 \]

- House 2013 With IAQ:
  \[ y = 0.5708x - 37.882 \]
  \[ R^2 = 0.8527 \]
# Fidelia Annual Cooling Savings by Situation

<table>
<thead>
<tr>
<th>As Found House HVAC System Efficiency vs. Ref System</th>
<th>Retrofitted House HVAC System Efficiency vs. Ref System</th>
</tr>
</thead>
<tbody>
<tr>
<td>42%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Savings from Shell &amp; HVAC between As Found and Retrofit Round Number 1</th>
<th>Shell Savings between As Found and Retrofit Round Number 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>71%</td>
<td>32%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HVAC Savings between As Found and Retrofit Round Number 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>57%</td>
<td>44%</td>
</tr>
</tbody>
</table>
Grange - Built 1948, 2 BR, 852 ft², slab on grade
Daily kWh 2012

- Reference 2012
- House 2012

\[ y = 0.6305x - 39.688 \]
\[ R^2 = 0.7594 \]

\[ y = 0.517x - 34.197 \]
\[ R^2 = 0.7279 \]
Grange Daily kWh Winter 2012 - 2013

- Reference Heating: $y = -0.9443x + 54.301$, $R^2 = 0.9261$
- House Heating: $y = -1.9847x + 109.21$, $R^2 = 0.9277$
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° Superheat Reorificed Furnace
- Coil Airflow 540 CFM/ton
- Concept3™ BPM Fan Motor (80W)
Attic Air Sealing
House Daily kWh 2012-2013

Dialy ACkWh

Average 24 hr. Temperature (F)

- $y = 0.6305x - 39.688$
  - $R^2 = 0.7594$
  - House 2012 no IAQ

- $y = 0.332x - 23.52$
  - $R^2 = 0.8294$
  - House 2013 With IAQ
## Grange Annual Cooling Savings by Situation

<table>
<thead>
<tr>
<th>As Found House HVAC System Efficiency vs. Ref System</th>
<th>Retrofitted House HVAC System Efficiency vs. Ref System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>65%</strong></td>
<td><strong>95%</strong></td>
</tr>
<tr>
<td><strong>Savings from Shell &amp; HVAC between As Found and Retrofit Round Number 1</strong></td>
<td><strong>Shell Savings between As Found and Retrofit Round Number 1</strong></td>
</tr>
<tr>
<td><strong>73%</strong></td>
<td><strong>61%</strong></td>
</tr>
<tr>
<td><strong>HVAC Savings between As Found and Retrofit Round Number 1</strong></td>
<td></td>
</tr>
<tr>
<td><strong>31%</strong></td>
<td></td>
</tr>
</tbody>
</table>
Grange

- Post-Retrofit House System with WHF: $y = 0.2308x - 16.184$, $R^2 = 0.6616$
- Post-Retrofit Reference System with WHF: $y = 0.2824x - 20.166$, $R^2 = 0.8623$
Mayfair - Built 1953, 3 BR, 1104 ft², crawl space
Daily kWh 2012

- Reference 2012
- House 2012

Equations:

- Reference 2012: $y = 0.824x - 53.062$, $R^2 = 0.847$
- House 2012: $y = 0.6404x - 42.488$, $R^2 = 0.8768$
Mayfair Daily kWh Winter 2012 - 2013

- Reference Heating: $y = -1.1616x + 65.919$, $R^2 = 0.9565$
- House Heating: $y = -2.335x + 125.16$, $R^2 = 0.9661$
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° Superheat
- Coil Airflow 612 CFM/ton
- X13 Fan Motor (140W)
New Ducts
Air Sealing
R-49 Attic Insulation
Drill and Fill
Daily kWh 2012

\[ y = 0.824x - 53.062 \]
\[ R^2 = 0.847 \]

- Blue diamonds: House 2012 No IAQ
- Red squares: House 2013 with IAQ

\[ y = 0.5804x - 41.885 \]
\[ R^2 = 0.8733 \]
## Mayfair Annual Cooling Savings by Situation

<table>
<thead>
<tr>
<th></th>
<th>As Found House HVAC System Efficiency vs. Ref System</th>
<th>Retrofitted House HVAC System Efficiency vs. Ref System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>62%</strong></td>
<td></td>
<td><strong>89%</strong></td>
</tr>
<tr>
<td>Savings from Shell &amp; HVAC between As Found and Retrofit Round Number 1</td>
<td></td>
<td>Shell Savings between As Found and Retrofit Round Number 1</td>
</tr>
<tr>
<td><strong>74%</strong></td>
<td></td>
<td><strong>60%</strong></td>
</tr>
<tr>
<td>HVAC Savings between As Found and Retrofit Round Number 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>30%</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Case of the Flexible Yardstick

Reference System

House System
Mayfair Example
Reference Outdoor Watt Draw
No Change

\[ y = 0.0319x - 0.0272 \]
\[ R^2 = 0.7816 \]

\[ y = 0.0325x - 0.0916 \]
\[ R^2 = 0.8746 \]
Reference Air Handler Watt Draw Changed Relative to Outdoor Temp

![Graph showing the relationship between outside temperature (degrees F) and air handler kW, with linear regression lines and R^2 values.](image)

- Pre: $y = -0.0073x + 1.0925$, $R^2 = 0.535$
- Post: $y = -0.0071x + 1.1428$, $R^2 = 0.5234$
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
Grange

Pre-Retrofit House: $y = 0.6305x - 39.688$
$R^2 = 0.7594$

Pre-Retrofit Reference System: $y = 0.517x - 34.197$
$R^2 = 0.7279$

Pre-Retrofit House System

Pre-Retrofit Reference System

Post-Retrofit Reference System with WHF
Grange

The graphs show the relationship between daily kWh consumption and average daily ambient temperature for different systems:

- **Pre-Retrofit House System**
- **Pre-Retrofit Reference System**
- **Post-Retrofit Reference System with WHF**
- **Post-Retrofit House System with WHF**

The left graph compares the consumption before and after retrofitting, with data points scattered across two systems. The right graph further categorizes the data with an additional comparison for systems incorporating WHF technology.
Grange
Grange

<table>
<thead>
<tr>
<th>System</th>
<th>Equation</th>
<th>R² Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Retrofit House System</td>
<td>$y = 0.2308x - 16.184$</td>
<td>0.6616</td>
</tr>
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<td>$y = 0.2824x - 20.166$</td>
<td>0.8623</td>
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<tr>
<td>Post-Retrofit House System with WHF</td>
<td></td>
<td></td>
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