



**GTI ENERGY**

*solutions that transform*



## Small Furnaces, Big Improvements Advanced Wall Furnaces

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# Presented Today

- What are Wall Furnaces?
- Wall Furnace Project Overview
- Laboratory Testing Highlights
- Field Monitoring Highlights
- Wall Furnace Performance
  - Wall Furnace Savings

Project funding from



**CALIFORNIA**  
**ENERGY COMMISSION** &



# What are Wall Furnaces?

- Small traditionally simple, furnaces that heat one or two rooms
- Usually (but not always) within wall cavity between studs on an inside wall



Wall Furnace Options	STANDARD	ADVANCED
<b>Heat Distribution:</b>	Gravity	Fan-type
<b>Combustion Air:</b>	Top vent / vented	Direct vent
<b>Burner Ignition:</b>	Standing pilot	Intermittent pilot or Hot surface igniter
<b>Heat Recovery:</b>	Non-condensing	Condensing
<b>Emissions:</b>	No controls	Low NOx controls
<b>Sides:</b>	Single-sided	Double-sided
<b>AC Power:</b>	Self-powered	AC power supply or Self-powered



# Wall Furnace Efficiency Standards

- **Many existing furnaces are old**
- Too old to have AFUE ratings
  - Eight of ten in this study
- Some with 50% thermal efficiency
  - Two of ten in this study

Minimum Wall Furnace Thermal Efficiency (Output Capacity / Input Capacity) Requirement from ANSI Z21.86-2016

	Gravity Wall Furnaces	Fan-Type Wall Furnaces
Minimum Thermal Efficiency	70%	75%

Minimum AFUE Requirements for Wall Furnaces manufactured after January 1, 1990 and April 16, 2013

Furnace Type	Input Capacity	AFUE 1990	AFUE 2013
Gas Wall Gravity	up to 10,000 Btu/hr	59%	65%
Gas Wall Gravity	over 10,000 up to 12,000 Btu/hr	60%	
Gas Wall Gravity	over 12,000 up to 15,000 Btu/hr	61%	
Gas Wall Gravity	over 15,000 up to 19,000 Btu/hr	62%	
Gas Wall Gravity	over 19,000 up to 27,000 Btu/hr	63%	
Gas Wall Gravity	over 27,000 up to 46,000 Btu/hr	64%	66%
Gas Wall Gravity	over 46,000 Btu/hr	65%	67%
Gas Wall Fan-Type	up to 42,000 Btu/hr	73%	75%
Gas Wall Fan-Type	over 42,000 Btu/hr	74%	76%

# Wall Furnace Requirements

- **Emissions and Indoor Air Quality Regulations, Standards, and Guidelines**

– None specifically apply to wall furnaces

Rule	Equipment	CO	NOx	PM2.5 & PM10
<b>Code of Federal Regulations (CFR)</b>	Residential forced-air furnaces, wood-burning stoves	n/a	n/a	0.93 lbm/MMBtu, 2015 0.15 lbm/MMBtu, 2020
<b>SCAQMD Rule 1111 &amp; SJVAPCD Rule 4905 (SCAQMD)</b>	<b>Central furnaces</b>	n/a	<b>0.033 lbm/MMBtu (14 nanograms/Joule)</b>	n/a
<b>US EPA reference levels of typical indoor pollutants (US EPA)</b>	Indoor air quality in homes	0 - 5 ppm normal 5 - 15 ppm near properly adjusted gas stoves 30 ppm or more near improperly adjusted gas stoves	n/a	n/a
<b>National Ambient Air Quality Standards (NAAQS)</b>	Outside air	9 ppm 8 hours 35 ppm 1 hour	100 ppb 1 hour 53 ppb 24 hours	PM2.5 35 ug/m <sup>3</sup> 24 hours PM10 150 ug/m <sup>3</sup> 24 hours
<b>California Ambient Air Quality Standards (CAAQS)</b>	Outside air	9 ppm 8 hours 20 ppm 1 hour	180 ppb 1 hour 30 ppb 24 hours	PM2.5 none 24 hours PM10 50 ug/m <sup>3</sup> 24 hours



# Wall Furnace Research Project Overview

# Monitoring & Testing Logistics

## • Laboratory Testing

- 10 **Baseline** furnaces tested
  - Actual furnaces from field tests
- 4 **Retrofit** furnace types tested
  - New furnaces from manufacturer
  - Installed at 10 field locations

## • Field Monitoring

- 10 **Baseline** furnaces monitored
  - 4 x Los Angeles
  - 1 x Oakland
  - 2 x Hayward
  - 3 x Sacramento
- 10 **Retrofit** furnaces installed & monitored
  - 4 x Los Angeles
  - 1 x Oakland
  - 2 x Hayward
  - 3 x Sacramento, 1 dropped, another monitored with 2 different tenants

# Wall Furnace Data Collection

- **Field Monitoring**


- Indoor T & RH
- Gas valve operation
- **Indoor Air Quality**
  - CO – Carbon Monoxide, ppm
  - NO<sub>x</sub> – Nitrogen Oxides, ppb
  - PM<sub>2.5</sub> – Particulate Matter, ug/m<sup>3</sup>
  - PM<sub>10</sub> – Particulate Matter, ug/m<sup>3</sup>
- Senseware Data Collection System
- Plus local weather and air quality data

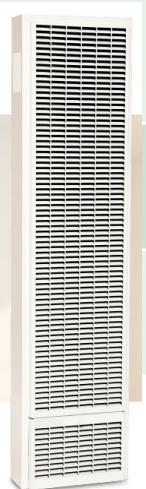
- **Laboratory Testing**

- Temperatures: Room T, WF Inlet T, WF Outlet T (9 T/C grid), WF Exhaust T (3 T/Cs)
- Fuel Use: Natural gas flow, Electricity use
- **Flue Gas Emissions**
  - O<sub>2</sub> %, CO<sub>2</sub> %
  - CO – Carbon Monoxide, ppm
  - NO<sub>x</sub> – Nitrogen Oxides, ppb
  - THC – Total Hydrocarbons, ppm
- Separate Data Logger & Gas Analyzer
- Not isolated or climate-controlled



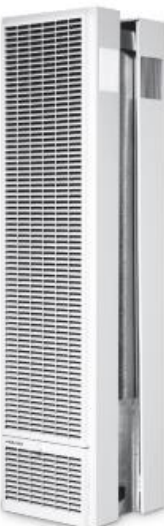
# Los Angeles Wall Furnaces

Apartment #	LA 104	LA 105	LA 106	LA 107
Baseline Units	<b>Williams 25GV-A1-5</b> Top Vent Gravity 25,000 Btu/hr 70% TE 	<b>Williams 35GV-C-5T</b> Top Vent Gravity 35,000 Btu/hr 70% TE 	<b>Williams 35GV-C-5T</b> Top Vent Gravity 35,000 Btu/hr 70% TE 	<b>Williams RMG35-IN</b> Top Vent Gravity 35,000 Btu/hr 70% TE 
Field Monitoring	<b>Complete</b> 2019-20	<b>Complete</b> 2019-20	<b>Complete</b> 2019-20	<b>Complete</b> 2019-20
Lab Testing	<b>Complete</b>	<b>Complete</b>	<b>Complete</b>	<b>Complete</b>
Retrofit Units	<b>Williams AC2030TN</b> installed in all four apartments Single-Sided, Top Vent, Fan-Type, <b>AC Power</b> , 30,000 Btu/hr, 85% TE, 82% AFUE, Low NOx			
Field Monitoring	<b>Complete</b> 2020-21			
Lab Testing	<b>Complete</b> Tests of <b>Four</b> Williams AC2030TN Units			







# Oakland Wall Furnace Testing



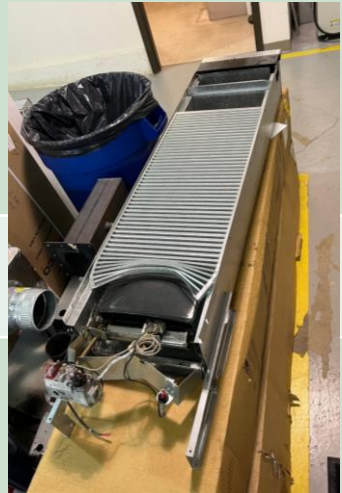
Apartment #	Oakland Single Family Home	
Baseline Unit		<b>Williams 5009622</b> Top Vent, Gravity Double-Sided, 50,000 Btu/hr, 70% TE
Field Monitoring		<b>Complete</b> 2019-20
Lab Testing		<b>Complete</b>
Retrofit Unit	<b>Williams AC3040TN</b> installed between LR/DR Double-Sided, Top Vent, Fan-Type, <b>AC Power</b> , 40,000 Btu/hr, 83% TE, 80% AFUE, Low NOx	
Field Monitoring	<b>Complete</b> 2020-21	
Lab Testing	<b>Complete</b> Test of <b>One</b> Williams AC3040TN Unit	



# Hayward Wall Furnace Testing

Apartment #	Hayward 3	Hayward 4		
Baseline Units	<b>Perfection Products PW8G25SEN-B-4</b> Top Vent Gravity 25,000 Btu/hr, 50% TE		<b>Perfection Products PW8G25SEN-B-4</b> Top Vent Gravity 25,000 Btu/hr, 50% TE	
Field Monitoring	<b>Complete</b> 2020-21		<b>Complete</b> 2020-21	
Lab Testing	<b>Complete</b>		<b>Complete</b>	
Retrofit Units	<b>Williams 1753012</b> installed in both apartments Direct Vent, Fan-Type, Condensing, 17,500 Btu/hr, 94% TE, 93% AFUE			
Field Monitoring	<b>Complete</b> 2021-22	<b>Complete</b> 2021-22		
Lab Testing	<b>Complete</b> Test of <b>Two</b> Williams 1753012 Units			

# Sacramento Wall Furnace Testing

Apartment #	4	15	19
Baseline Units	<b>Holly-General 35S-D</b> 35,000 Btu/hr 70% TE 	<b>Holly-General 35S-D</b> 35,000 Btu/hr 70% TE 	<b>Williams 3509622</b> 35,000 Btu/hr 74% TE 
Field Monitoring	<b>Complete</b> 2020-21	<b>Complete</b> 2020-21	<b>Complete</b> 2020-21
Lab Testing	<b>Complete</b>	<b>Complete</b>	Broken in transit, gas valve replaced <b>Complete</b>
Retrofit Units	<b>Williams TG2030TN</b> installed in all three apartments Single Sided Top Vent Wall Furnace, <b>Self-Powered</b> , 35,000 Btu/hr, 80% AFUE, Low NOx		
Field Monitoring	<b>Complete</b>	Installed March 2022 Unit failure & removal	<b>Tenant 1 2021-22</b> <b>Tenant 2 Nov/Dec 2022</b>
Lab Testing	<b>Complete</b> Test of <b>Three</b> Williams TG2030TN Units		





# Laboratory Testing Highlights

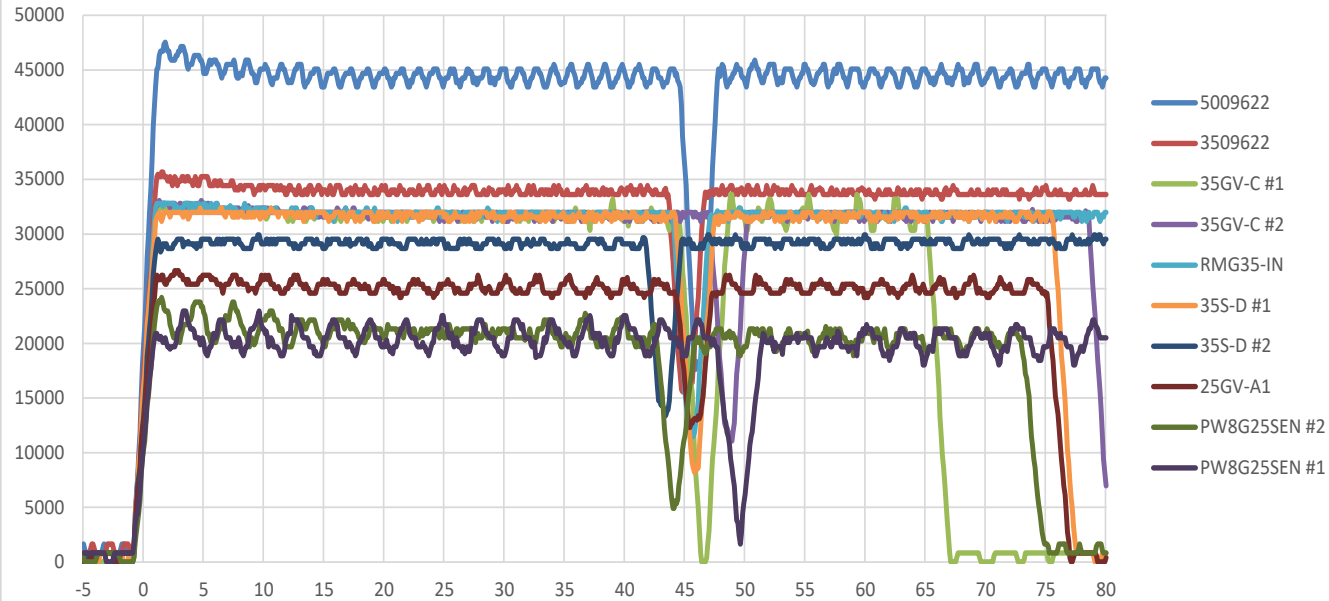
# Lab Data Cold Start and Hot Start Test Procedure



- **Standby**
  - Pilot gas flow only
- **Startup**
  - Gas flow increase, O2% decrease
- **Steady State**
  - Exhaust T reaches 2°F of maximum
- **Shutdown**
  - Gas flow decrease, O2% increase
  - Ends after 1.5 minutes
- **Why these categories?**
  - To capture emissions over each furnace on-off cycle, not just runtime

# Lab Data Wall Furnace Natural Gas Use

Baseline Wall Furnaces - Natural Gas Input Btu/hr

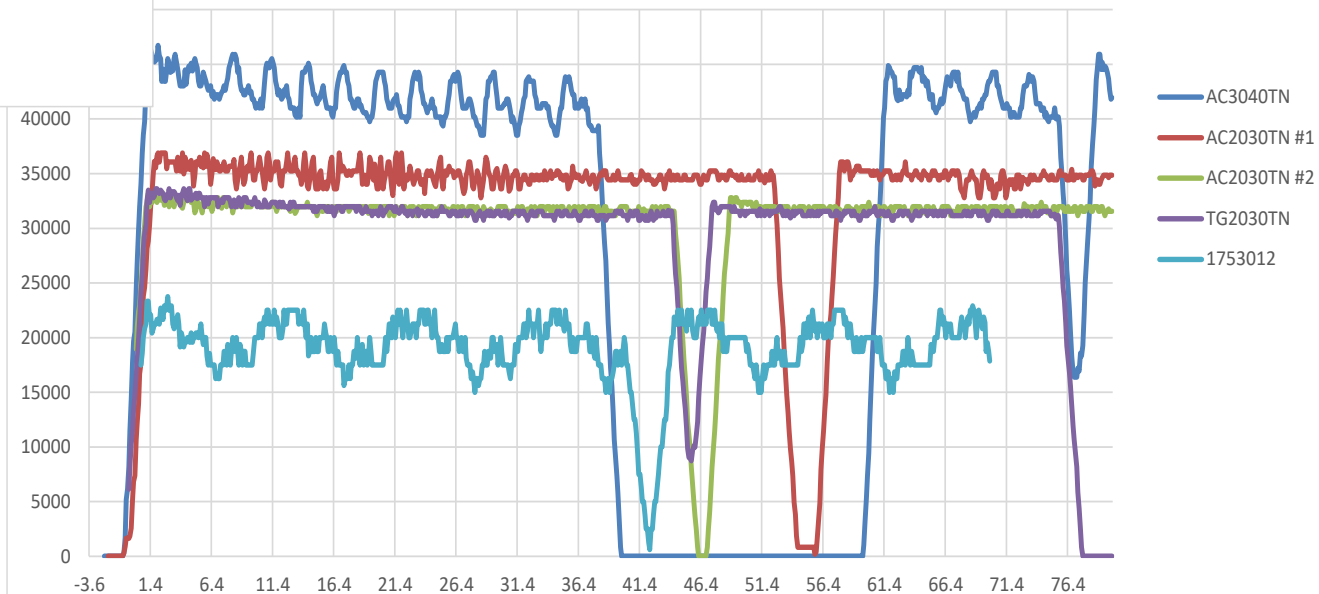


Baseline Wall Furnaces

Lines look wavy due to pulse metering

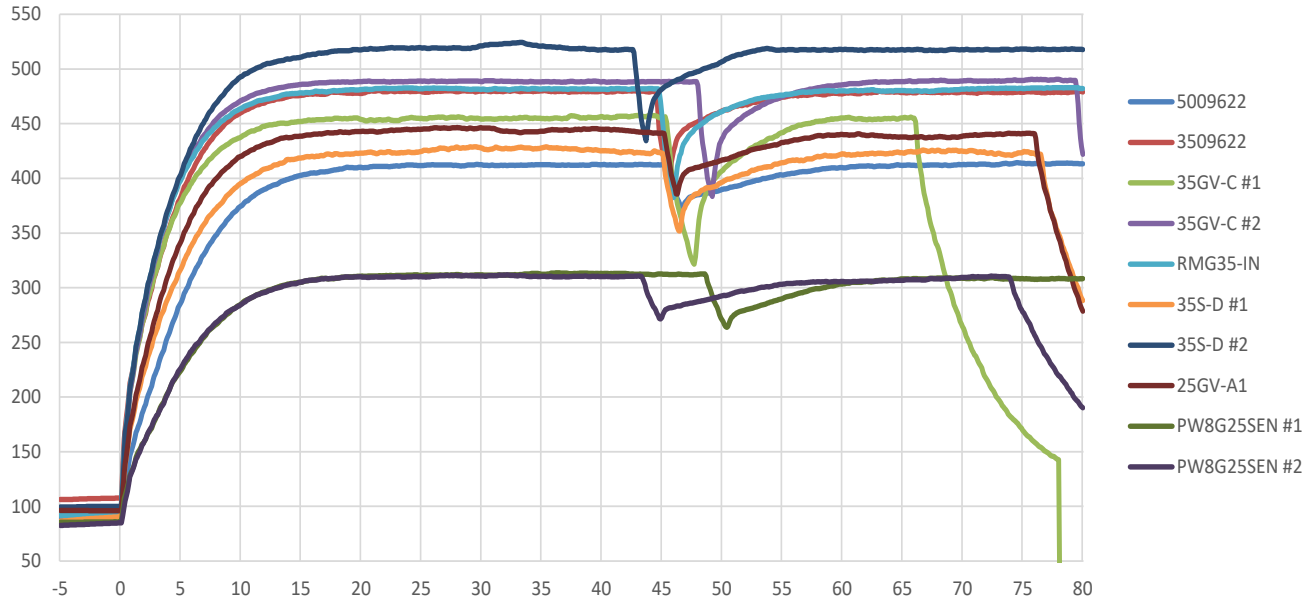
## Retrofit Wall Furnaces

Retrofit Wall Furnaces - Natural Gas Input Btu/hr



# Lab Data Wall Furnace Exhaust Temperatures

Baseline Wall Furnaces - Average Exhaust Temperatures °F

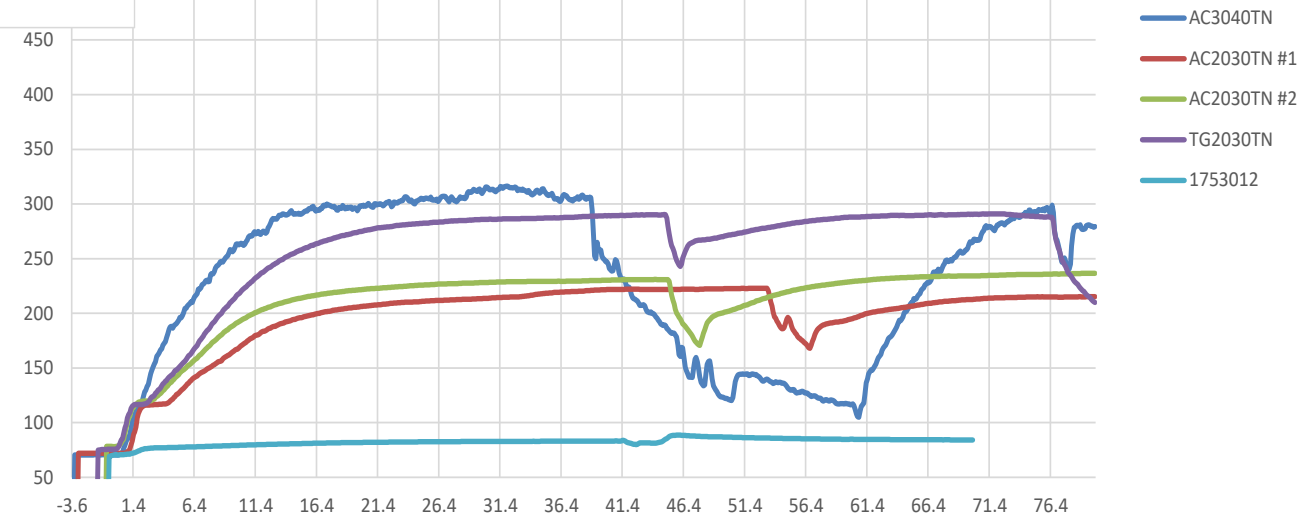


Baseline Wall Furnaces

Exhaust temperatures used to determine efficiency,  
Higher exhaust temperature means more wasted energy

## Retrofit Wall Furnaces

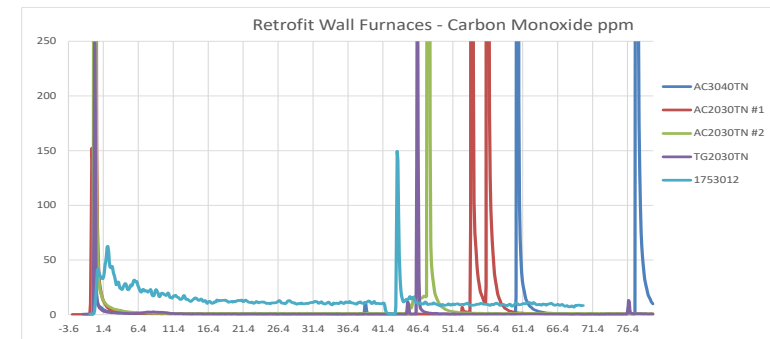
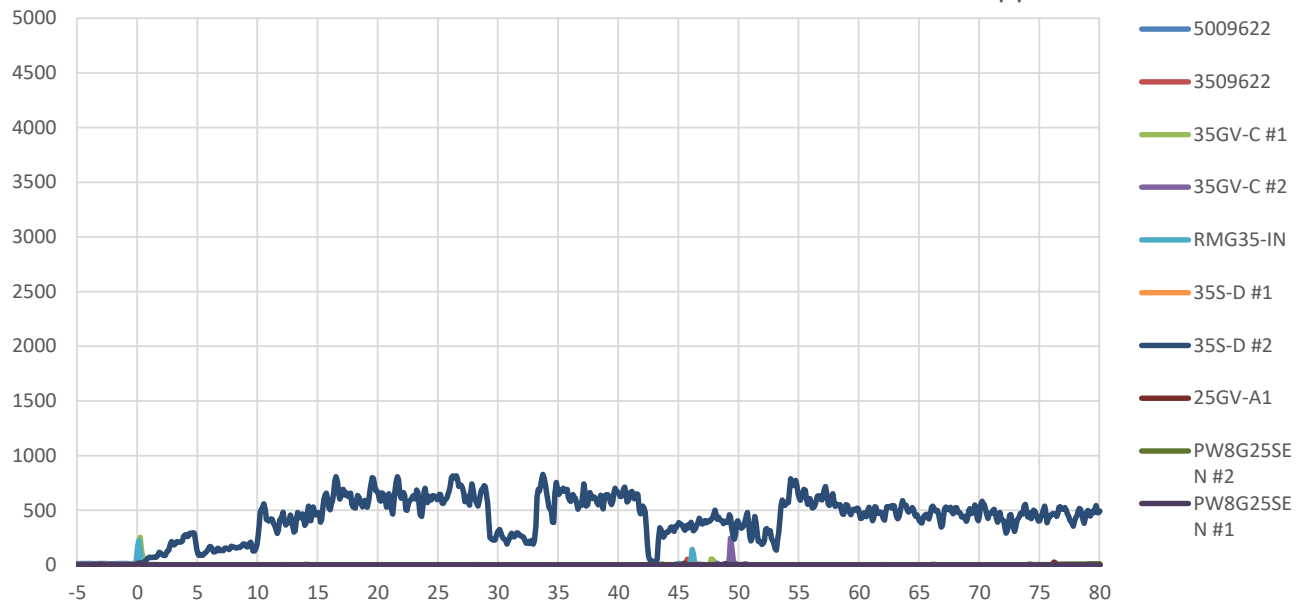
Retrofit Wall Furnaces - Average Exhaust Temperatures °F





# Lab Data Wall Furnace Carbon Monoxide in Flue Gases

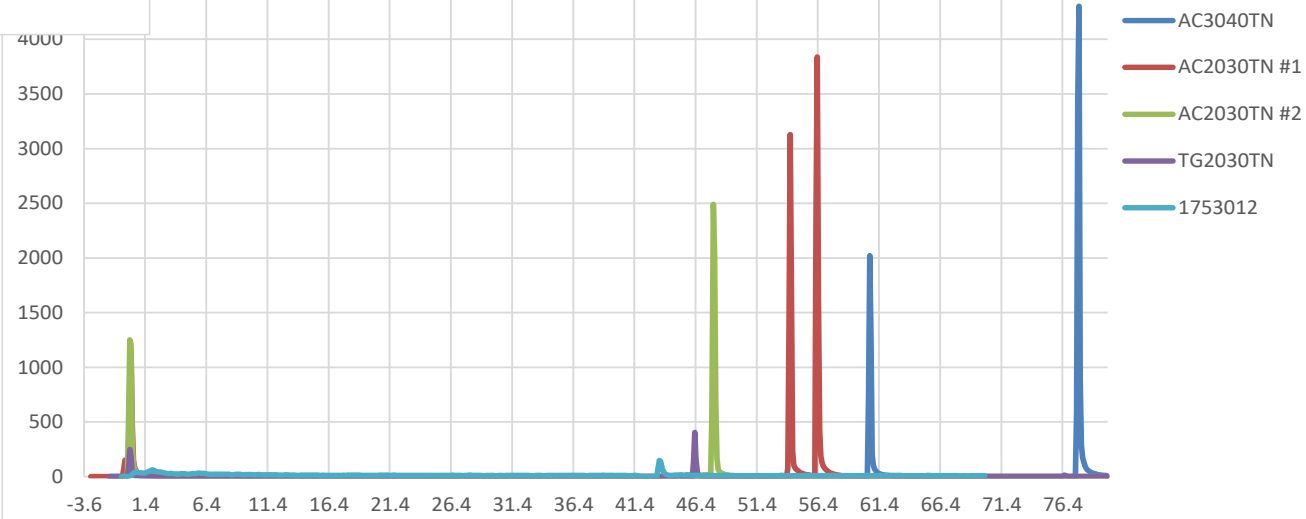
Baseline Wall Furnaces - Carbon Monoxide ppm



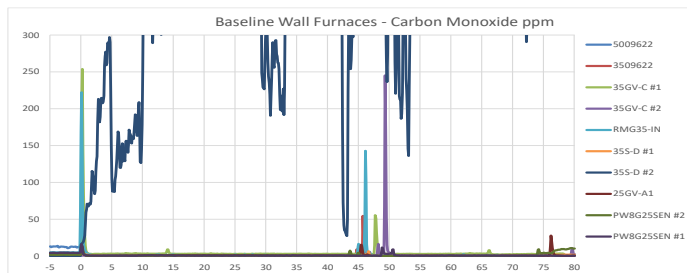
## Retrofit Wall Furnaces

high ppm but low flow at shutdown

Retrofit Wall Furnaces - Carbon Monoxide ppm

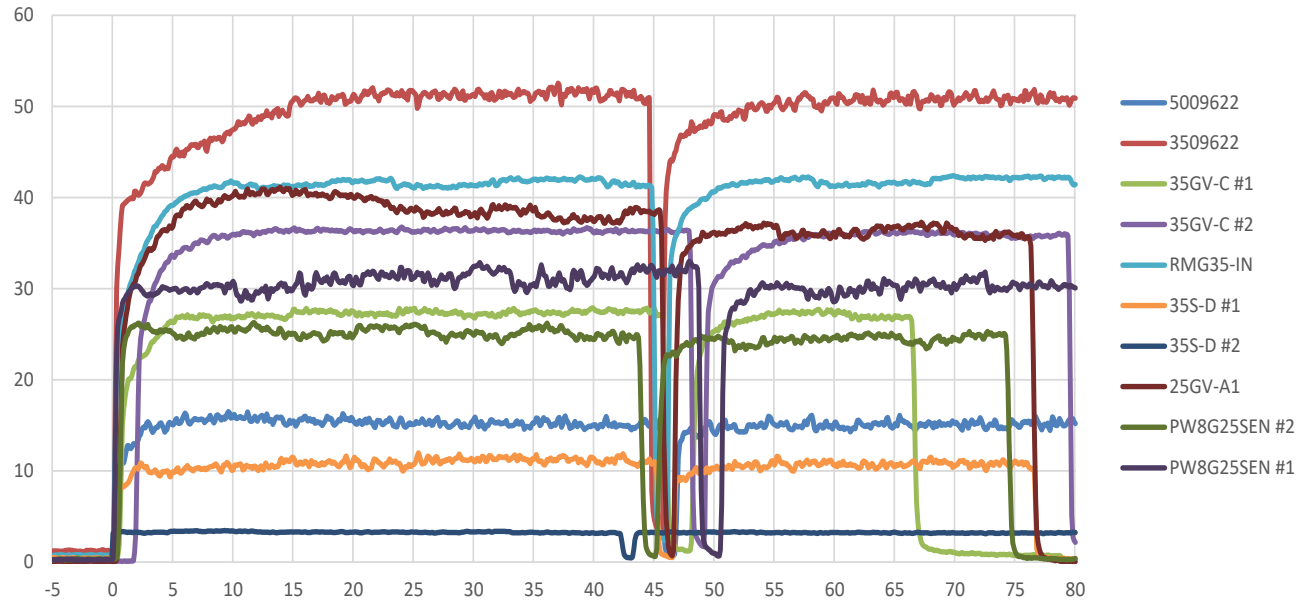


## Baseline Wall Furnaces Suspected gas leak on one unit



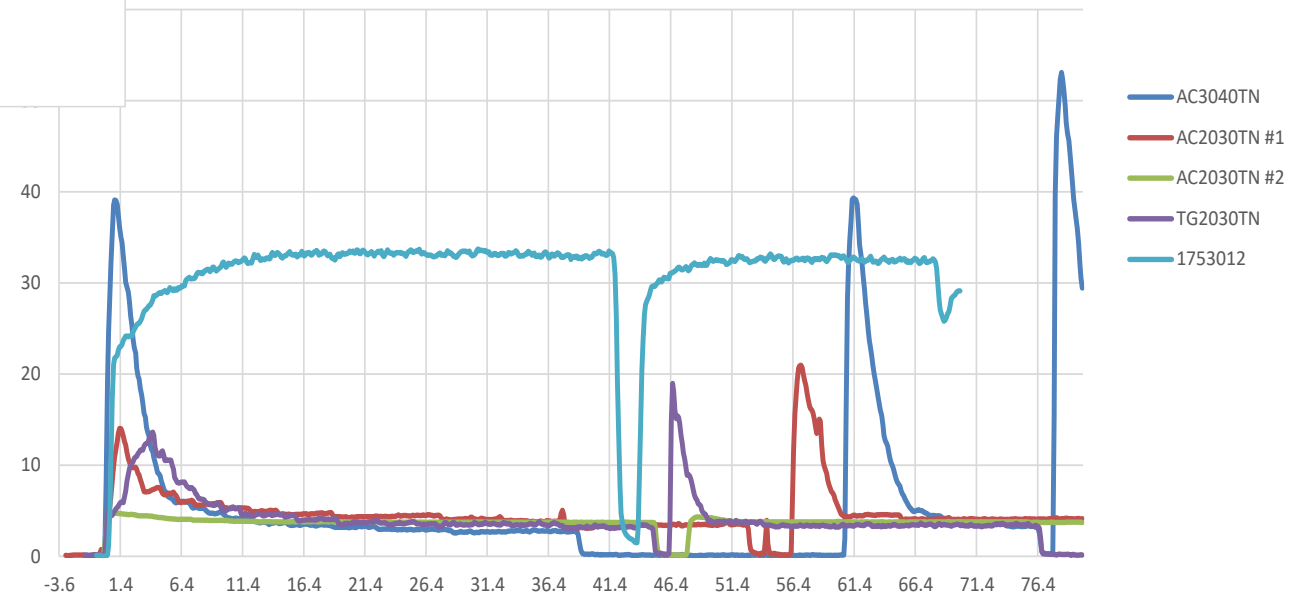
# Lab Data Wall Furnace Nitrogen Oxides in Flue Gases

Baseline Wall Furnaces - Nitrogen Oxides ppm



Retrofit Wall Furnaces  
Low NOx models are working

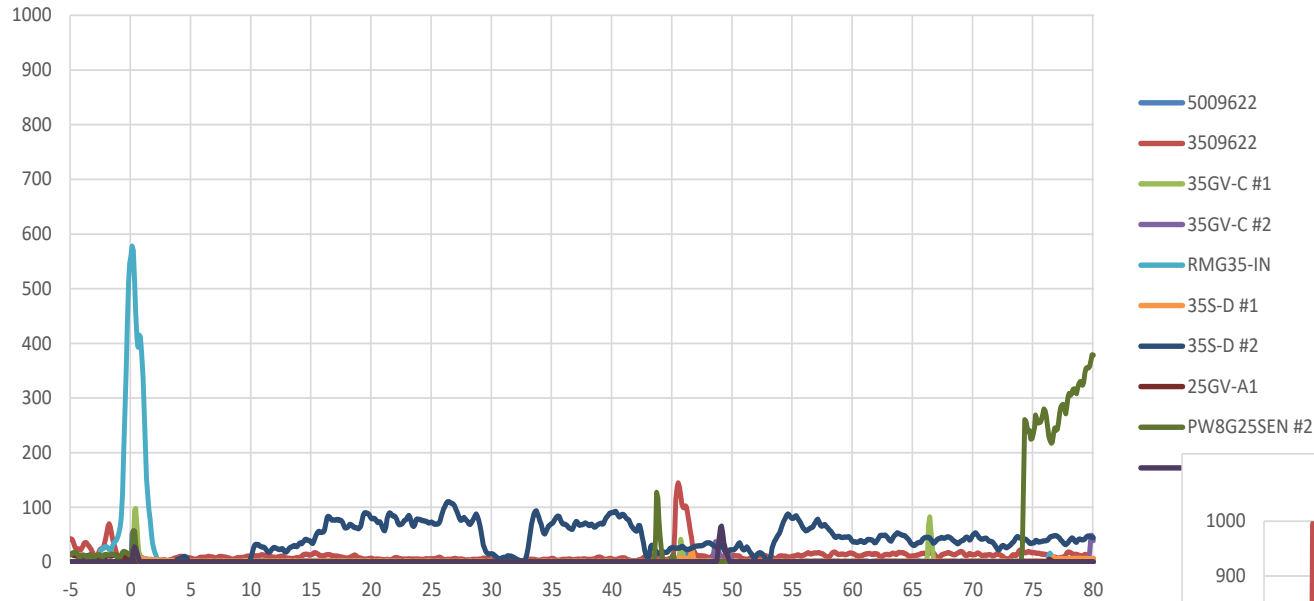
Retrofit Wall Furnaces - Nitrogen Oxides ppm



## Baseline Wall Furnaces

# Lab Data Wall Furnace Total Hydrocarbons in Flue Gases

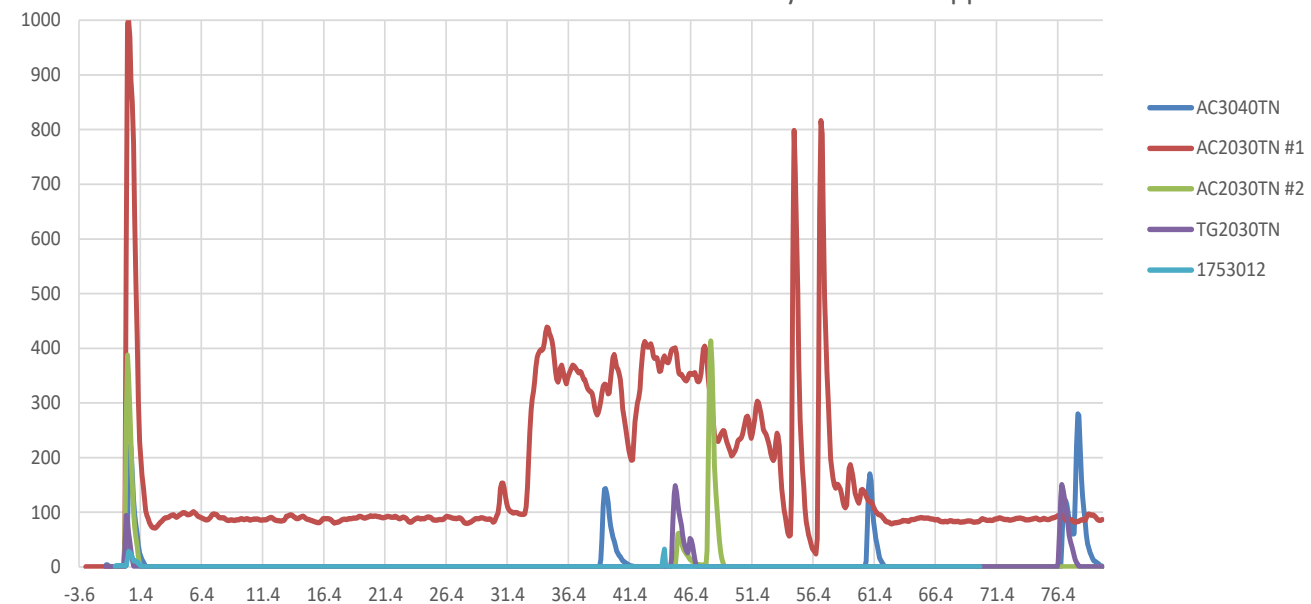
Baseline Wall Furnaces - Total HydroCarbons ppm



**Baseline Wall Furnaces**  
Suspected gas leak on one unit

**Retrofit Wall Furnaces**  
high ppm but low flow at shutdown

Retrofit Wall Furnaces - Total HydroCarbons ppm



# Lab Data High Pollutant Concentration $\neq$ High Emissions

- Convert emission concentration (ppm) to emission rate (lbm/MMBtu) to actual emissions (lbm)

- Find emission rates based on %O<sub>2</sub> in flue gases

$$\text{Emission Rate, lbm/MMBtu} = \frac{\text{Concentration} \times \text{Molecular Weight} \times \text{Fd} \times 20.9}{(20.9 - \text{O}_2\%) \times \text{Molar Volume}}$$

Concentration, ppm = absolute measured pollutant concentration

Molecular weight, lbm/lbmole = 28.0097 for CO, 46.0047 for NO<sub>x</sub> as NO<sub>2</sub>, and 16.04206 for Total Hydrocarbons (THC) as methane

Fd, lbm/MMBtu =  $10^6 \times (3.64 \times \%H + 1.53 \times \%C + 0.57 \times \%S + 0.14 \times \%N - 0.46 \times \%O) / \text{HHV}$ , using dry weight percentages of each element in the house natural gas used for testing

O<sub>2</sub>% = adjusted oxygen percentage in exhaust stream

HHV, Btu/lbm = higher heating value of house natural gas used for testing

Molar Volume, dry ft<sup>3</sup>/lbmole = 385.3 at 68°F and 1 atmosphere

- Multiply by gas flow rates to get actual emissions

- Startup & steady state gas flow = input rate

- Standby gas flow = pilot flow rate or zero

- Shutdown gas flow = pilot flow rate

- For furnaces with no standing pilot

- Standby gas flow = zero

- Shutdown gas flow ~ zero

# Lab Data Baseline & Retrofit Emission Rates in Categories

Wall Furnace Tested			Carbon Monoxide, lbm/MMBtu			
Manufacturer	Model	Field Site	Standby	Startup	Steady State	Shutdown
Perfection Prod	PW8G25SEN #1	Hayward 3 Baseline	0.459	0.005	0.001	0.314
Perfection Prod	PW8G25SEN #2	Hayward 4 Baseline	0.078	0.002	0.019	0.178
Williams	25GV-A1	LA 104 Baseline	0.253	0.002	0.001	0.271
Williams	35GV-C #1	LA 105 Baseline	0.190	0.018	0.063	0.175
Williams	35GV-C #2	LA 106 Baseline	0.105	0.010	0.001	0.057
Williams	RMG35-IN	LA 107 Baseline	0.183	0.012	0.001	0.059
Williams	5009622	Oakland SF Baseline	0.809	0.008	0.002	0.261
Holly General	35S-D #1	Sacramento 4 Baseline	0.166	0.004	0.002	0.072
Holly General	35S-D #2	Sacramento 15 Baseline	0.000	0.880	1.194	1.065
Williams	3509622	Sacramento 19 Baseline	0.122	0.006	0.001	0.064
<b>Average</b>			<b>0.237</b>	<b>0.095</b>	<b>0.128</b>	<b>0.251</b>

Wall Furnace Tested			Carbon Monoxide, lbm/MMBtu			
Manufacturer	Model	Field Site	Standby	Startup	Steady State	Shutdown
Williams	1753012	Hayward 3 & 4 Retrofit	1.093	0.027	0.017	0.023
Williams	AC2030TN #1	LA 104-107 Retrofit	0.620	0.045	0.001	3.106
Williams	AC2030TN #2	LA 104-107 Retrofit	2.216	0.183	0.002	0.681
Williams	AC3040TN	Oakland SF Retrofit	0.230	0.145	0.348	0.048
Williams	TG2030TN	Sacramento 4, 15 & 19 Retrofit	0.075	0.042	0.012	0.041
<b>Average</b>			<b>0.846</b>	<b>0.088</b>	<b>0.076</b>	<b>0.780</b>

Wall Furnace Tested			Nitrogen Oxides, lbm/MMBtu			
Manufacturer	Model	Field Site	Standby	Startup	Steady State	Shutdown
Perfection Prod	PW8G25SEN #1	Hayward 3 Baseline	0.049	0.102	0.105	0.125
Perfection Prod	PW8G25SEN #2	Hayward 4 Baseline	0.021	0.095	0.133	0.309
Williams	25GV-A1	LA 104 Baseline	0.009	0.105	0.108	0.890
Williams	35GV-C #1	LA 105 Baseline	0.038	0.073	0.113	0.414
Williams	35GV-C #2	LA 106 Baseline	0.032	0.076	0.071	0.061
Williams	RMG35-IN	LA 107 Baseline	0.045	0.081	0.084	0.091
Williams	5009622	Oakland SF Baseline	0.037	0.103	0.106	0.077
Holly General	35S-D #1	Sacramento 4 Baseline	0.036	0.088	0.093	0.045
Holly General	35S-D #2	Sacramento 15 Baseline	0.028	0.012	0.012	0.031
Williams	3509622	Sacramento 19 Baseline	0.058	0.115	0.121	0.107
<b>Average</b>			<b>0.035</b>	<b>0.085</b>	<b>0.095</b>	<b>0.215</b>

Wall Furnace Tested			Nitrogen Oxides, lbm/MMBtu			
Manufacturer	Model	Field Site	Standby	Startup	Steady State	Shutdown
Williams	1753012	Hayward 3 & 4 Retrofit	0.178	0.083	0.089	0.266
Williams	AC2030TN #1	LA 104-107 Retrofit	0.027	0.018	0.012	0.019
Williams	AC2030TN #2	LA 104-107 Retrofit	0.030	0.012	0.012	0.015
Williams	AC3040TN	Oakland SF Retrofit	0.077	0.032	0.043	0.032
Williams	TG2030TN	Sacramento 4, 15 & 19 Retrofit	0.039	0.014	0.013	0.016
<b>Average</b>			<b>0.070</b>	<b>0.031</b>	<b>0.034</b>	<b>0.069</b>

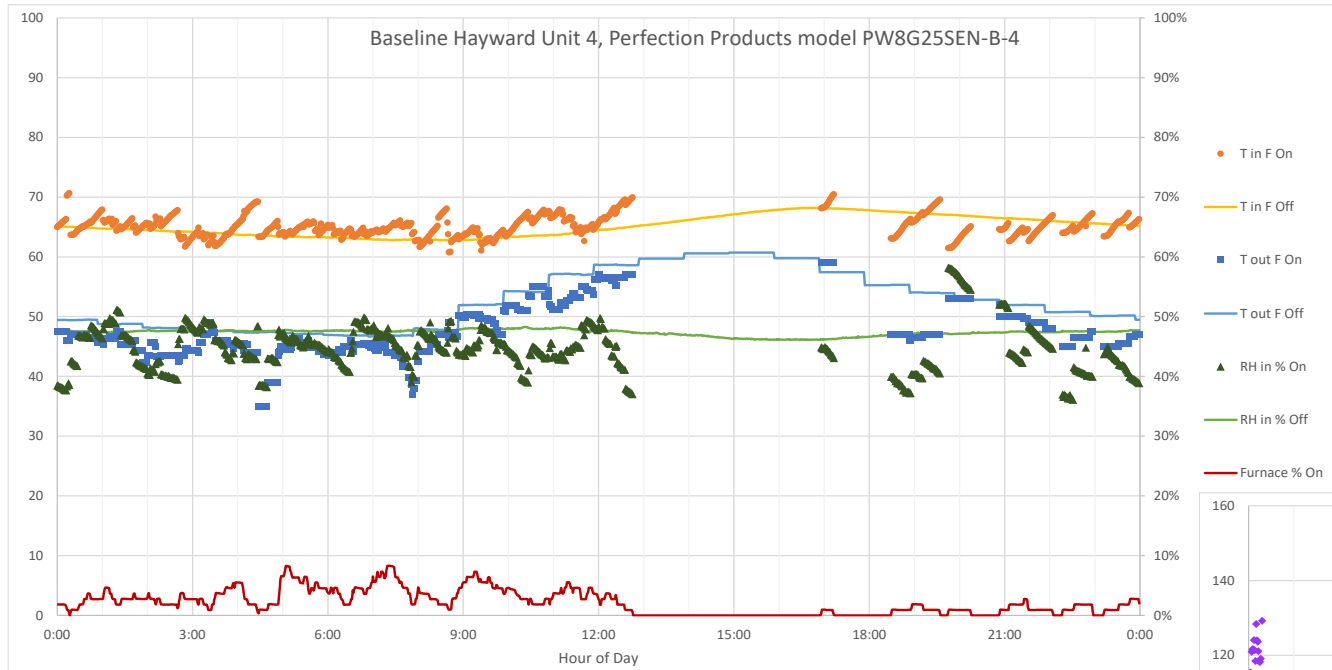
Wall Furnace Tested			Total Hydrocarbons, lbm/MMBtu			
Manufacturer	Model	Field Site	Standby	Startup	Steady State	Shutdown
Perfection Prod	PW8G25SEN #1	Hayward 3 Baseline	0.126	0.001	0.000	1.889
Perfection Prod	PW8G25SEN #2	Hayward 4 Baseline	0.383	0.002	0.642	6.767
Williams	25GV-A1	LA 104 Baseline	0.558	0.001	0.000	0.003
Williams	35GV-C #1	LA 105 Baseline	0.012	0.001	0.009	0.097
Williams	35GV-C #2	LA 106 Baseline	0.000	0.000	0.000	0.140
Williams	RMG35-IN	LA 107 Baseline	0.448	0.025	0.000	0.000
Williams	5009622	Oakland SF Baseline	0.000	0.014	0.004	0.586
Holly General	35S-D #1	Sacramento 4 Baseline	0.000	0.009	0.004	0.161
Holly General	35S-D #2	Sacramento 15 Baseline	0.000	0.047	0.075	0.140
Williams	3509622	Sacramento 19 Baseline	0.287	0.023	0.007	0.939
<b>Average</b>			<b>0.181</b>	<b>0.012</b>	<b>0.074</b>	<b>1.072</b>

Wall Furnace Tested			Total Hydrocarbons, lbm/MMBtu			
Manufacturer	Model	Field Site	Standby	Startup	Steady State	Shutdown
Williams	1753012	Hayward 3 & 4 Retrofit	0.004	0.003	0.000	0.000
Williams	AC2030TN #1	LA 104-107 Retrofit	0.171	0.160	0.258	1.499
Williams	AC2030TN #2	LA 104-107 Retrofit	0.008	0.013	0.000	0.597
Williams	AC3040TN	Oakland SF Retrofit	0.004	0.013	0.026	1.386
Williams	TG2030TN	Sacramento 4, 15 & 19 Retrofit	0.002	0.004	0.032	1.144
<b>Average</b>			<b>0.038</b>	<b>0.038</b>	<b>0.063</b>	<b>0.925</b>



# Field Monitoring Highlights

# Typical Field Data Tin, Tout, RHin, % On, Watts vs Time of Day

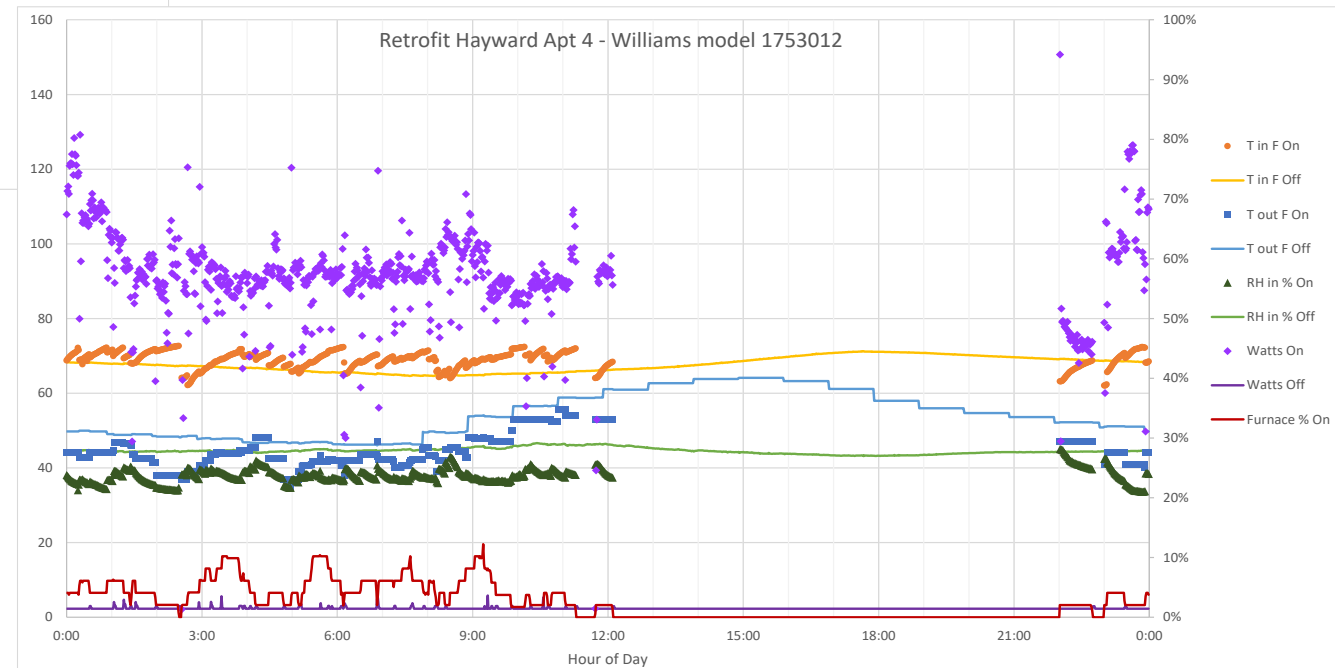


Baseline Wall Furnace  
Top Vent Gravity

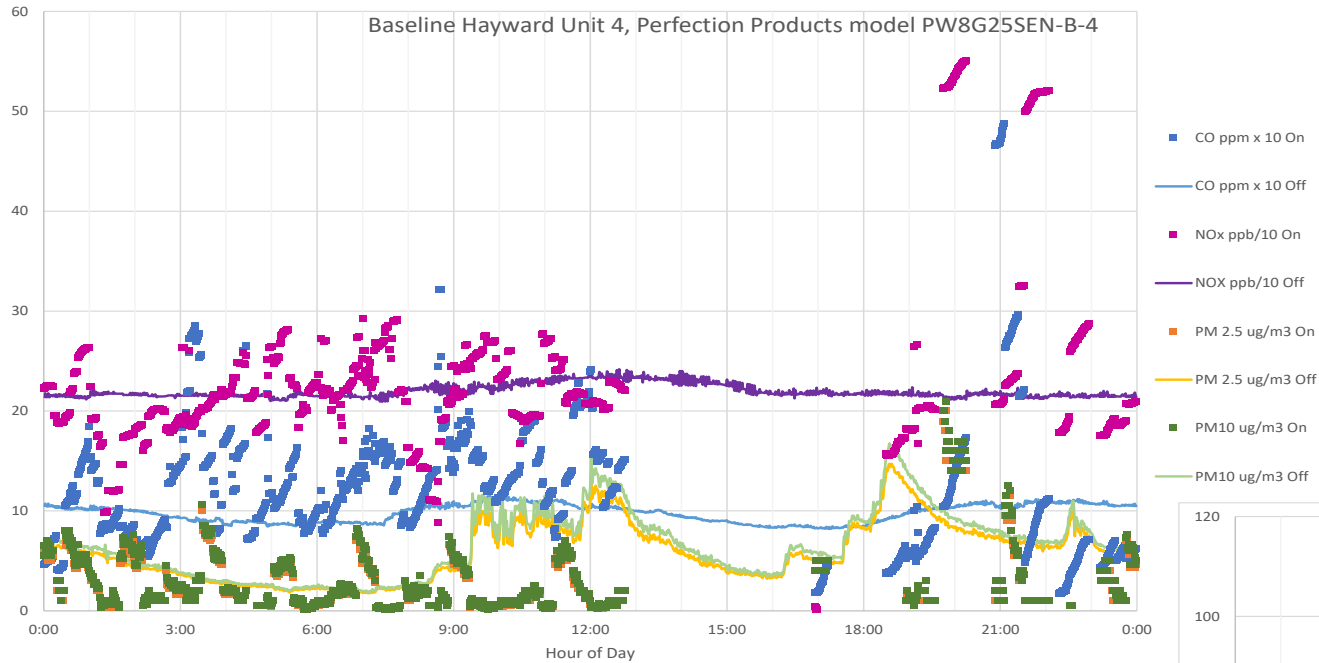
## HAYWARD 4

Average Heating Season  
On & Off Operation

Retrofit Wall Furnace  
Direct Vent Fan-Type Condensing



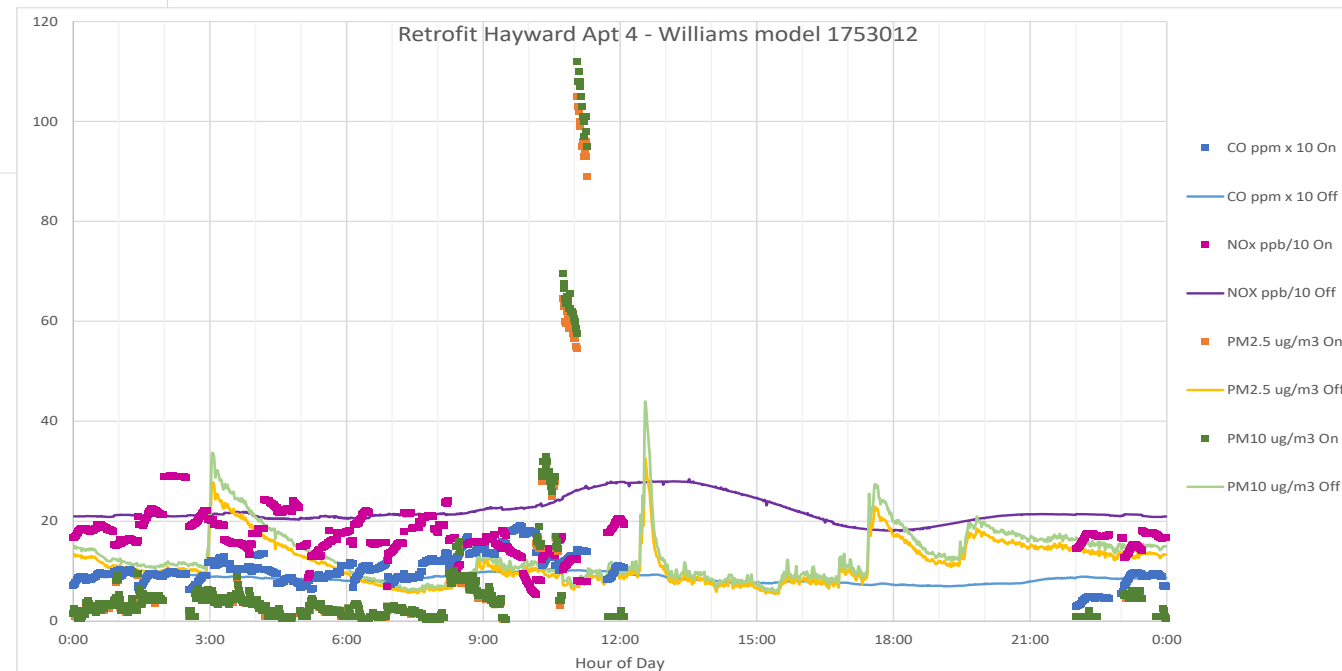
# Typical Field Data CO, NO<sub>x</sub>, PM<sub>2.5</sub>, PM<sub>10</sub> vs Time of Day



Baseline Wall Furnace  
Top Vent Gravity

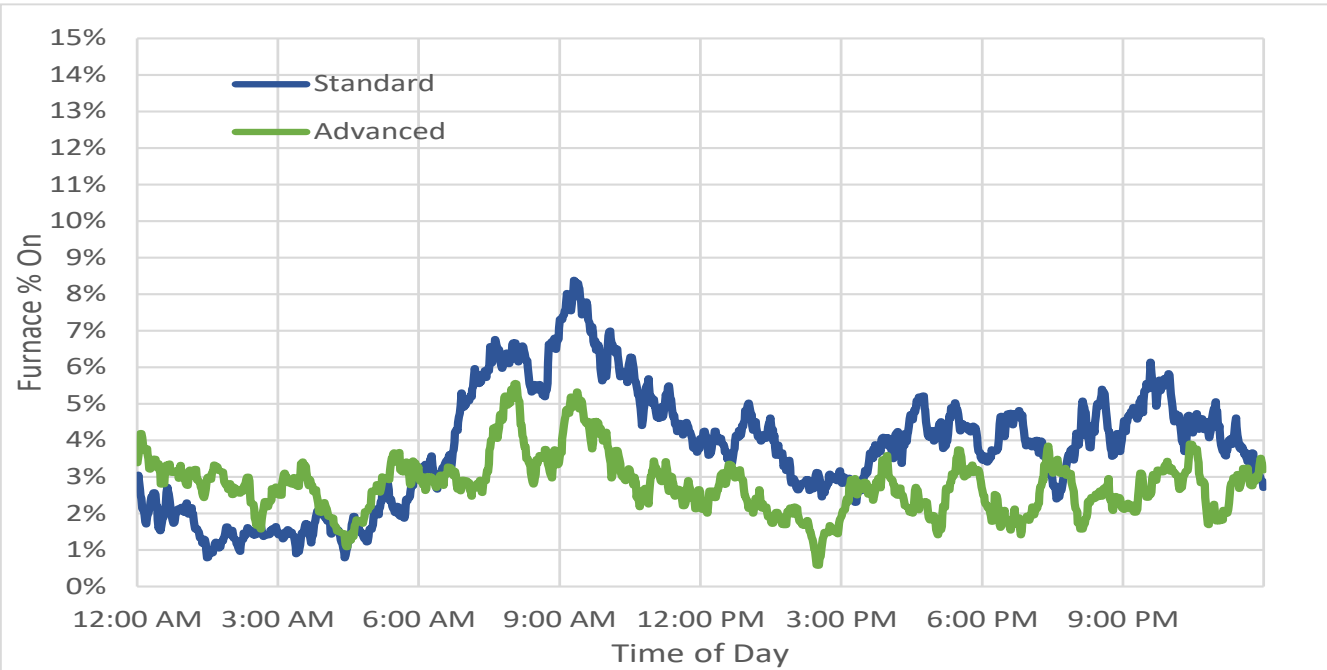
## HAYWARD 4 Average Heating Season On & Off Operation

Retrofit Wall Furnace  
Direct Vent Fan-Type Condensing



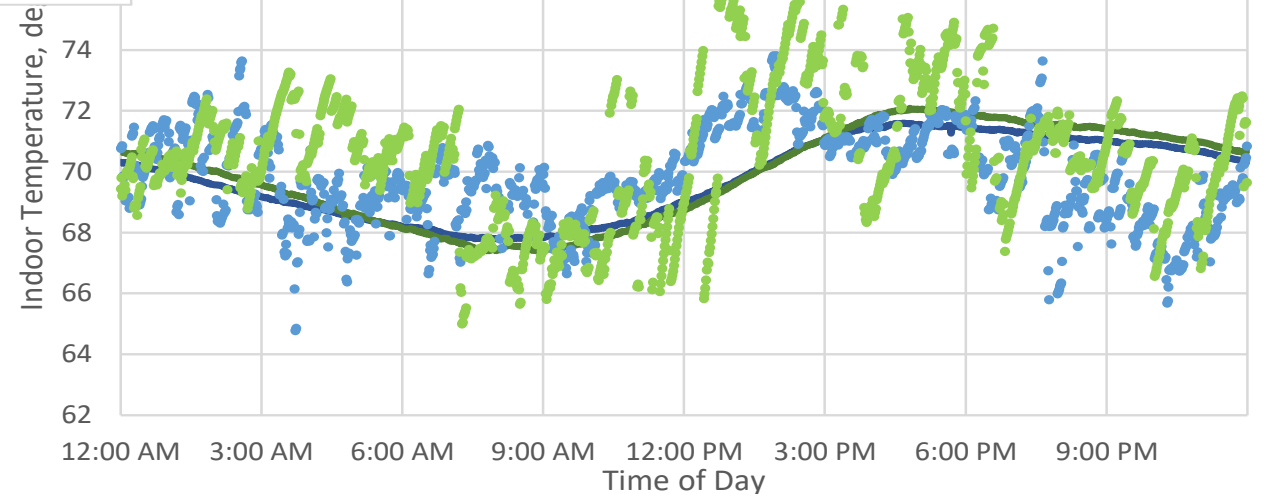
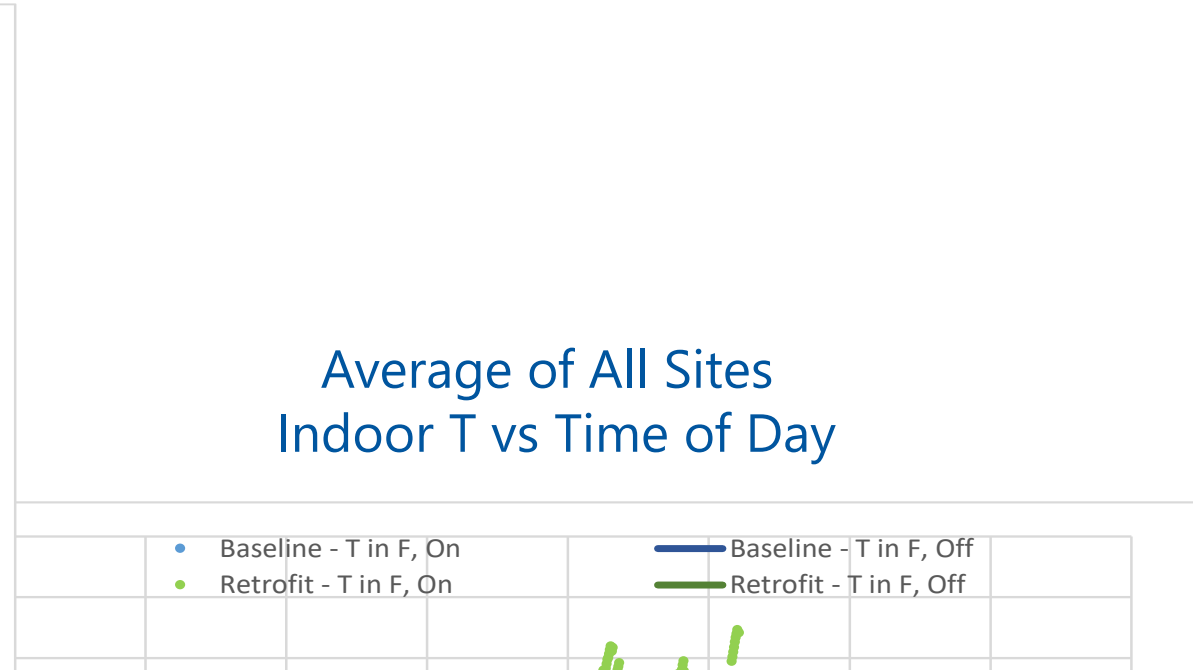


# Field Data Heating Season Operation vs Time of Day

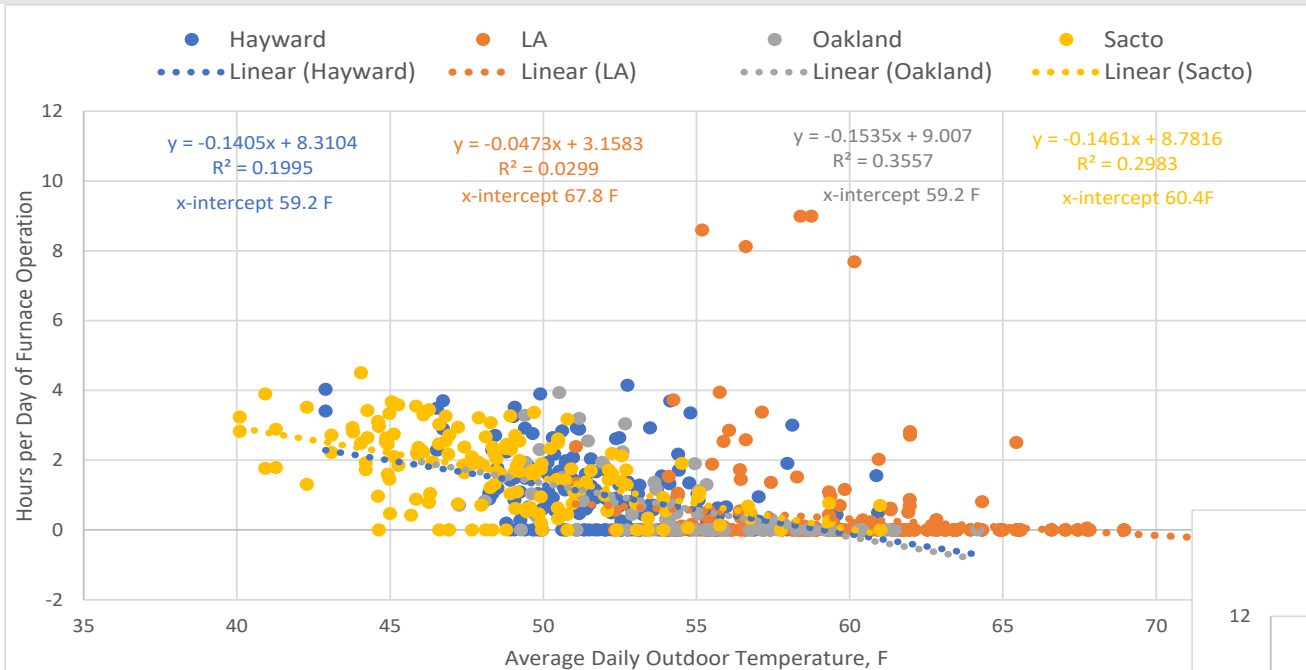


## Average of All Sites % On vs Time of Day

Wall furnace use not the same as central furnaces  
More manual on-off control, use only when needed

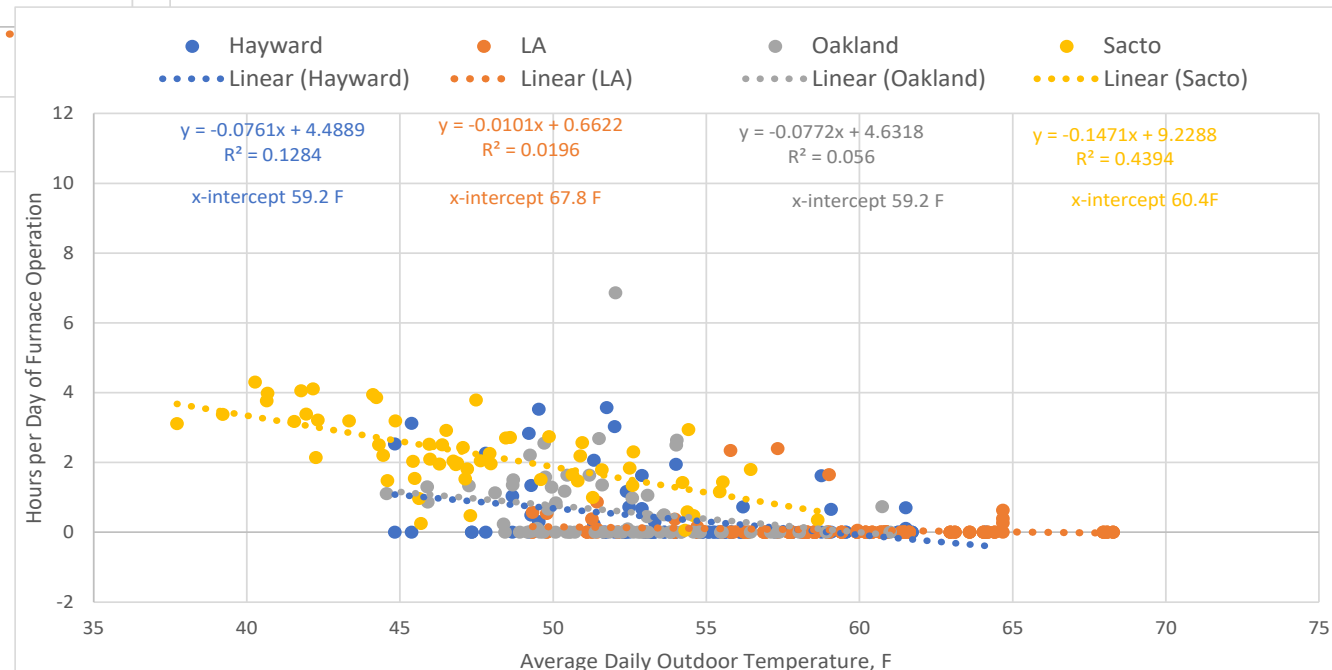


# Field Data Daily Hours of Operation vs Outdoor Temperature

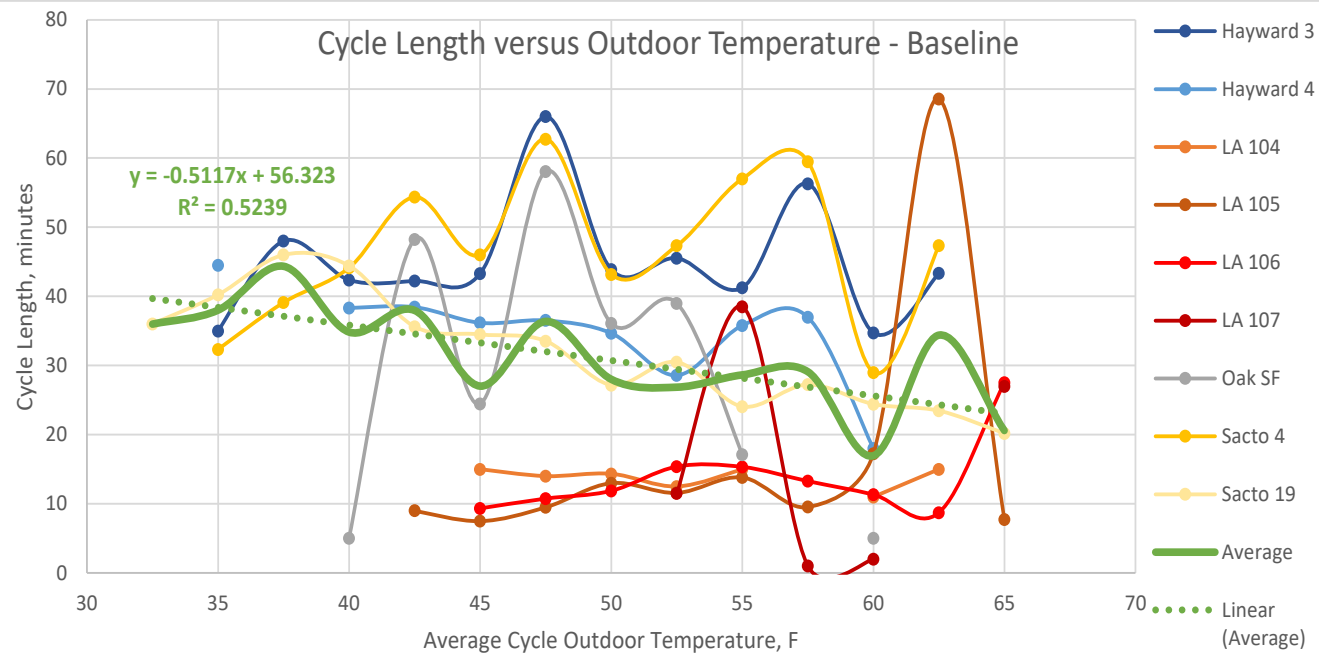


Baseline Wall Furnaces

## Retrofit Wall Furnaces

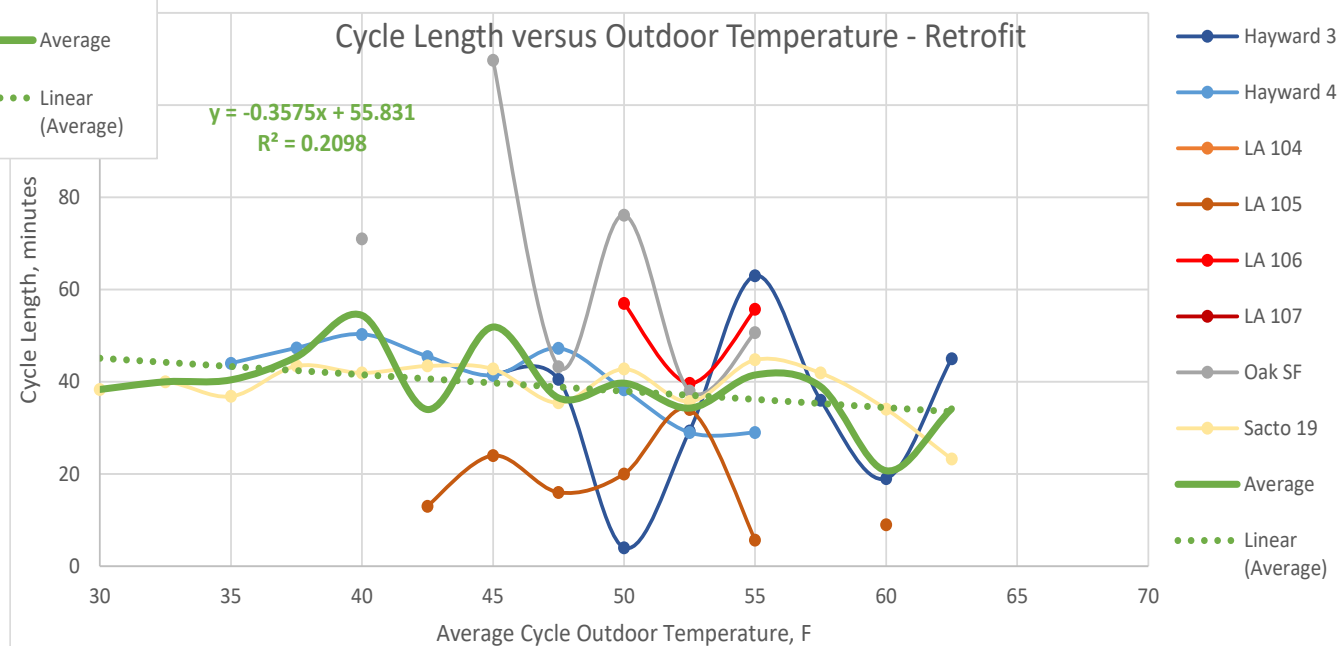


# Field Data Cycle Length vs Outdoor Temperature



Cycle length >> cycles per day used to determine emissions

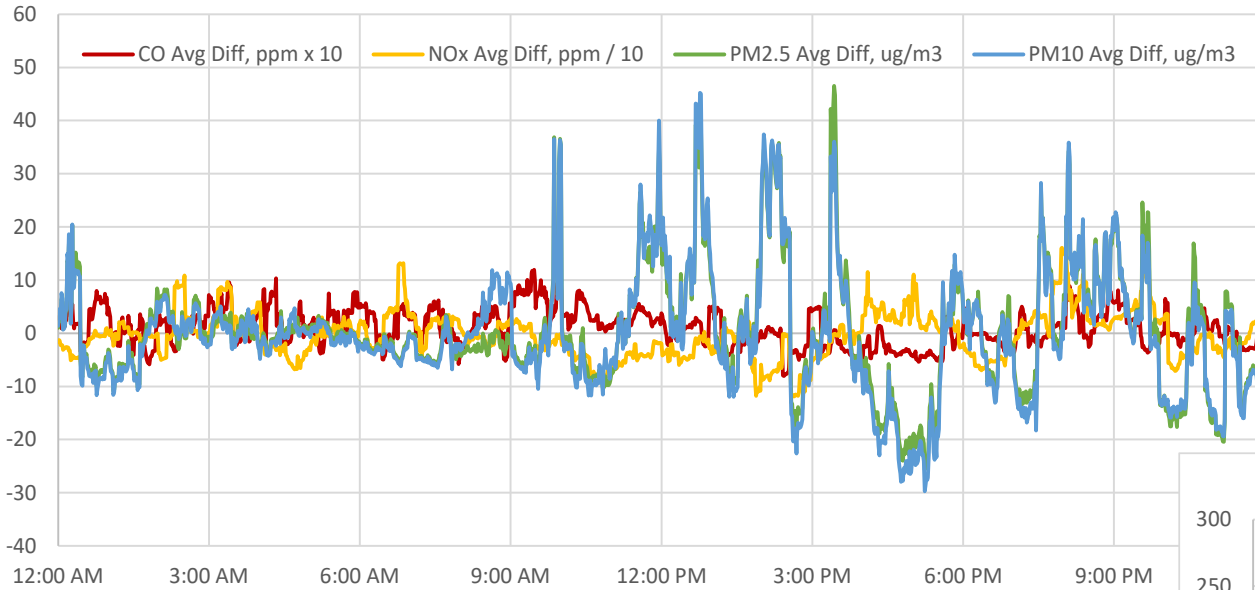
## Retrofit Wall Furnaces



## Baseline Wall Furnaces

# Field Data On-Off IAQ Differences vs Time of Day

IAQ Furnace On-Off Differences

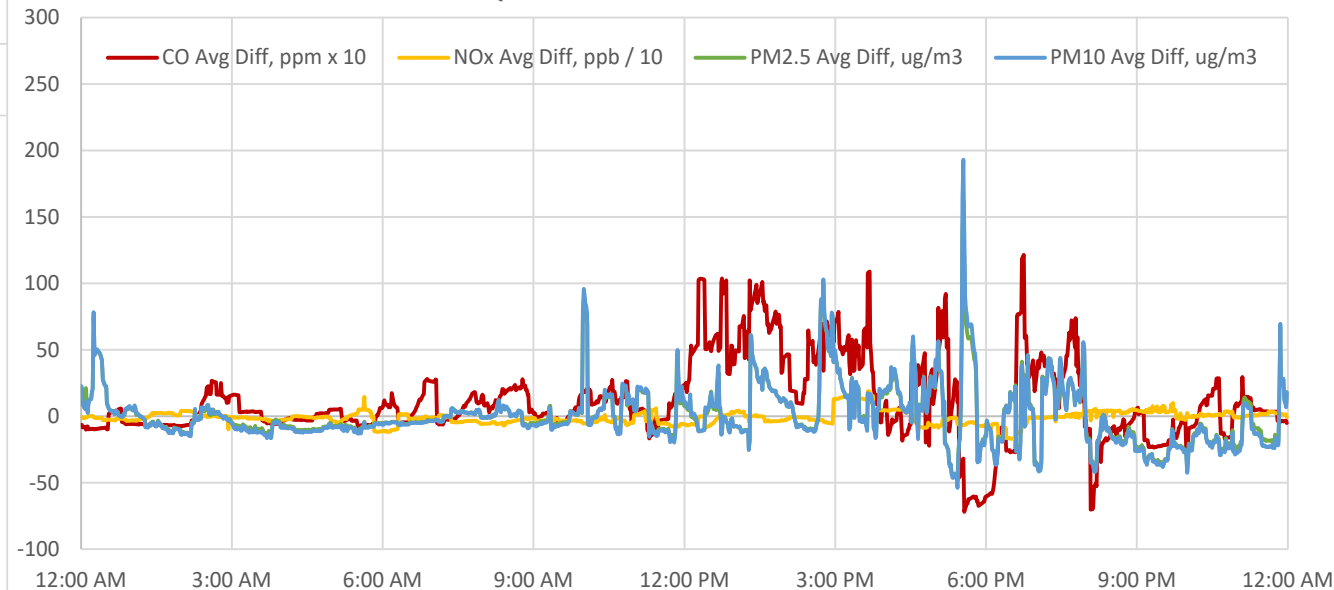


Indoor pollutant concentrations while furnaces were on & off, to see how furnaces impact IAQ

Retrofit Wall Furnaces

Baseline Wall Furnaces

IAQ Furnace On-Off Differences





# Wall Furnace Performance

# Wall Furnace Fuel Use & Efficiency from Lab Tests

BASELINE Wall Furnace			Natural Gas Input Capacity				Thermal Efficiency		Natural Gas Output Capacity			AC Power
Model	Field Sites	Age years	Rated Input Btu/hr	Tested Input Btu/hr	% Rated Input	Pilot Btu/hr	Rated TE	Tested TE	Output Btu/hr	Tested Output Btu/hr	% Rated Output	Active W
PW8G25SEN	Hayward 3	~40	25000	20280	81%	520	70.0%	76.3%	17500	15470	88%	0
PW8G25SEN	Hayward 4	~40	25000	20210	81%	510	70.0%	71.8%	17500	14510	83%	0
25GV-A1	LA 104	~35	25000	25100	100%	750	70.0%	70.5%	17500	17700	101%	0
35GV-C #1	LA 105	~35	35000	31720	91%	520	70.0%	62.8%	24500	19920	81%	0
35GV-C #2	LA 106	~35	35000	31800	91%	570	70.0%	73.6%	24500	23400	96%	0
RMG35-IN	LA 107	~35	35000	31810	91%	500	70.0%	75.1%	24500	23890	98%	0
5009622	Oak SF	~15	50000	44500	89%	1090	76.0%	50.1%	38000	22290	59%	0
35S-D #1	Sacto 4	40+	35000	31530	90%	720	50.0%	39.0%	17500	12300	70%	0
35S-D #2	Sacto 15	40+	35000	29110	83%	710	50.0%	60.8%	17500	17700	101%	0
3509622	Sacto 19	~10	35000	33800	97%	1050	74.0%	73.2%	25900	24740	96%	0
	<b>Average</b>	<b>32</b>	<b>33500</b>	<b>29990</b>	<b>89%</b>	<b>690</b>	<b>67.0%</b>	<b>65.3%</b>	<b>22490</b>	<b>19190</b>	<b>87%</b>	<b>0</b>

Baseline  
Wall  
Furnaces

Retrofit  
Wall  
Furnaces

RETROFIT Wall Furnace			Natural Gas Input Capacity				Thermal Efficiency		Natural Gas Output Capacity			AC Power
Model	Field Sites	Age years	Rated Input Btu/hr	Tested Input Btu/hr	% Rated Input	Pilot Btu/hr	Rated TE	Tested TE	Output Btu/hr	Tested Output Btu/hr	% Rated Output	Active W
1753012	Hayward 3 &	0	17500	19790	113%	0	94%	89.5%	28200	30950	109.8%	100.1
AC2030TN #1	LA 104-107	0	30000	34580	115%	0	85%	81.8%	25500	26000	102.0%	12.5
AC2030TN #2	LA 104-107	0	30000	31780	106%	0	85%	81.2%	34000	33880	99.6%	12.6
AC3040TN	Oakland SFH	0	40000	41720	104%	0	83%	79.0%	24900	24810	99.6%	12.4
TG2030TN	Sacto 4, 15 &	0	30000	31410	105%	0	82%	78.5%	23370	24200	103.6%	0.0
	<b>Average</b>	<b>0</b>	<b>28500</b>	<b>30830</b>	<b>109%</b>	<b>0</b>	<b>85.7%</b>	<b>82.0%</b>	<b>24190</b>	<b>25050</b>	<b>103.9%</b>	<b>26.3</b>

# Wall Furnace Emissions Rates from Lab, Field, TMY Data

During Typical Heating Use

Baseline  
Wall  
Furnaces

SCAQMD Rule 1111  
SJVAPCD Rule 4905  
NOx 0.033 lbm/MMBtu  
max for central furnaces

BASELINE Wall Furnace			AVERAGE Operation - TMY3 Annual - Pilot on All Year						
Manufacturer	Model	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	MMBtu/year	CO lbm/MMBtu	NOx lbm/MMBtu	THC lbm/MMBtu
fection Products	PW8G25SEN #1	Hayward 3	188.5	417	27.1	8.28	0.249	0.074	0.070
fection Products	PW8G25SEN #2	Hayward 4	188.5	417	27.1	8.18	0.044	0.059	0.306
lliams	25GV-A1	LA 104	188.5	417	27.1	11.16	0.147	0.051	0.322
lliams	35GV-C #1	LA 105	188.5	417	27.1	10.44	0.100	0.066	0.006
lliams	35GV-C #2	LA 106	188.5	417	27.1	10.88	0.051	0.055	0.000
lliams	RMG35-IN	LA 107	188.5	417	27.1	10.28	0.081	0.067	0.197
lliams	5009622.0	Oakland SF	188.5	417	27.1	17.73	0.429	0.069	0.006
lly General	35S-D #1	Sacto 4	188.5	417	27.1	12.11	0.086	0.062	0.004
lly General	35S-D #2	Sacto 15	188.5	417	27.1	11.57	0.458	0.020	0.022
lliams	3509622.0	Sacto 19	188.5	417	27.1	15.37	0.073	0.083	0.176
<b>Baseline Average</b>			<b>188.5</b>	<b>417</b>	<b>27.1</b>	<b>11.60</b>	<b>0.172</b>	<b>0.061</b>	<b>0.111</b>

Retrofit  
Wall  
Furnaces

RETROFIT Wall Furnace			AVERAGE Operation - TMY3 Annual - No Standing Pilot						
Manufacturer	Model	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	MMBtu/year	CO lbm/MMBtu	NOx lbm/MMBtu	THC lbm/MMBtu
lliams	1753012.0	Hayward 3	118.7	208	34.3	2.35	0.022	0.086	0.002
lliams	1753012.0	Hayward 4	118.7	208	34.3	2.35	0.022	0.086	0.002
lliams	AC2030TN	LA 104	118.7	208	34.3	3.94	0.093	0.014	0.086
lliams	AC2030TN	LA 105	118.7	208	34.3	3.94	0.093	0.014	0.086
lliams	AC2030TN	LA 106	118.7	208	34.3	3.94	0.093	0.014	0.086
lliams	AC2030TN	LA 107	118.7	208	34.3	3.94	0.093	0.014	0.086
lliams	AC3040TN	Oakland SFH	118.7	208	34.3	4.95	0.253	0.038	0.017
lliams	TG2030TN	Sacto 4	118.7	208	34.3	3.73	0.036	0.013	0.004
lliams	TG2030TN	Sacto 19 T2	118.7	208	34.3	3.73	0.036	0.013	0.004
lliams	TG2030TN	Sacto 19	118.7	208	34.3	3.73	0.036	0.013	0.004
<b>Retrofit Average</b>			<b>118.7</b>	<b>208</b>	<b>34.3</b>	<b>3.66</b>	<b>0.078</b>	<b>0.031</b>	<b>0.037</b>

# Average On-Off IAQ Differences at Each Site from Field Data

Baseline  
Wall  
Furnaces

AVERAGES Field Site	Regional CO ppmx10	CO Off ppmx10	CO On ppmx10	CO On-Off Difference %	Regional NOx ppb/10	NOx Off ppb/10	NOx On ppb/10	NOx On-Off Difference %	Regional PM2.5 ug/m3	PM2.5 Off ug/m3	PM2.5 On ug/m3	PM2.5 On-Off Difference %	PM10 Off ug/m3	PM10 On ug/m3	PM10 On-Off Difference %	
Hayward 3	4.7	23.5	23.4	0%	2.0	32.3	30.9	-4%	9.8	6.0	3.0	-50%	6.5	0.1	-99%	
Hayward 4	4.7	9.8	12.4	26%	2.0	22.0	23.1	5%	9.8	5.9	3.1	-48%	6.5	3.2	-51%	
LA 104	5.6	17.7	43.3	145%	4.1	24.8	45.2	83%	13.1	10.9	5.1	-53%	9.7	4.7	-52%	
LA 105	5.2	24.2	23.9	-1%	3.7	2.8	3.7	31%	12.5	26.3	33.8	29%	29.3	36.8	25%	
LA 106	5.2	17.3	16.5	-5%	3.7	1.3	2.0	51%	12.3	15.5	21.7	40%	17.5	23.6	34%	
LA 107	5.4	31.2	31.4	1%	3.9	26.2	24.5	-7%	12.7	12.8	13.3	4%	15.0	38.0	154%	
Oak SF	4.7	4.2	5.5	30%	2.5	5.3	3.3	-37%	7.0	5.7	9.4	65%	6.2	10.1	65%	
Sacto 4	4.1	10.4	10.8	4%	2.4	49.4	47.7	-4%	16.1	33.1	28.4	-14%	37.1	31.0	-16%	
Sacto 15	3.8	9.3	10.8	16%	2.2	1.8	2.4	30%	13.5	10.2	9.1	-11%	10.3	9.1	-11%	
Sacto 19	3.9	9.1	10.9	19%	2.1	7.9	7.5	-5%	15.0	25.5	28.0	10%	26.5	28.8	9%	
<b>Average</b>	<b>4.7</b>	<b>15.7</b>	<b>18.9</b>	<b>21%</b>	<b>2.9</b>	<b>17.4</b>	<b>19.0</b>	<b>9%</b>	<b>12.2</b>	<b>15.2</b>	<b>15.5</b>	<b>2%</b>	<b>16.5</b>	<b>18.5</b>	<b>13%</b>	
Comparative Limit	50-150 ppmx10 inside properly adjusted (US EPA)				3.0 ppb/10 24 hour outside (CAAQS)				35 ug/m3 24 hour outside (NAAQS)				50 ug/m3 24 hour outside (CAAQS)			

Retrofit  
Wall  
Furnaces

AVERAGES Field Site	Regional CO ppmx10	CO Off ppmx10	CO On ppmx10	CO On-Off Difference %	Regional NOx ppb/10	NOx Off ppb/10	NOx On ppb/10	NOx On-Off Difference %	Regional PM2.5 ug/m3	PM2.5 Off ug/m3	PM2.5 On ug/m3	PM2.5 On-Off Difference %	PM10 Off ug/m3	PM10 On ug/m3	PM10 On-Off Difference %	
Hayward 3	3.9	11.6	12.2	5%	1.2	31.4	33.7	7%	8.7	29.4	21.1	-28%	36.0	25.2	-30%	
Hayward 4	4.0	8.6	10.4	21%	1.3	22.1	17.3	-22%	8.7	11.6	7.7	-33%	13.1	8.0	-38%	
LA 104	4.7	14.3	0.0	-100%	3.2	58.5	23.8	-59%	9.4	6.7	2.2	-67%	7.5	2.5	-66%	
LA 105	5.0	12.3	0.0	-100%	3.5	8.2	1.0	-88%	11.1	39.6	57.7	46%	44.6	65.0	46%	
LA 106	5.0	13.4	16.6	24%	3.5	25.3	29.3	16%	11.1	11.5	13.0	13%	12.8	14.3	12%	
LA 107	5.0	29.4	0.0	-100%	3.5	23.3	1.7	-93%	11.1	9.5	2.5	-74%	12.9	3.7	-72%	
Oak SF	5.3	2.1	2.8	31%	3.2	7.1	7.3	2%	10.6	20.4	20.9	3%	23.3	23.6	1%	
Sacto 4	4.4	12.5	15.3	22%	4.7	49.9	54.1	8%	6.6	29.7	26.9	-9%	33.4	29.7	-11%	
Sacto 19	6.5	41.7	63.6	53%	2.2	10.0	9.6	-4%	12.5	37.8	37.8	0%	38.4	38.4	0%	
Sacto 19 T2	4.4	13.7	15.6	14%	4.7	10.7	10.3	-4%	6.6	19.9	13.6	-32%	20.0	13.7	-32%	
<b>Average</b>	<b>4.8</b>	<b>15.9</b>	<b>13.6</b>	<b>-14%</b>	<b>3.1</b>	<b>24.7</b>	<b>18.8</b>	<b>-24%</b>	<b>9.6</b>	<b>21.6</b>	<b>20.4</b>	<b>-6%</b>	<b>24.2</b>	<b>22.4</b>	<b>-7%</b>	
Comparative Limit	50-150 ppmx10 inside property adjusted (US EPA)				3.0 ppb/10 24 hour outside (CAAQS)				35 ug/m3 24 hour outside (NAAQS)				50 ug/m3 24 hour outside (CAAQS)			

WALL FURNACE



# Maximum On-Off IAQ Differences at Each Site from Field Data

Baseline  
Wall  
Furnaces

MAXIMUMS Field Site	Regional CO ppmx10	CO Off ppmx10	CO On ppmx10	CO On-Off Difference %	Regional NOx ppb/10	NOx Off ppb/10	NOx On ppb/10	NOx On-Off Difference %	Regional PM2.5 ug/m3	PM2.5 Off ug/m3	PM2.5 On ug/m3	PM2.5 On-Off Difference %	PM10 Off ug/m3	PM10 On ug/m3	PM10 On-Off Difference %	
Hayward 3	6.2	49.1	34.1	-31%	3.1	93.3	57.2	-39%	13.3	106.3	9.6	-91%	112.1	0.1	-100%	
Hayward 4	6.2	43.2	20.1	-53%	3.1	61.7	29.6	-52%	13.3	132.0	7.9	-94%	151.2	8.2	-95%	
LA 104	7.8	84.9	47.4	-44%	7.6	117.8	48.0	-59%	16.5	62.2	5.9	-91%	52.1	5.4	-90%	
LA 105	7.6	24.2	23.9	-1%	7.1	2.8	3.7	31%	14.7	26.3	33.8	29%	29.3	36.8	25%	
LA 106	7.4	104.7	25.3	-76%	7.0	9.9	2.9	-70%	15.5	197.4	33.6	-83%	221.6	36.6	-83%	
LA 107	7.6	50.9	31.4	-38%	7.3	67.2	24.5	-64%	15.8	22.5	13.3	-41%	83.4	38.0	-54%	
Oak SF	7.0	12.5	7.4	-41%	5.1	26.4	7.5	-72%	8.7	44.3	29.6	-33%	48.7	31.1	-36%	
Sacto 4	5.6	30.0	17.5	-42%	4.0	138.5	74.2	-46%	22.8	353.7	91.2	-74%	403.6	100.3	-75%	
Sacto 15	5.2	29.9	19.5	-35%	3.7	6.5	4.1	-38%	19.4	119.9	25.3	-79%	121.0	25.5	-79%	
Sacto 19	5.1	26.4	18.8	-29%	3.3	24.3	13.3	-45%	20.1	277.8	108.5	-61%	306.3	112.2	-63%	
<b>Average</b>	<b>4.9</b>	<b>45.6</b>	<b>24.5</b>	<b>-46%</b>	<b>5.1</b>	<b>54.9</b>	<b>26.5</b>	<b>-52%</b>	<b>16.0</b>	<b>134.2</b>	<b>35.9</b>	<b>-73%</b>	<b>152.9</b>	<b>39.4</b>	<b>-74%</b>	
Comparative Limit	50-150 ppmx10 inside properly adjusted (US EPA)				18 ppb/10 1 hour outside (CAAQS)				35 ug/m3 24 hour outside (NAAQS)				50 ug/m3 24 hour outside (CAAQS)			

Retrofit  
Wall  
Furnaces

MAXIMUMS Field Site	Regional CO ppmx10	CO Off ppmx10	CO On ppmx10	CO On-Off Difference %	Regional NOx ppb/10	NOx Off ppb/10	NOx On ppb/10	NOx On-Off Difference %	Regional PM2.5 ug/m3	PM2.5 Off ug/m3	PM2.5 On ug/m3	PM2.5 On-Off Difference %	PM10 Off ug/m3	PM10 On ug/m3	PM10 On-Off Difference %	
Hayward 3	5.8	49.1	34.1	-31%	2.2	93.3	57.2	-39%	11.1	336.4	21.8	-94%	456.0	26.0	-94%	
Hayward 4	5.8	37.5	12.5	-67%	2.2	49.6	20.3	-59%	11.2	195.3	12.3	-94%	224.6	12.7	-94%	
LA 104	7.7	34.1	0.0	-100%	7.7	110.8	23.8	-79%	12.9	17.7	2.2	-87%	19.5	2.5	-87%	
LA 105	7.2	41.7	0.0	-100%	7.2	31.6	1.0	-97%	14.0	294.0	58.3	-80%	331.5	65.7	-80%	
LA 106	7.2	59.5	16.9	-72%	7.2	63.8	30.8	-52%	14.0	62.6	13.3	-79%	69.2	14.6	-79%	
LA 107	7.2	67.2	0.0	-100%	7.2	69.0	1.7	-97%	14.0	69.9	2.5	-96%	92.2	3.7	-96%	
Oak SF	7.5	9.0	3.6	-60%	5.3	15.9	9.4	-41%	12.7	76.8	29.5	-62%	87.7	33.9	-61%	
Sacto 4	6.0	29.0	19.3	-34%	5.9	122.5	72.8	-41%	9.4	226.8	46.5	-79%	255.6	51.7	-80%	
Sacto 19	7.6	260.3	205.6	-21%	3.5	24.1	16.5	-32%	17.8	330.2	129.7	-61%	337.3	132.5	-61%	
Sacto 19 T2	6.0	35.8	24.5	-32%	5.9	26.0	13.1	-50%	9.4	244.2	29.4	-88%	244.2	29.4	-88%	
<b>Average</b>	<b>6.8</b>	<b>62.3</b>	<b>31.6</b>	<b>-49%</b>	<b>5.4</b>	<b>60.7</b>	<b>24.7</b>	<b>-59%</b>	<b>12.7</b>	<b>185.4</b>	<b>34.5</b>	<b>-81%</b>	<b>211.8</b>	<b>37.3</b>	<b>-82%</b>	
Comparative Limit	50-150 ppmx10 inside property adjusted (US EPA)				18 ppb/10 1 hour outside (CAAQS)				35 ug/m3 24 hour outside (NAAQS)				50 ug/m3 24 hour outside (CAAQS)			

WALL FURNACES

# Operability & Reliability from Field Data

- Switch from gravity to fan-type furnaces
  - More inherent furnace noise
    - ASHRAE Standard 62 requires 3 sones or less for intermittent ventilation fans
  - Change in heat distribution
    - Occupants felt too warm then too cold
- Controls issues
  - Thermostat 15-second wake up
  - One-minute delay to start or stop
  - Deadband around setpoint of +2°F / -1°F
- Self-charging batteries were unreliable
  - Fixes by manufacturer need to be tested
  - Charging procedures need clarification
- Installation Issues
  - Contractors always need more training
  - Work on other components may be needed
    - Replacement of exhaust flue
    - Resize wall cavity
    - AC power access: plug in or hard-wire
    - Drain access: for condensing furnaces



# Wall Furnace Savings

# Average Energy & Cost Savings Lab, Field, TMY, Utility Data

Annual	Baseline	Retrofit	Savings	% Savings
Operating Hours	188	118	<b>70</b>	<b>37%</b>
Cycles	420	210	<b>210</b>	<b>50%</b>
MMBtu	11.5	3.7	<b>7.8</b>	<b>68%</b>
kWh	0	2.4	<b>-2.3</b>	<b>+100%</b>
Utility Cost	\$220	\$70	<b>\$150</b>	<b>68%</b>

- More efficient units without standing pilots
- More output & distribution > fewer operating hours

BASELINE Wall Furnace			ACTUAL Operation - TMY3 Annual - Pilot on All Year					
Manufacturer	Model	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	MMBtu/year	kWh/year	Utility Cost
Perfection Products	PW8G25SEN #1	Hayward 3	385.3	568	40.7	12.17	0.0	\$231
Perfection Products	PW8G25SEN #2	Hayward 4	156.3	295	31.8	7.55	0.0	\$143
Williams	25GV-A1	LA 104	23.0	113	12.2	7.13	0.0	\$135
Williams	35GV-C #1	LA 105	298.0	721	24.8	13.85	0.0	\$263
Williams	35GV-C #2	LA 106	114.0	573	11.9	8.55	0.0	\$163
Williams	RMG35-IN	LA 107	23.9	94	15.3	5.13	0.0	\$97
Williams	5009622.0	Oakland SF	189.3	346	32.9	17.77	0.0	\$338
Holly General	35S-D #1	Sacto 4	170.2	237	43.1	11.55	0.0	\$219
Holly General	35S-D #2	Sacto 15	262.5	515	30.6	13.67	0.0	\$260
Williams	3509622.0	Sacto 19	262.4	570	27.6	17.79	0.0	\$338
Baseline Average			188.5	417	27.1	11.52	0.0	\$219
RETROFIT Wall Furnace			ACTUAL Operation - TMY3 Annual - No Standing Pilot					
Manufacturer	Model	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	MMBtu/year	kWh/year	Utility Cost
Williams	1753012	Hayward 3	36.5	83	26.4	0.72	3.6	\$15
Williams	1753012	Hayward 4	166.0	269	37.0	3.28	16.6	\$67
Williams	AC2030TN	LA 104	20.0	84	14.2	0.66	0.3	\$13
Williams	AC2030TN	LA 105	19.0	87	13.1	0.63	0.2	\$12
Williams	AC2030TN	LA 106	78.6	121	38.8	2.61	1.0	\$50
Williams	AC2030TN	LA 107	28.9	79	21.9	0.96	0.4	\$18
Williams	AC3040TN	Oakland SFH	178.0	240	44.5	7.43	2.2	\$142
Williams	TG2030TN	Sacto 4	128.5	223	34.5	4.03	0.0	\$77
Williams	TG2030TN	Sacto 19 T2	239.0	224	63.9	7.51	0.0	\$143
Williams	TG2030TN	Sacto 19	292.8	360	48.9	9.20	0.0	\$175
Retrofit Average			118.7	208	34.3	3.70	2.4	\$71
TMY3 Actual Annual Savings								
Baseline to Retrofit Description	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	MMBtu/year	kWh/year	Utility Cost	
Gravity to Direct Vent Condensing	Hayward 3	348.8	485	34.4	11.45	-3.6	\$217	
Gravity to Direct Vent Condensing	Hayward 4	-9.7	26	5.2	4.26	-16.6	\$77	
Gravity to Fan-Type w/AC Power	LA 104	3.0	29	2.0	6.47	-0.3	\$123	
Gravit		279.0	633	11.7	13.22	-0.2	\$251	
Gravit		35.4	451	26.9	5.95	-1.0	\$113	
Gravit		-5.0	14	6.6	4.17	-0.4	\$79	
2-Side		11.3	106	11.6	10.34	-2.2	\$196	
Gravity to Fan-Type Self-Powered	Sacto 4	41.7	13	8.6	7.52	0.0	\$143	
Gravity to Fan-Type Self-Powered	Sacto 15 to 19 T2	23.4	291	33.4	6.17	0.0	\$117	
Gravity to Fan-Type Self-Powered	Sacto 19	-30.4	210	21.2	8.60	0.0	\$163	
Savings		69.7	226	18.5	7.81	-2.4	\$148	
% Savings		37%	54%	68%	68%		68%	

\$19 per MMBtu,  
\$0.25 per kWh

# Average Emission Reductions Lab, Field, TMY Data

Annual	Baseline	Retrofit	Savings	% Savings
Operating Hours	188	118	<b>70</b>	<b>37%</b>
Cycles	420	210	<b>210</b>	<b>50%</b>
CO lbm	2.39	0.32	<b>2.07</b>	<b>87%</b>
NOx lbm (lbm/MMBtu)	0.70 (0.061)	0.10 (0.031)	<b>0.60 (0.030)</b>	<b>86%</b>
THC lbm	1.21	0.08	<b>1.12</b>	<b>93%</b>

- Fewer operating hours & cycles, no standing pilot
- Improved combustion, low NOx controls

BASELINE Wall Furnace			ACTUAL Operation - TMY3 Annual - Pilot on All Year					
Manufacturer	Model	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	CO lbm/year	NOx lbm/year	THC lbm/year
Perfection Products	PW8G25SEN #1	Hayward 3	385.3	568	40.7	2.02	1.02	0.58
Perfection Products	PW8G25SEN #2	Hayward 4	156.3	295	31.8	0.37	0.43	2.57
Williams	25GV-A1	LA 104	23.0	113	12.2	1.66	0.12	3.66
Williams	35GV-C #1	LA 105	298.0	721	24.8	1.13	0.97	0.07
Williams	35GV-C #2	LA 106	114.0	573	11.9	0.55	0.43	0.00
Williams	RMG35-IN	LA 107	23.9	94	15.3	0.81	0.26	1.98
Williams	5009622.0	Oakland SF	189.3	346	32.9	7.61	1.22	0.10
Holly General	35S-D #1	Sacto 4	170.2	237	43.1	1.04	0.71	0.04
Holly General	35S-D #2	Sacto 15	262.5	515	30.6	7.57	0.26	0.36
Williams	3509622.0	Sacto 19	262.4	570	27.6	1.12	1.56	2.74
Baseline Average			188.5	417	27.1	2.39	0.70	1.21
RETROFIT Wall Furnace			ACTUAL Operation - TMY3 Annual - No Standing Pilot					
Manufacturer	Model	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	CO lbm/year	NOx lbm/year	THC lbm/year
Williams	1753012	Hayward 3	36.5	83	26.4	0.02	0.06	0.00
Williams	1753012	Hayward 4	166.0	269	37.0	0.07	0.28	0.01
Williams	AC2030TN	LA 104	20.0	84	14.2	0.08	0.01	0.06
Williams	AC2030TN	LA 105	19.0	87	13.1	0.07	0.01	0.06
Williams	AC2030TN	LA 106	78.6	121	38.8	0.22	0.04	0.24
Williams	AC2030TN	LA 107	28.9	79	21.9	0.11	0.01	0.08
Williams	AC3040TN	Oakland SFH	178.0	240	44.5	2.04	0.29	0.15
Williams	TG2030TN	Sacto 4	128.5	223	34.5	0.14	0.05	0.02
Williams	TG2030TN	Sacto 19 T2	239.0	224	63.9	0.19	0.10	0.12
Williams	TG2030TN	Sacto 19	292.8	360	48.9	0.26	0.12	0.10
Retrofit Average			118.7	208	34.3	0.32	0.10	0.08
TMY3 Actual Annual Savings								
Baseline to Retrofit Description	Field Site	Operating hrs/year	Cycles/year	Avg Cycle Minutes	CO lbm/year	NOx lbm/year	THC lbm/year	
Gravity to Direct Vent Condensing	Hayward 3	348.8	485	14.4	2.01	0.96	0.58	
Gravity to Direct Vent Condensing	Hayward 4	-9.7	26	5.2	0.30	0.15	2.56	
Gravity to Fan-Type w/AC Power	LA 104	3.0	29	2.0	1.58	0.11	3.60	
Gravity to Fan-Type w/AC Power	LA 105	279.0	633	11.7	1.05	0.96	0.01	
Gravity to Fan-Type w/AC Power	LA 106	35.4	451	26.9	0.34	0.40	-0.23	
Gravity to Fan-Type w/AC Power	LA 107	-5.0	14	6.6	0.70	0.24	1.89	
2-Sided Gravity to Fan-Type w/AC Power	Oakland SF	11.3	106	11.6	5.57	0.93	-0.05	
Gravity to Fan-Type Self-Powered	Sacto 4	41.7	13	8.6	0.90	0.65	0.02	
Gravity to Fan-Type Self-Powered	Sacto 15 to 19 T2	23.4	291	33.4	7.39	0.16	0.24	
Gravity to Fan-Type Self-Powered	Sacto 19	-30.4	210	21.2	0.86	1.44	2.64	
Savings		69.7	210	7.2	2.07	0.60	1.12	
% Savings		37%	50%	-27%	87%	86%	93%	

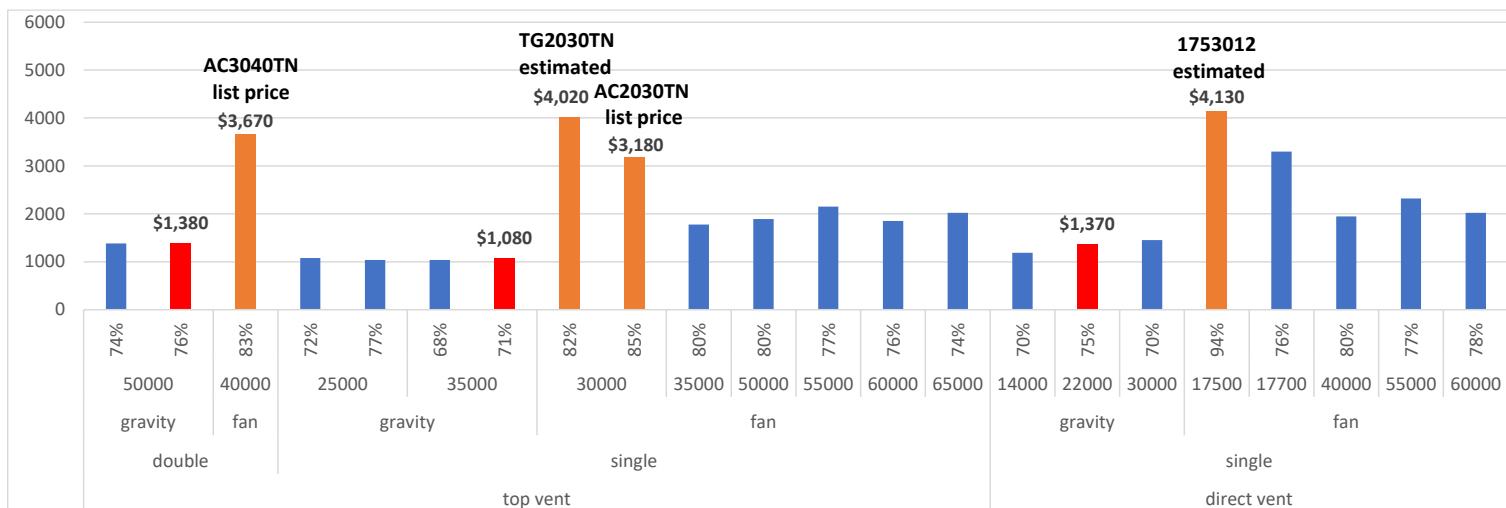
# Indoor Air Quality Improvements **Field Data**

Average IAQ Concentrations	CO Off ppmx10	CO On ppmx10	NOx Off ppb/10	NOx On ppb/10	PM2.5 Off ug/m3	PM2.5 On ug/m3	PM10 Off ug/m3	PM10 On ug/m3
Baseline Average	15.7	18.9	17.4	19.0	15.2	15.5	16.5	18.5
Retrofit Average	15.9	13.6	24.7	18.8	21.6	20.4	24.2	22.4
Reduction	-0.3	5.2	-7.3	0.2	-6.4	-4.9	-7.7	-3.9
% Reduction	-2%	28%	-42%	1%	-42%	-31%	-47%	-21%
Comparative Limit	50-150 ppmx10 inside properly adjusted (US EPA)		3.0 ppb/10 24 hour outside (CAAQS)		35 ug/m3 24 hour outside (NAAQS)		50 ug/m3 24 hour outside (CAAQS)	

Maximum IAQ Concentrations	CO Off ppmx10	CO On ppmx10	NOx Off ppb/10	NOx On ppb/10	PM2.5 Off ug/m3	PM2.5 On ug/m3	PM10 Off ug/m3	PM10 On ug/m3
Baseline Average	45.6	24.5	54.9	26.5	134.2	35.9	152.9	39.4
Retrofit Average	70.7	29.5	58.8	22.4	185.4	34.5	211.8	37.3
Reduction	-25.2	-5.0	-4.0	4.1	-51.2	1.3	-58.9	2.2
% Reduction	-55%	-20%	-7%	16%	-38%	4%	-38%	5%
Comparative Limit	50-150 ppmx10 inside properly adjusted (US EPA)		18 ppb/10 1 hour outside (CAAQS)		35 ug/m3 24 hour outside (NAAQS)		50 ug/m3 24 hour outside (CAAQS)	

- Retrofits did not improve IAQ much
  - Despite large emission reductions
  - There are other sources of pollution
- Operating furnace improves IAQ
  - Max ppm values lower when ON
- Even running pilot improves IAQ
  - Baseline < Retrofit ppm when OFF
- **Need to control other sources**

# Cost Effectiveness



- Advanced wall furnace costs are high compared to standard wall furnaces
- Low energy use reduces advanced furnace cost effectiveness
- Hope for advanced furnace prices to decrease over time

Baseline to Retrofit Description	Field Site	Annual Energy Cost Savings	Advanced Furnace Cost	Standard Furnace Cost	Installation Cost Added	Incremental Cost	Payback Years	Adv Cost for 7.5 Year Payback	Incentive Amount	Incentivized Payback
Gravity to Direct Vent Condensing	Hayward 3	\$217	\$4,130	\$1,370	\$150	\$2,910	13.4	\$3,590	\$750	7.5
Gravity to Direct Vent Condensing	Hayward 4	\$77	\$4,130	\$1,370	\$150	\$2,910	37.9	\$2,550	\$750	7.6
Gravity to Fan-Type w/AC Power	LA 104	\$123	\$3,180	\$1,080	\$0	\$2,100	17.1	\$2,500	\$500	7.5
Gravity to Fan-Type w/AC Power	LA 105	\$251	\$3,180	\$1,080	\$0	\$2,100	8.4	\$3,460	\$500	7.5
Gravity to Fan-Type w/AC Power	LA 106	\$113	\$3,180	\$1,080	\$0	\$2,100	18.6	\$2,430	\$500	7.5
Gravity to Fan-Type w/AC Power	LA 107	\$79	\$3,180	\$1,080	\$0	\$2,100	26.5	\$2,170	\$500	7.5
2-Sided Gravity to Fan-Type w/AC Power	Oakland SFH	\$196	\$3,670	\$1,380	\$0	\$2,290	11.7	\$3,350	\$500	7.5
Gravity to Fan-Type Self-Powered	Sacramento 4	\$143	\$4,020	\$1,080	\$0	\$2,940	20.6	\$2,650	\$500	7.5
Gravity to Fan-Type Self-Powered	Sacto 15 to 19 T2	\$117	\$4,020	\$1,080	\$0	\$2,940	25.1	\$2,460	\$500	7.5
Gravity to Fan-Type Self-Powered	Sacramento 19	\$163	\$4,020	\$1,080	\$0	\$2,940	18.0	\$2,800	\$500	7.5
	<b>Average</b>	<b>\$148</b>	<b>\$3,670</b>	<b>\$1,170</b>	<b>\$30</b>	<b>\$2,530</b>	<b>19.7</b>	<b>\$2,800</b>	<b>\$550</b>	<b>7.5</b>

# Takeaways for Advanced Wall Furnaces

- Wall furnaces are not operated like central furnaces
  - **Manual on-off control** instead of automatic control
- Advanced furnaces save a lot of energy (68%) & reduce emissions (86% or more)
  - All but condensing & double-sided furnaces **achieved 0.033 lbm/MMBtu limit** for central furnaces in CA (double-sided was just over the limit)
  - But advanced furnaces **did not help IAQ**
- Work still needed to **reduce noise, improve controls, ensure reliability**
- Advanced furnaces are not currently cost effective based on energy savings alone
  - **Utility incentives needed** for now

FOR MORE INFO <https://www.gti.energy/california-wall-furnaces/>