California Gas Emerging Technology

The Gas Emerging Technologies Program (GET) advances promising natural gas technologies as potential measures for energy-efficiency programs. Working with cross functional stakeholders, the GET program sources and screens technologies at a TRL of 4 and higher to gather necessary technical and savings potential data, identify key market barriers to adoption, and develop strategies to overcome these barriers.

- Scanning and Screening
- Planning and Prioritization
- Technolog y Evaluation
- Dissemination
- Technolog y Transfer

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ICF

GTI ENERGY

solutions that transform

Small Furnaces, Big Improvements

Advanced Wall Furnaces

Dr. Lisa Gartland, *Project Manager*

GTI Energy

Gas Emerging Technologies (GET) Webinar

March 24, 2023

Presented Today

GTI ENERGY

- 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 & SoCalGas

Thanks to the Team

- CEC and SoCalGas for funding and guidance
- Williams Comfort Products for information, furnaces, and technical support
- Frontier Energy for field monitoring, analysis, and outreach
- GTI Energy for research, lab testing, field work, analysis, and outreach
- Technical Advisory Committee for oversight and input
- Field participants for allowing us in their homes

- **Great work pulling off a multi-faceted project through a pandemic!**

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
Heat Distribution:	Gravity	Fan-type
Combustion Air:	Top vent / vented	Direct vent
Burner Ignition:	Standing pilot	Intermittent pilot or Hot surface igniter
Heat Recovery:	Non-condensing	Condensing
Emissions:	No controls	Low NOx controls
Sides:	Single-sided	Double-sided
AC Power:	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
Code of Federal Regulations (CFR)	Residential forced-air furnaces, wood-burning stoves	n/a	n/a	0.93 lbm/MMBtu, 2015 0.15 lbm/MMBtu, 2020
SCAQMD Rule 1111 & SJVAPCD Rule 4905 (SCAQMD)	**Central furnaces**	n/a	**0.033 lbm/MMBtu (14 nanograms/Joule)**	n/a
US EPA reference levels of typical indoor pollutants (US EPA)	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
National Ambient Air Quality Standards (NAAQS)	Outside air	9 ppm 8 hours 35 ppm 1 hour	100 ppb 1 hour 53 ppb 24 hours	PM2.5 35 ug/m^3 24 hours PM10 150 ug/m^3 24 hours
California Ambient Air Quality Standards (CAAQS)	Outside air	9 ppm 8 hours 20 ppm 1 hour	180 ppb I hour 30 ppb 24 hours	PM2.5 none 24 hours PM10 50 ug/m3 24 hours

Wall Furnace Research Project Overview

Monitoring & Testing Logistics

- **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

- **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

Wall Furnace Data Collection

- **Field Monitoring**
  - Indoor T & RH
  - Gas valve operation
  - Indoor Air Quality
    - CO – Carbon Monoxide, ppm
    - NOx – Nitrogen Oxides, ppb
    - PM2.5 – Particulate Matter, ug/m3
    - PM10 – Particulate Matter, ug/m3
  - 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
    - O2 %, CO2 %
    - CO – Carbon Monoxide, ppm
    - NOx – Nitrogen Oxides, ppb
    - THC – Total Hydrocarbons, ppm
  - Separate Data Logger & Gas Analyzer
  - Not isolated or climate-controlled

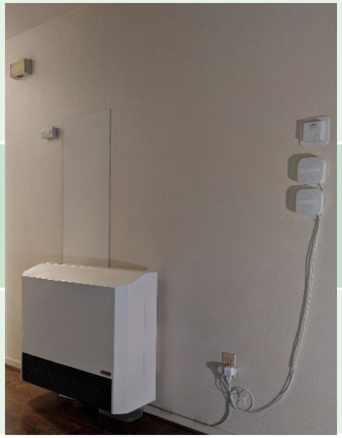
Los Angeles Wall Furnaces

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

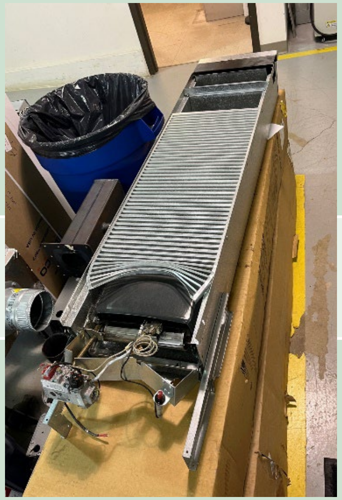
Oakland Wall Furnace Testing

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

Hayward Wall Furnace Testing

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

Sacramento Wall Furnace Testing

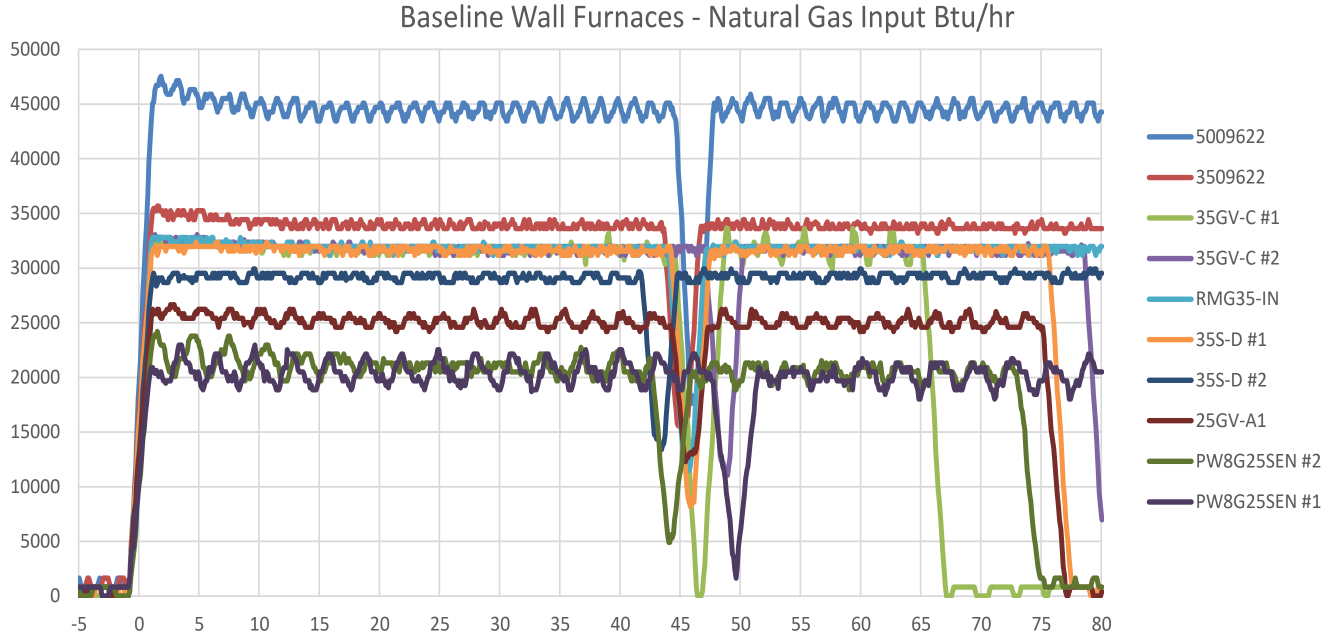
Apartment #	4	15	19
Baseline Units	**Holly-General 35S-D** 35,000 Btu/hr 70% TE 	**Holly-General 35S-D** 35,000 Btu/hr 70% TE 	**Williams 3509622** 35,000 Btu/hr 74% TE 
Field Monitoring	**Complete** 2020-21	**Complete** 2020-21	**Complete** 2020-21
Lab Testing	**Complete**	**Complete**	Broken in transit,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

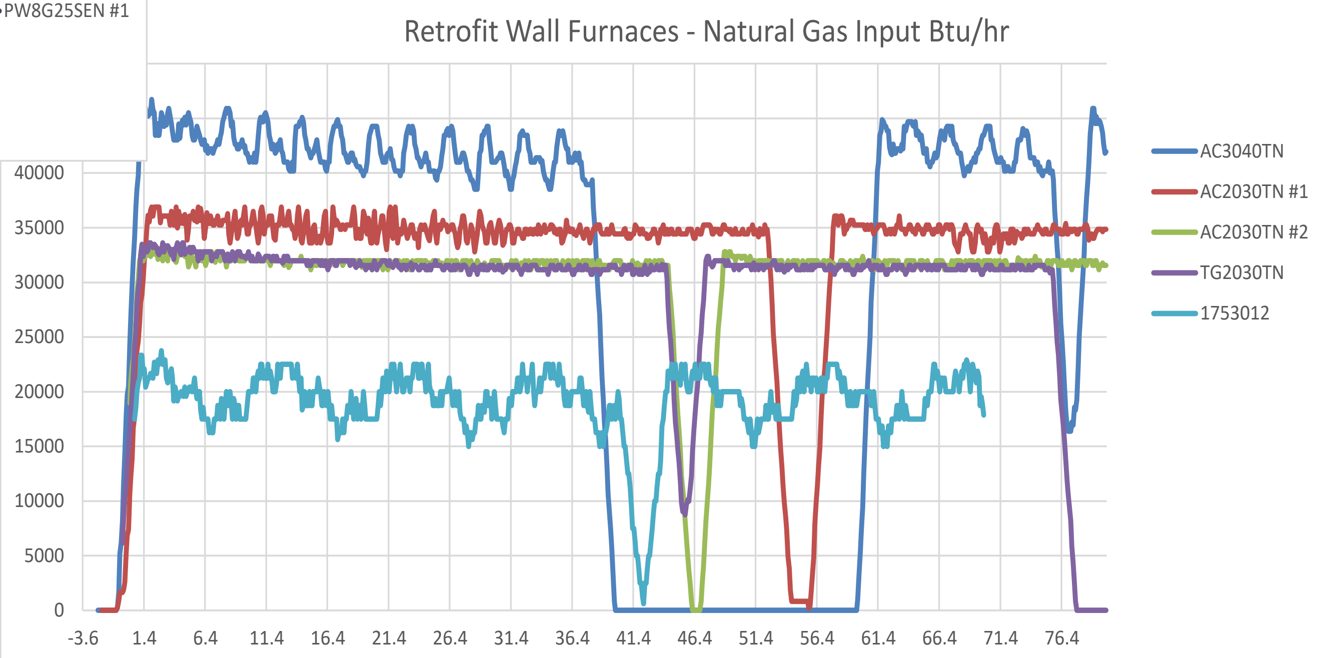
Lab Data Wall Furnace Natural Gas Use



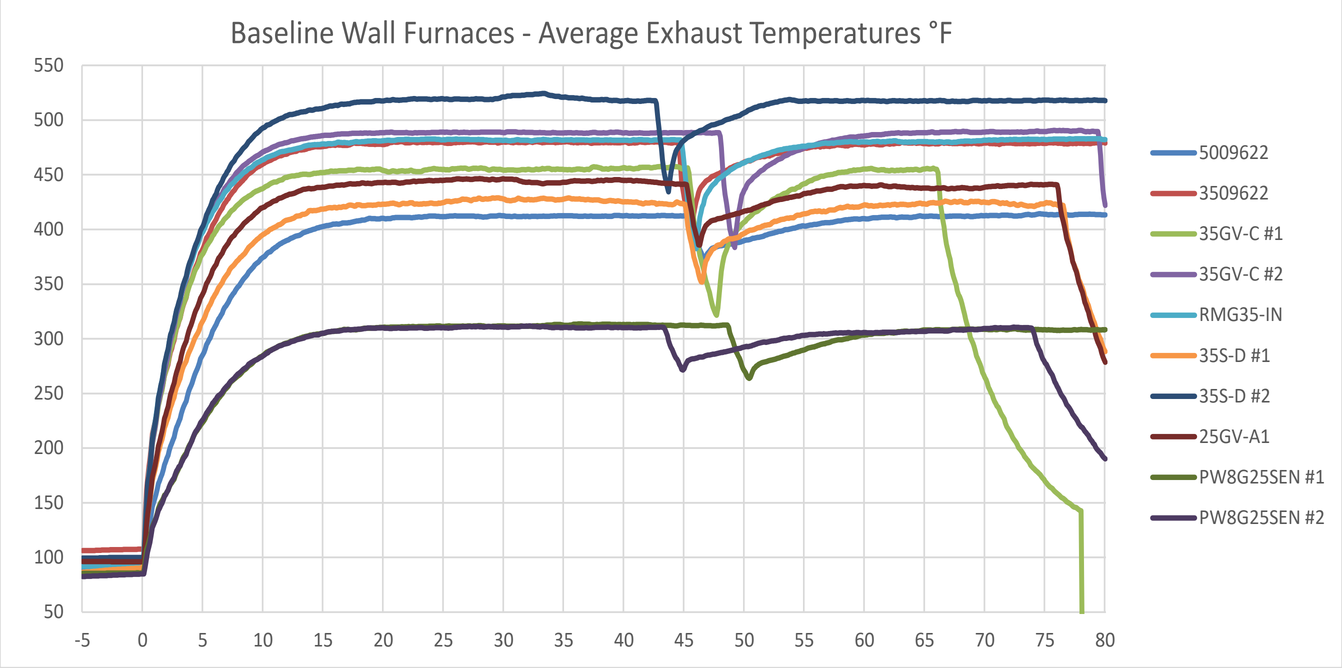
Lines look wavy due to pulse metering

Baseline Wall Furnaces

Retrofit Wall Furnaces



Lab Data Wall Furnace Exhaust Temperatures

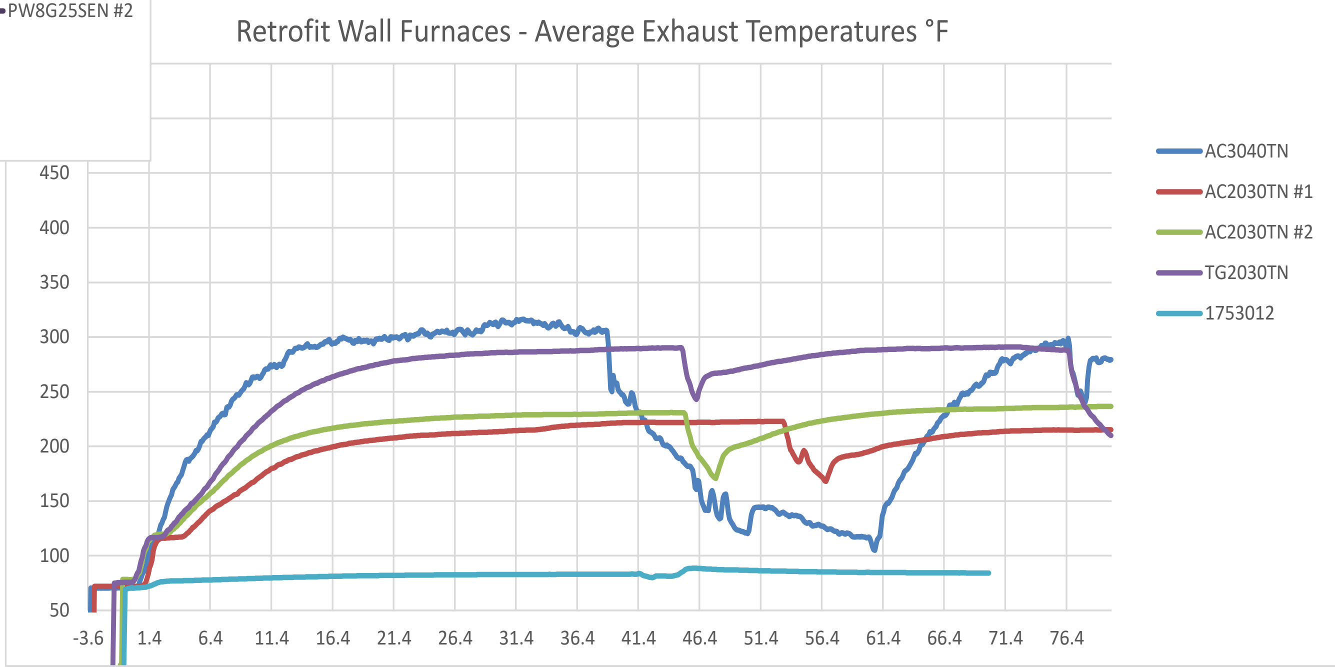


Baseline Wall Furnaces

Exhaust temperatures used to determine efficiency,

Higher exhaust temperature means more wasted energy

Retrofit Wall Furnaces



Lab Data Wall Furnace Carbon Monoxide in Flue Gases

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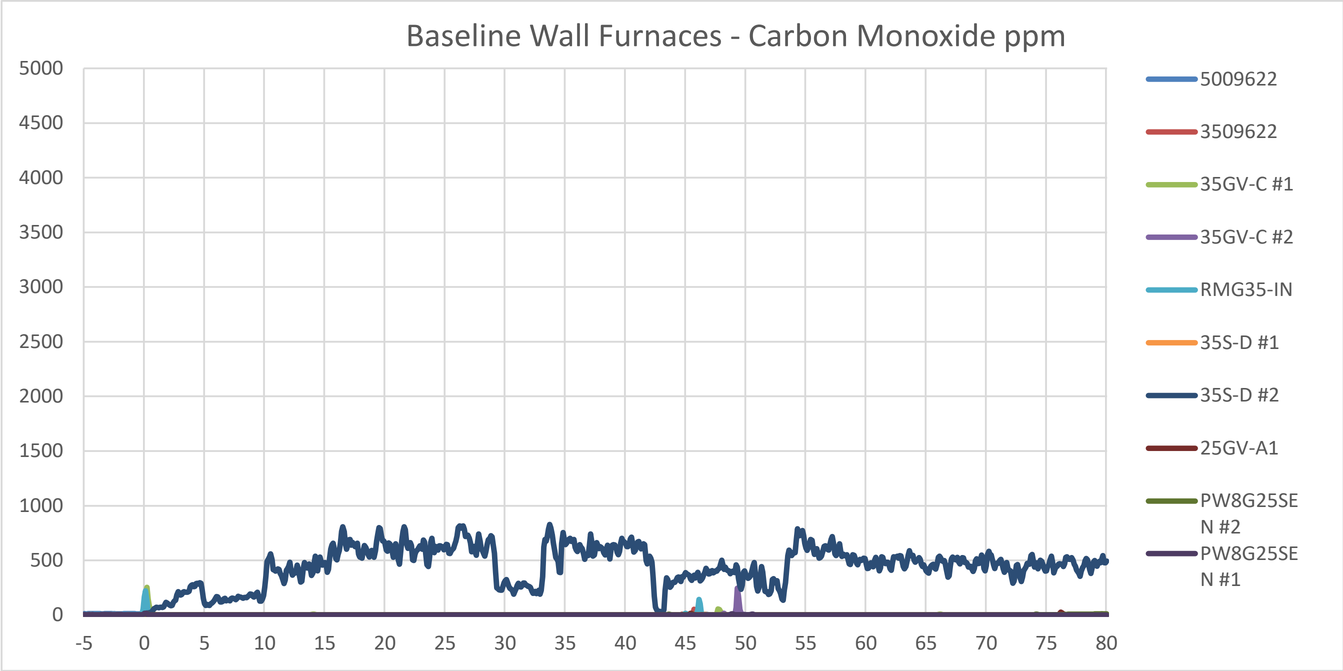
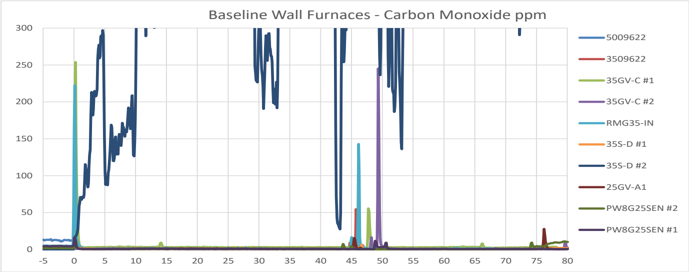
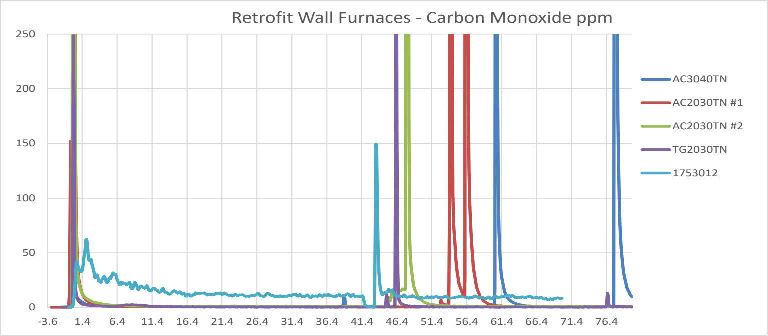


Baseline Wall Furnaces

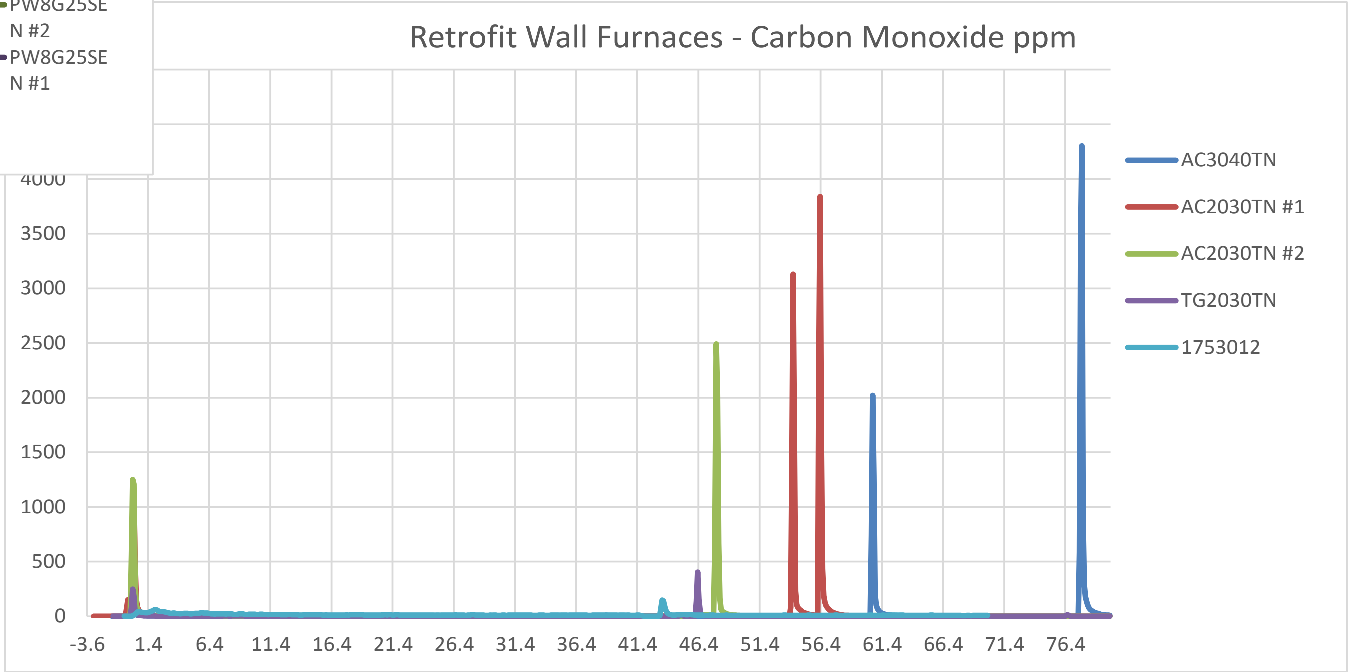
Suspected gas leak on one unit



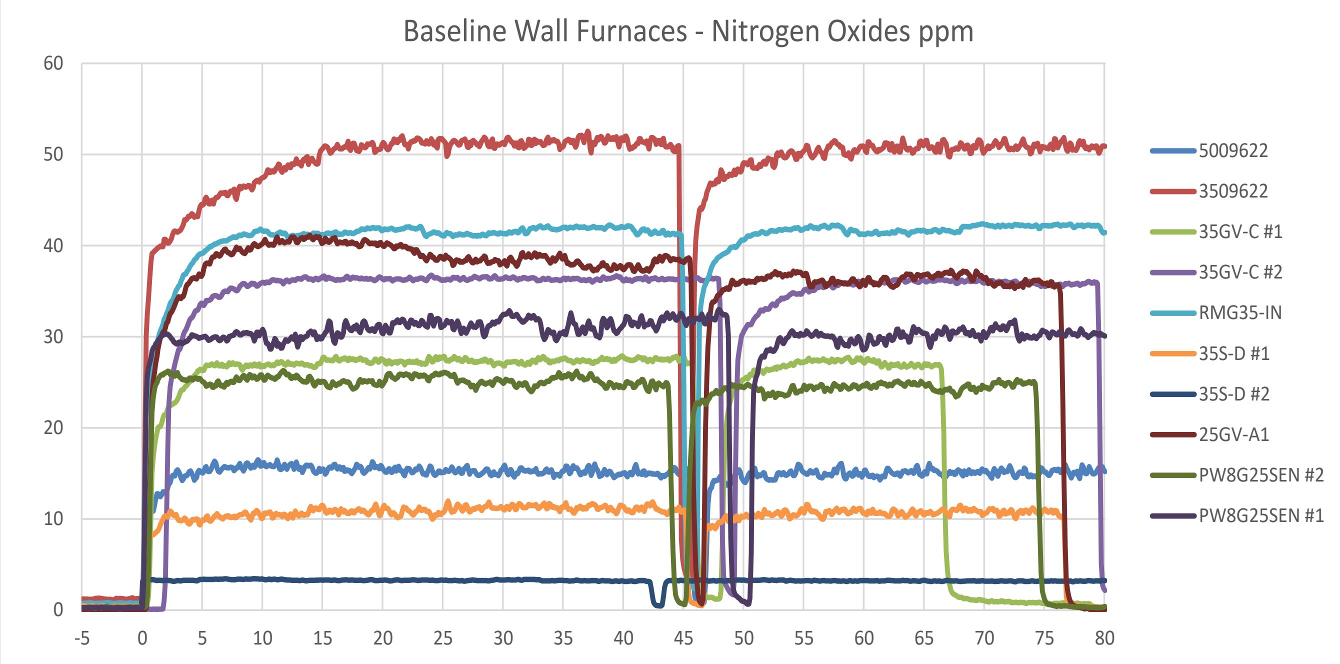


Retrofit Wall Furnaces

high ppm but low flow at shutdown



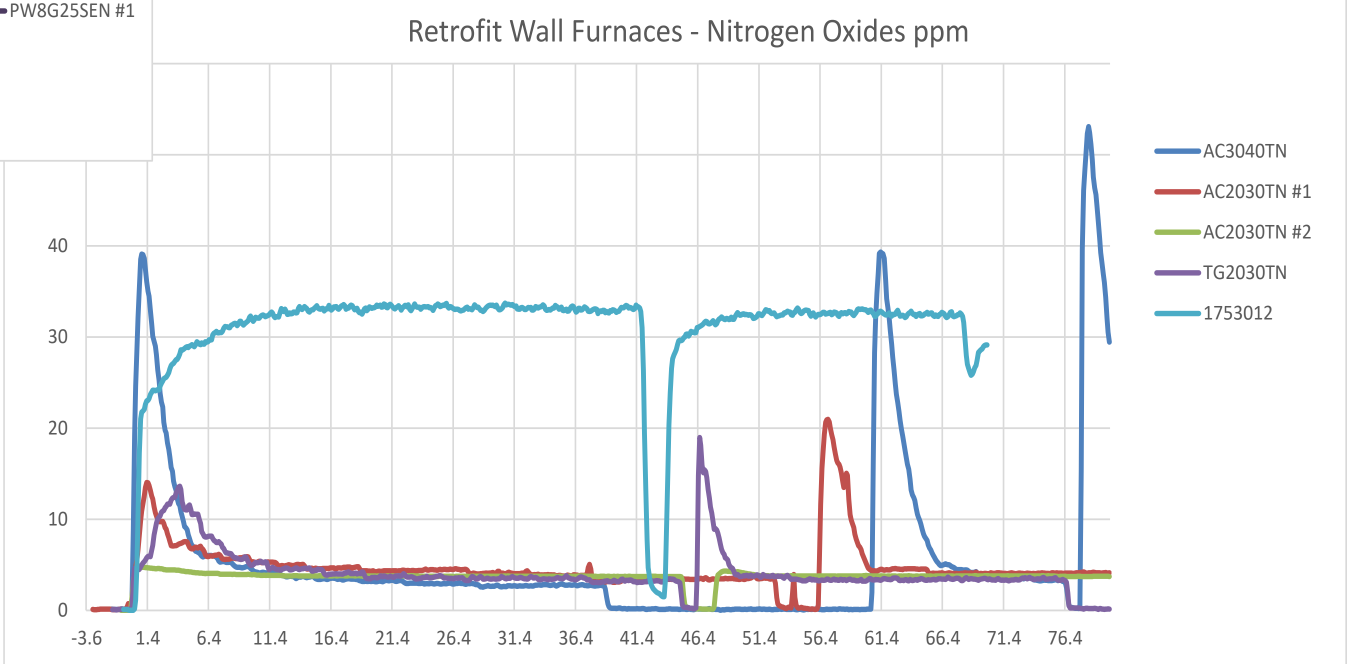
Lab Data Wall Furnace Nitrogen Oxides in Flue Gases



Baseline Wall Furnaces

Retrofit Wall Furnaces

Low NOx models are working



Lab Data Wall Furnace Total Hydrocarbons in Flue Gases

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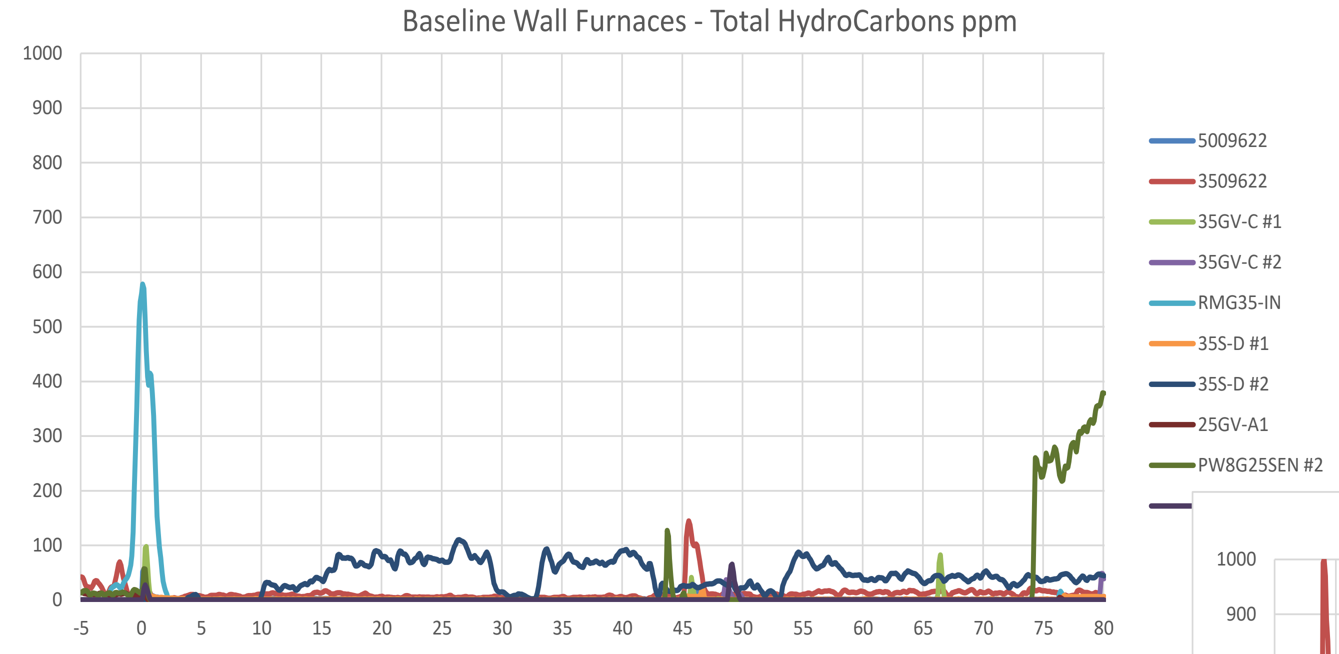
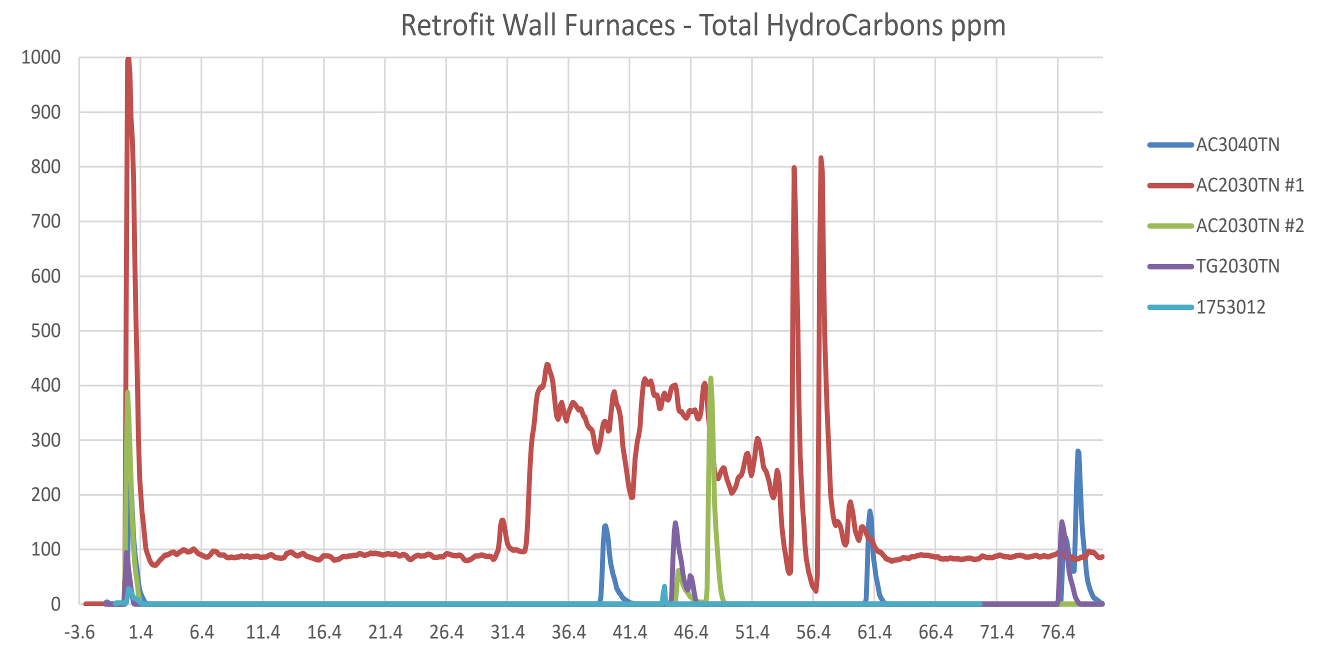


Baseline Wall Furnaces

Suspected gas leak on one unit

Retrofit Wall Furnaces

high ppm but low flow at shutdown



Lab Data High Pollutant Concentration ≠ High Emissions

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- Convert emission concentration (ppm) to emission rate (lbm/MMBtu) to actual emissions (lbm)
  - Find emission rates based on %O2 in flue gases

$$\text{Emission Rate, lbm/MMBtu} = \frac{\text{Concentration x Molecular Weight x Fd x 20.9}}{(20.9 - \text{O2\%}) \text{ x Molar Volume}}$$

Concentration, ppm = absolute measured pollutant concentration

Molecular weight, lbm/lbmole = 28.0097 for CO, 46.0047 for NOx as NO_2, and 16.04206 for Total Hydrocarbons (THC) as methane

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

O2% = adjusted oxygen percentage in exhaust stream

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

Molar Volume, dry ft^3/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

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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
		Average	**0.237**	**0.095**	**0.128**	**0.251**

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
		Average	**0.846**	**0.088**	**0.076**	**0.780**

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
		Average	**0.035**	**0.085**	**0.095**	**0.215**

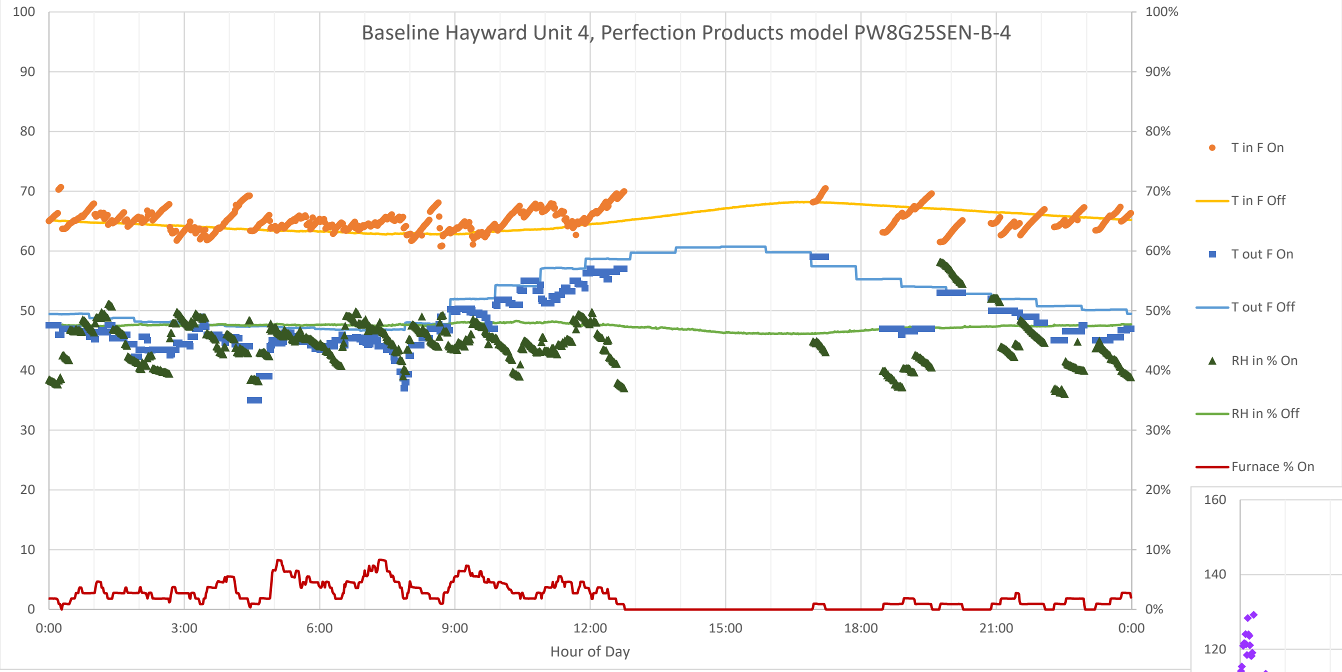
Wall Furnace Tested			Nitrogen Oxides, lbm/MMBtu			
Manufacturer	Model	Field Site	Standby	Startup	Steady State	Shutdown
Williams	1753012	Hayward 3 & 4 Retrofit	0.178	0.083	0.089	0.266
Williams	AC2030TN #1	LA 104-107 Retrofit	0.027	0.018	0.012	0.019
Williams	AC2030TN #2	LA 104-107 Retrofit	0.030	0.012	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
		Average	**0.070**	**0.031**	**0.034**	**0.069**

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
		Average	**0.181**	**0.012**	**0.074**	**1.072**

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
		Average	**0.038**	**0.038**	**0.063**	**0.925**

Field Monitoring Highlights

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

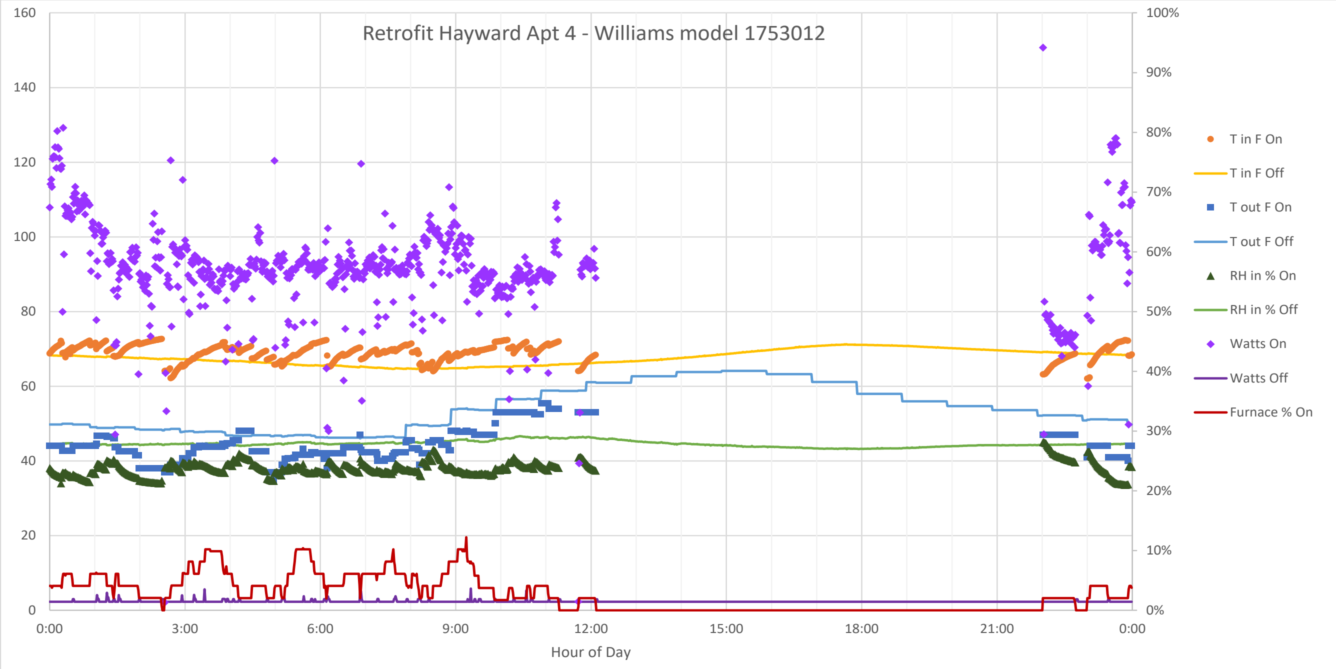


HAYWARD 4

Average Heating Season
On & Off Operation

Retrofit Wall Furnace

Direct Vent Fan-Type Condensing



Baseline Wall Furnace

Top Vent Gravity

Typical Field Data CO, NOx, PM2.5, PM10 vs Time of Day

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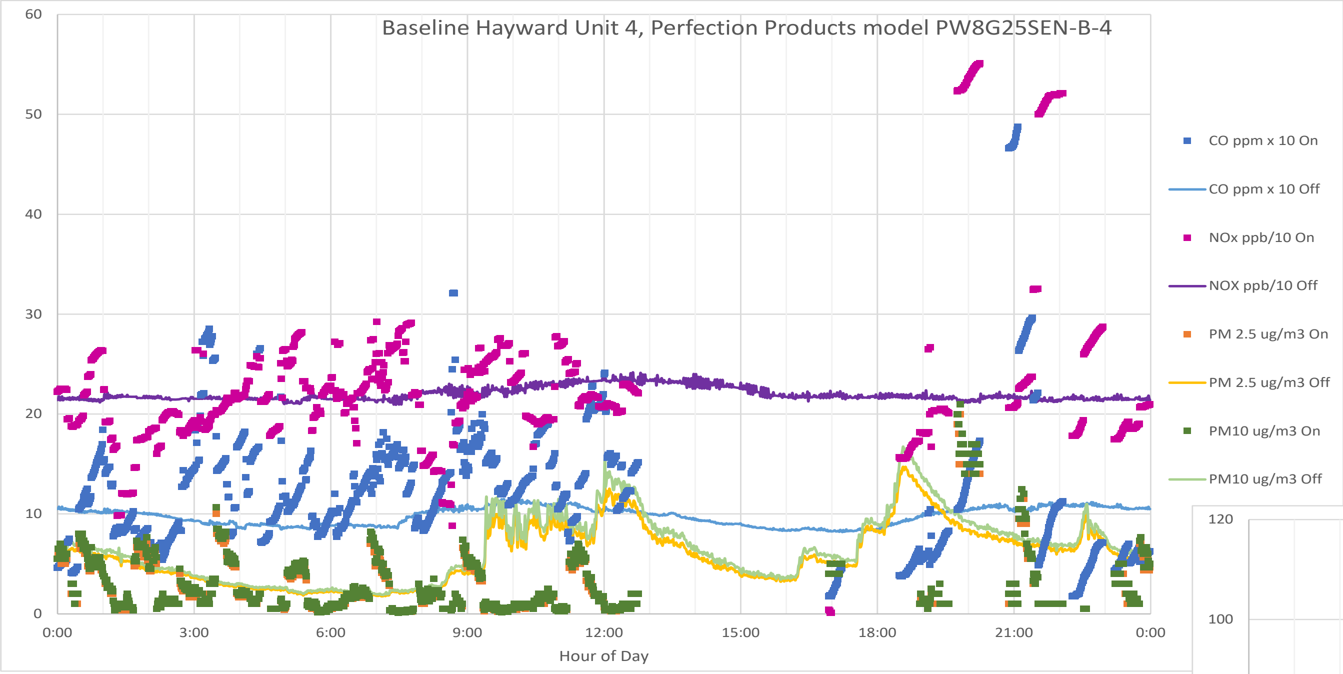
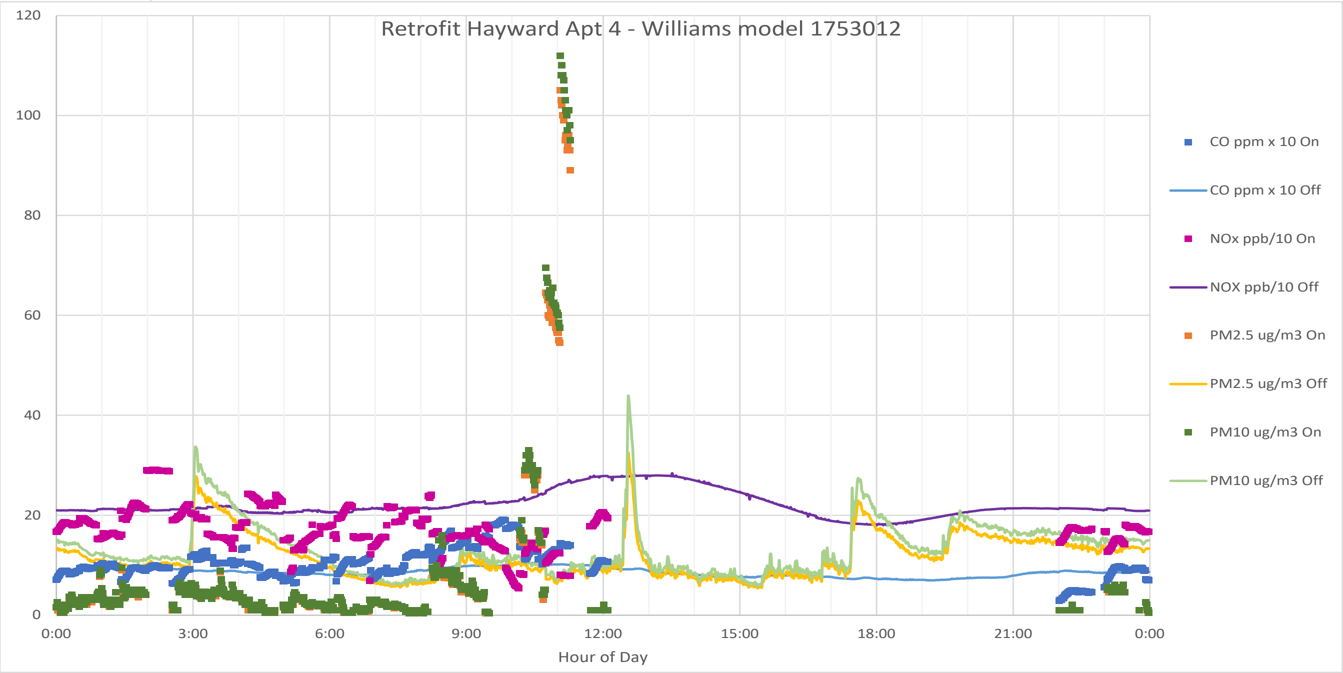


HAYWARD 4

Average Heating Season
On & Off Operation

Retrofit Wall Furnace

Direct Vent Fan-Type Condensing



Baseline Wall Furnace

Top Vent Gravity

Field Data Heating Season Operation vs Time of Day

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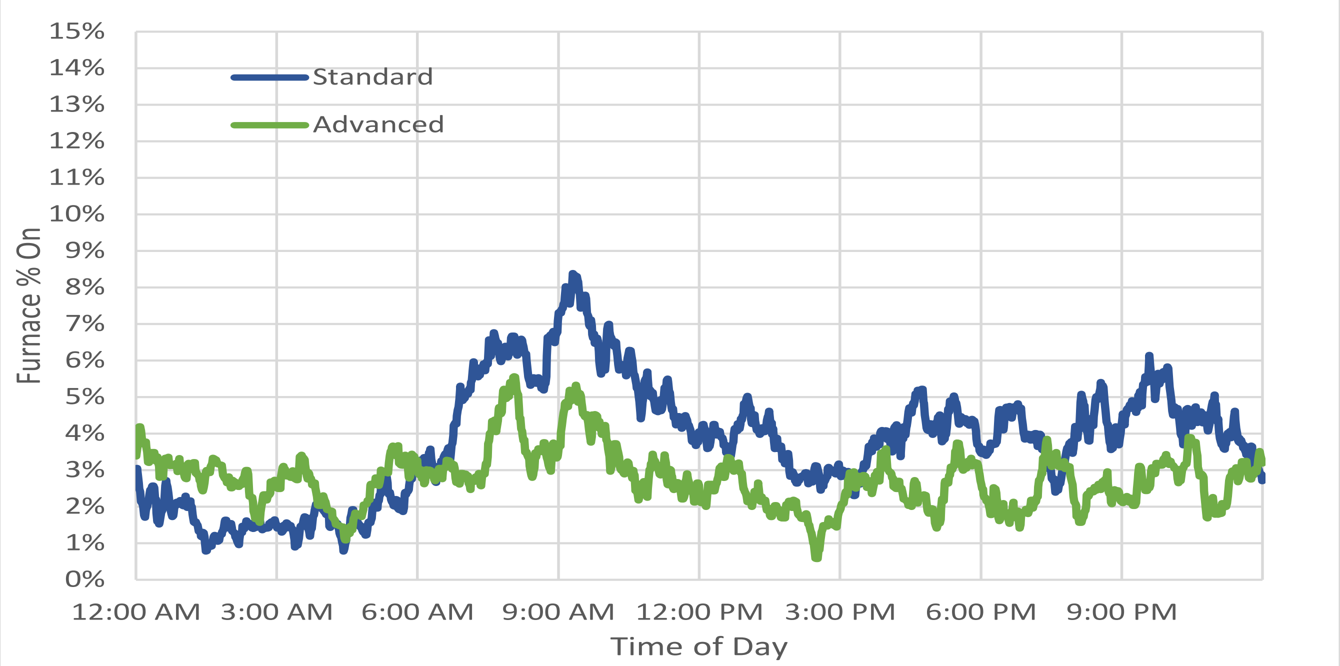
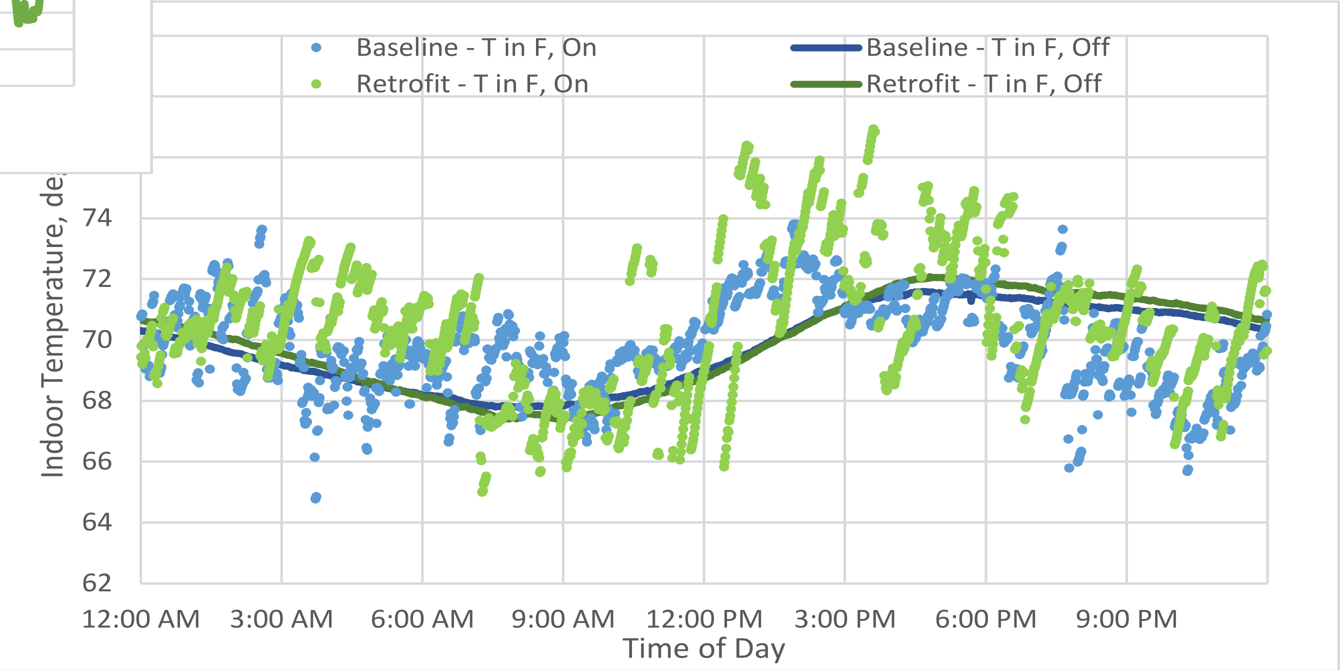


Average of All Sites
% On vs Time of Day

Wall furnace use not the same as central furnaces

More manual on-off control, use only when needed

Average of All Sites
Indoor T vs Time of Day



Field Data Daily Hours of Operation vs Outdoor Temperature

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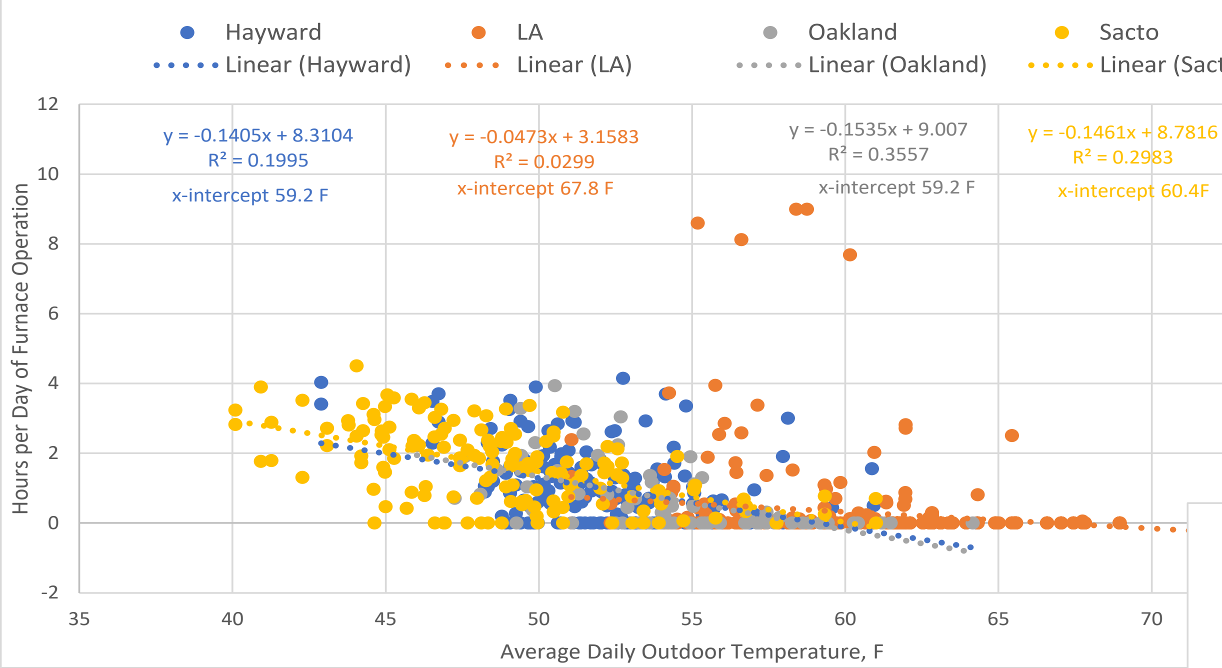
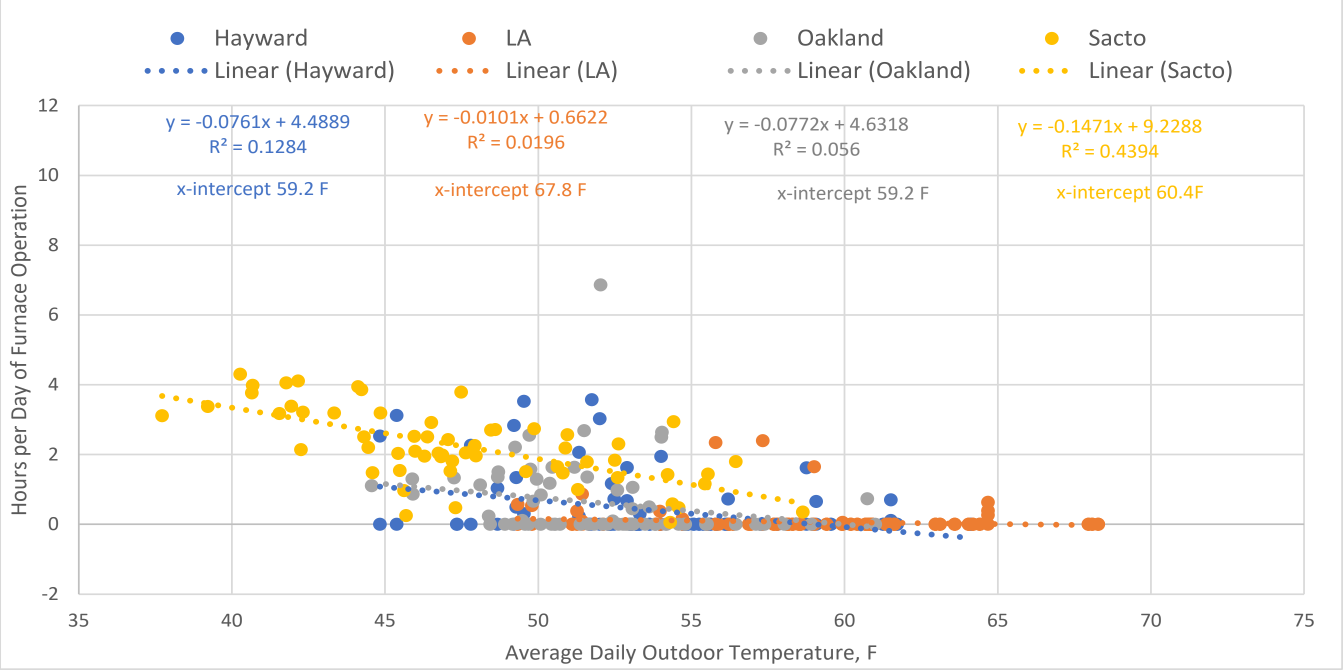


Baseline Wall Furnaces

Retrofit Wall Furnaces



Field Data Cycle Length vs Outdoor Temperature

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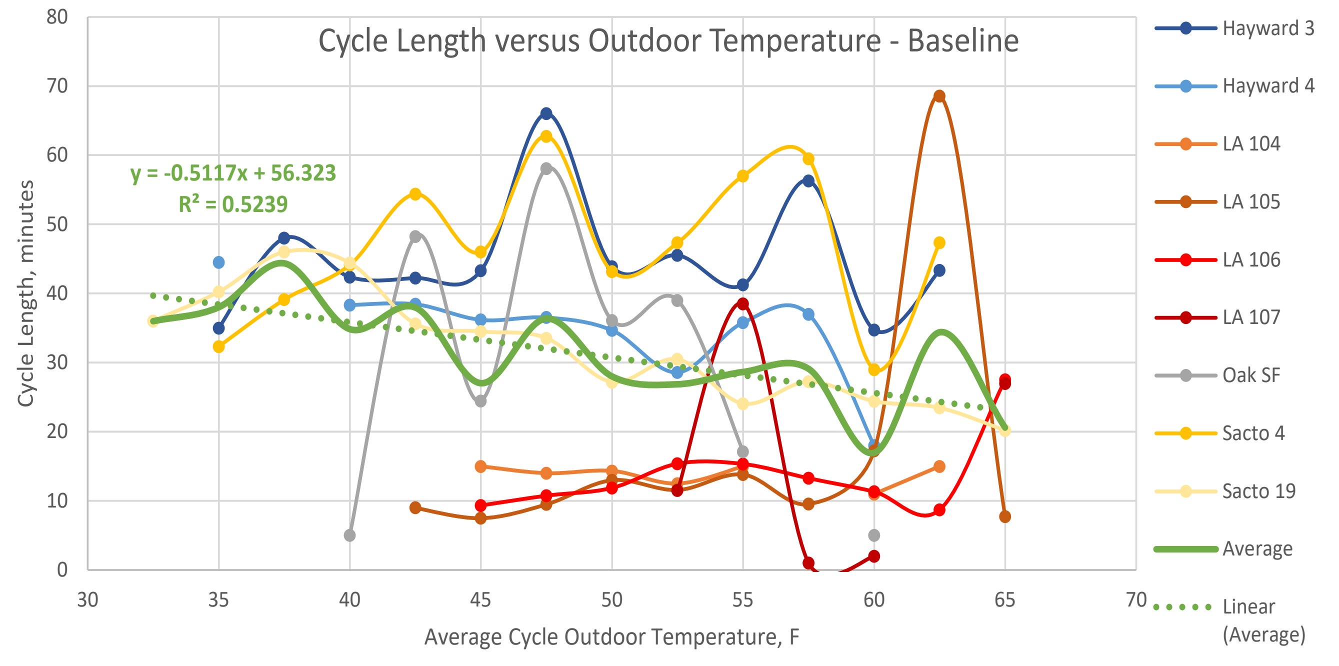
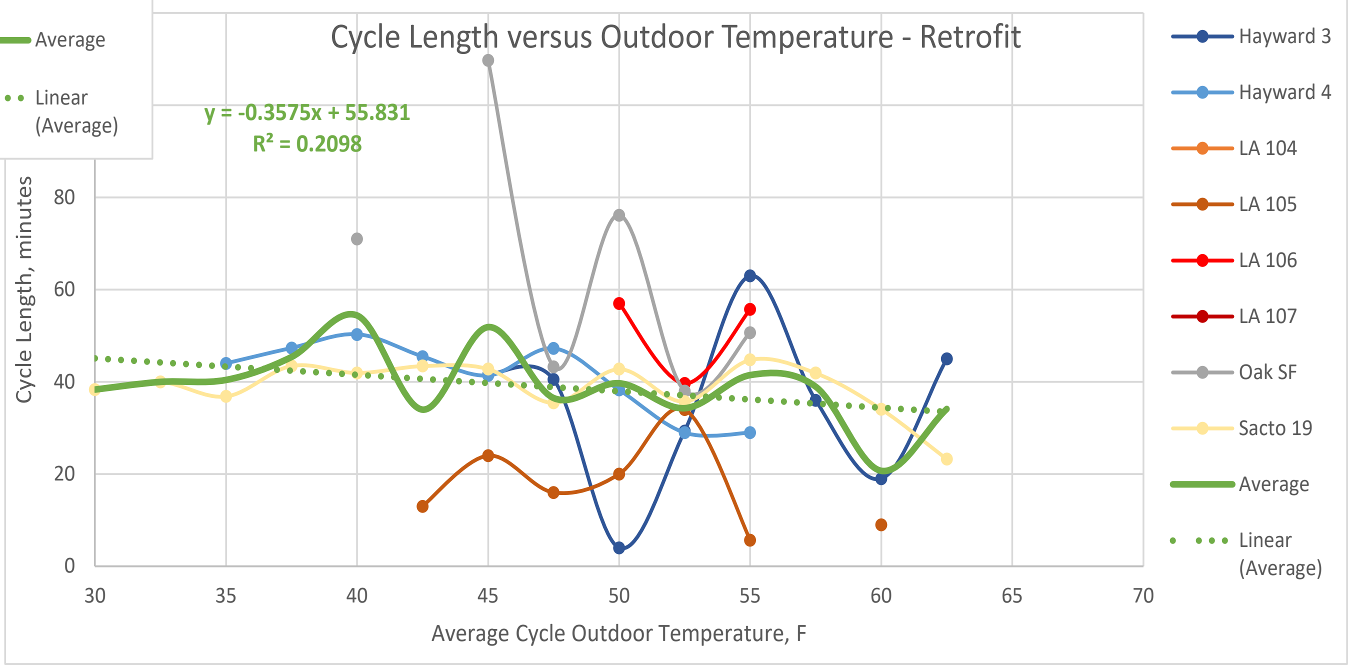


Cycle length >> cycles per day used to determine emissions

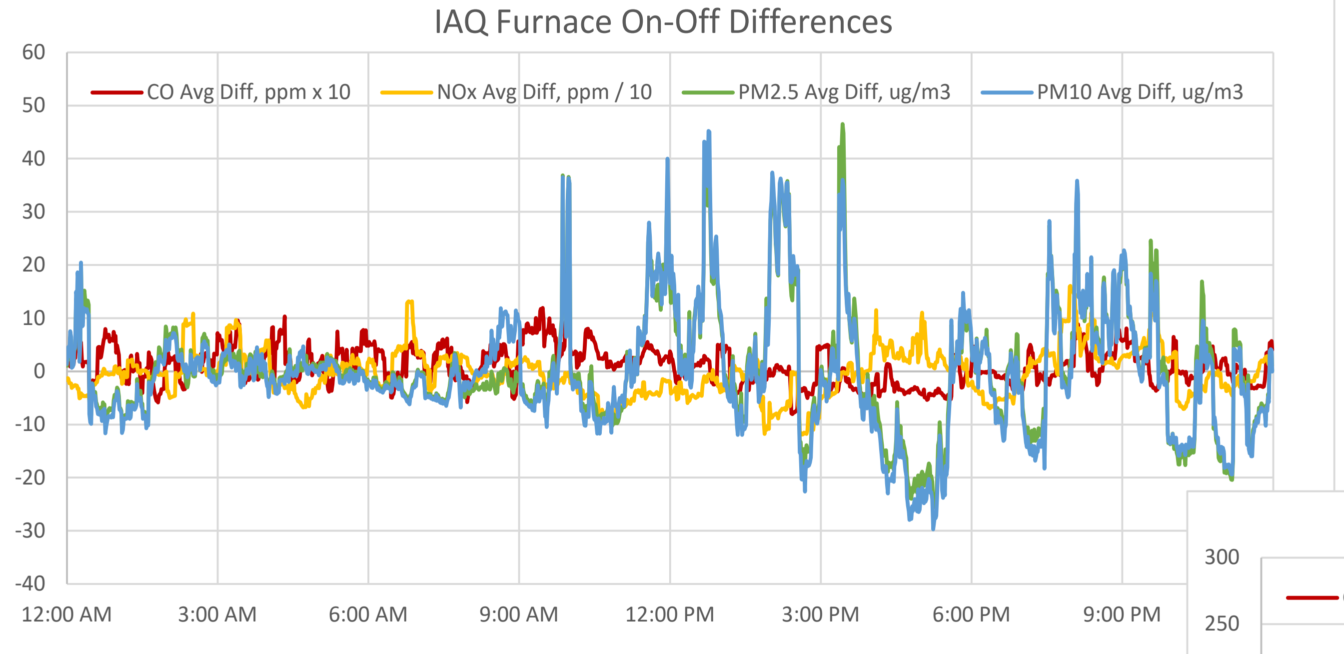
Retrofit Wall Furnaces

Baseline Wall Furnaces



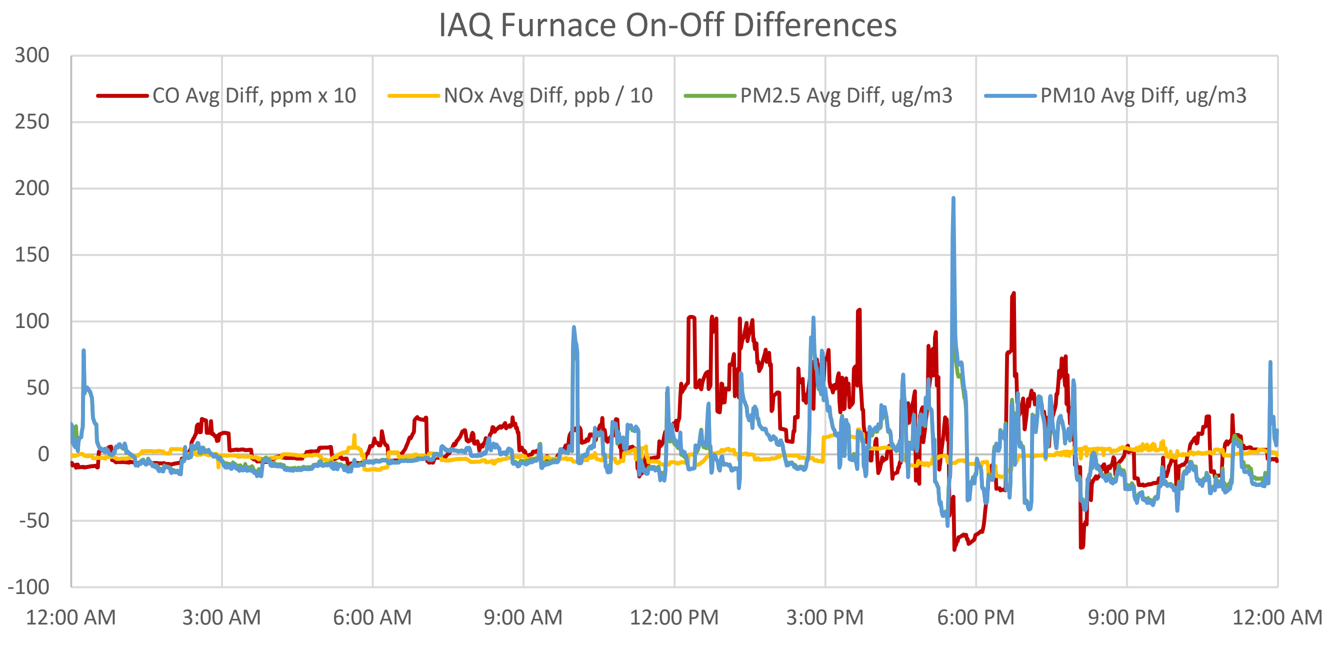
Field Data On-Off IAQ Differences vs Time of Day

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



Baseline Wall Furnaces

Retrofit Wall Furnaces



Wall Furnace Performance

Wall Furnace Fuel Use & Efficiency from Lab Tests

GTI ENERGY

Baseline Wall Furnaces

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
	Average	**32**	**33500**	**29990**	**89%**	**690**	**67.0%**	**65.3%**	**22490**	**19190**	**87%**	**0**

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
	Average	**0**	**28500**	**30830**	**109%**	**0**	**85.7%**	**82.0%**	**24190**	**25050**	**103.9%**	**26.3**

Wall Furnace Emissions Rates from Lab, Field, TMY Data

GTI ENERGY

During Typical Heating Use

Baseline Wall 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
		Baseline Average	**188.5**	**417**	**27.1**	**11.60**	**0.172**	**0.061**	**0.111**

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

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
		Retrofit Average	**118.7**	**208**	**34.3**	**3.66**	**0.078**	**0.031**	**0.037**

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

GTI ENERGY

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%
Average	**4.7**	**15.7**	**18.9**	**21%**	**2.9**	**17.4**	**19.0**	**9%**	**12.2**	**15.2**	**15.5**	**2%**	**16.5**	**18.5**	**13%**
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%
Average	**4.8**	**15.9**	**13.6**	**-14%**	**3.1**	**24.7**	**18.8**	**-24%**	**9.6**	**21.6**	**20.4**	**-6%**	**24.2**	**22.4**	**-7%**
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 FU

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

GTI ENERGY

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%
Average	**4.9**	**45.6**	**24.5**	**-46%**	**5.1**	**54.9**	**26.5**	**-52%**	**16.0**	**134.2**	**35.9**	**-73%**	**152.9**	**39.4**	**-74%**
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%
Average	**6.8**	**62.3**	**31.6**	**-49%**	**5.4**	**60.7**	**24.7**	**-59%**	**12.7**	**185.4**	**34.5**	**-81%**	**211.8**	**37.3**	**-82%**
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 FU

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

GTI ENERGY

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

- 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	14.4	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	**70**	**37%**
Cycles	420	210	**210**	**50%**
CO lbm	2.39	0.32	**2.07**	**87%**
NOx lbm (lbm/MMBtu)	0.70 (0.061)	0.10 (0.031)	**0.60 (0.030)**	**86%**
THC lbm	1.21	0.08	**1.12**	**93%**

- 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 Pow		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

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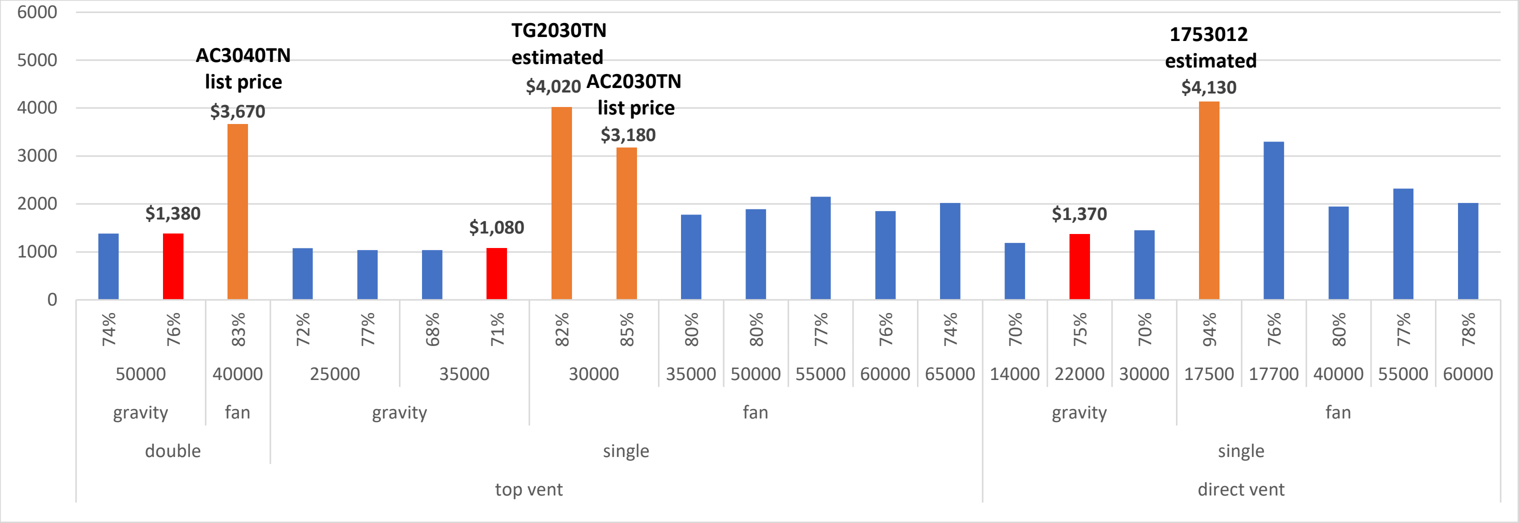
Average IAQ Concentrations	CO Off ppmx10	CO On ppmx10	NOx Off ppb/10	NOx On ppb/10	PM2.5 Off ug/m3	PM2.5 On ug/m3	PM10 Off ug/m3	PM10 On ug/m3
Baseline Average	15.7	18.9	17.4	19.0	15.2	15.5	16.5	18.5
Retrofit Average	15.9	13.6	24.7	18.8	21.6	20.4	24.2	22.4
Reduction	-0.3	5.2	-7.3	0.2	-6.4	-4.9	-7.7	-3.9
% 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
	Average	**$148**	**$3,670**	**$1,170**	**$30**	**$2,530**	**19.7**	**$2,800**	**$550**	7.5

Takeaways for Advanced Wall Furnaces

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- 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/

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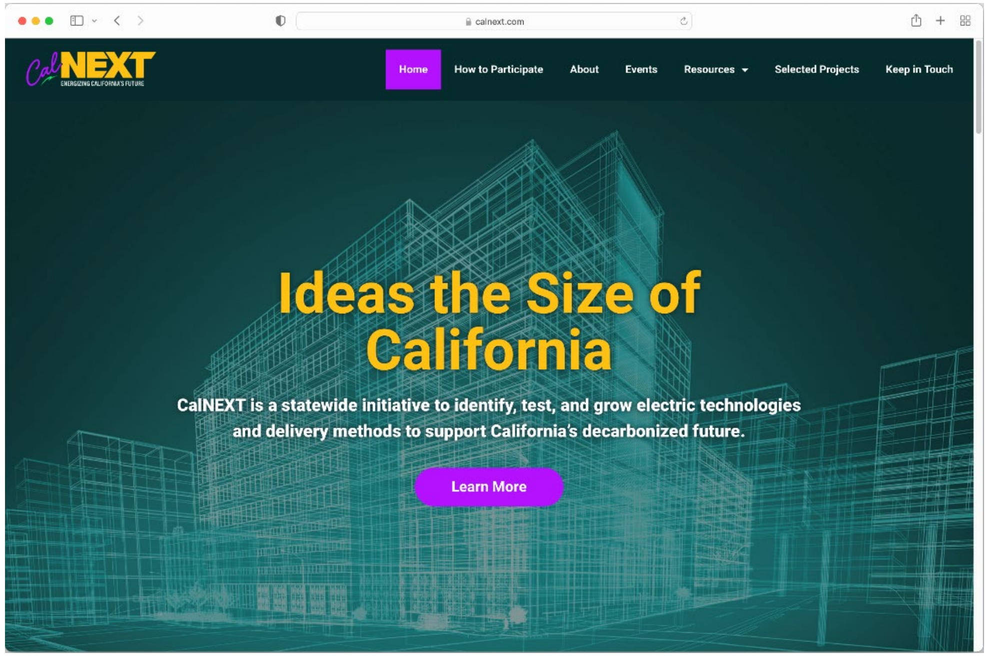
CalNEXT

CalNEXT's vision is to identify emerging electric technologies across six priority areas and bring them to the IOU energy efficiency programs portfolio.

To learn more and sign up for our email list, please visit calnext.com



Appliances & Plug Loads

HVAC

Lighting

Process Loads

Water Heating

Whole Buildings

Other California Emerging Technology Efforts

California Statewide Emerging Technologies Program assesses the performance of high-efficiency technologies and makes recommendations to customer funded programs as to whether these technologies are suitable.

For more information, visit [ca-etp.com](ca-etp.com)

Demand Response Emerging Technologies Program is investing more than $25 million over five years in scientific and technological research accelerating the market adoption of emerging demand response enabling technologies in all customer sectors to meet California's electric reliability and climate goals.

For more information, visit dret-ca.com

Emerging Technologies Coordinating Council was created to facilitate collaborations on emerging technologies projects. It was created by Pacific Gas and Electric Company, Southern California Edison, Southern California Gas Company, San Diego Gas & Electric, and the California Energy Commission and includes Sacramento Municipal Utility District and Los Angeles Department of Water and Power

For more information, visit etcc-ca.com