



→ **California Statewide Gas Emerging Technologies**  
**Boiler Related EE Measure Assessment**



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# Agenda

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- Project Background
- Assessment Objectives
- Introduction
- Literature Review
- Historical IOU Participation Data Analysis
- Customer Surveys: Methodology and Results
- Manufacturer Interviews: Summary of Emerging Technologies in Boiler Accessories
- Conclusions and Future Recommendations

# ETO4 – Project Goals

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## **ET22SWG0004: Research energy efficiency measures related to boiler accessories through the lens of California**

- a) Estimate number of boilers in California by sector and end usage
- b) Historical IOU participation data analysis to determine the prevalence of measures related to boilers and accessories
- c) Customer surveys – methodology and data analysis
- d) Evaluation of boiler centric technologies and add-on measures that should be added to program delivery
- e) Identification of market barriers or gaps in measure implementation
- f) Recommendations for future projects and follow-up considerations

# ETO4 – Project Findings and Recommendations

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- Customer Survey Results Discussion
- Number of boiler manufacturers and distributors interviewed: **25**
- **Measure Table:** Number of boiler add-on related measures identified from the literature review and U.S. DOE tip sheets: **10**
- Number of boiler add-on related measures derived from the manufacturer interviews: **11**
- Estimated efficiency increase ranges for the identified commercially available technologies and products **from 1% to 8%**
- **Barriers in measure implementation:** space constraint, variability in size of boilers, installation limitations, high upfront costs, etc.
- **Recommendations** of measures for near term hits, field/lab testing and listing of non-viable measures



# ETO4 – Project Background

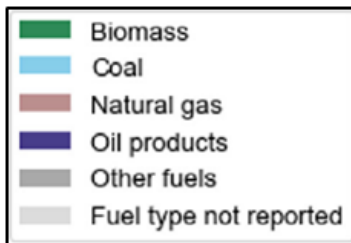
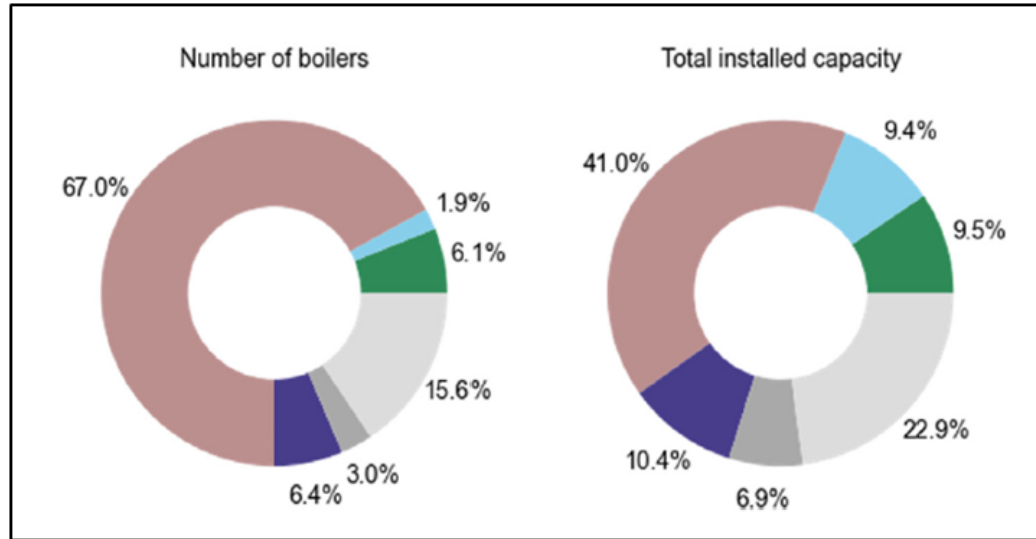
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- Boiler systems are used to produce steam and/or hot water which is used for several primary
- purposes such as space heating, domestic hot water uses, pool heating, etc.
- **Categorization:** Industrial, Commercial, Institutional and Multifamily boilers
- Focus on boiler add-ons and not the entire boiler retrofits!
- Introduction on boiler accessories and their impact on boiler system efficiency improvement
- Most of the previous studies are either outdated and not specific to California



# ET04 – Literature Review

# ETO4 – Literature Review



	Sector	Number of Estimated Boilers
1	Multifamily	22,631
2	Industrial	3,170
3	Commercial	3,483
4	Others	151

## Boiler Inventory Categorization in California

Basis of Information:

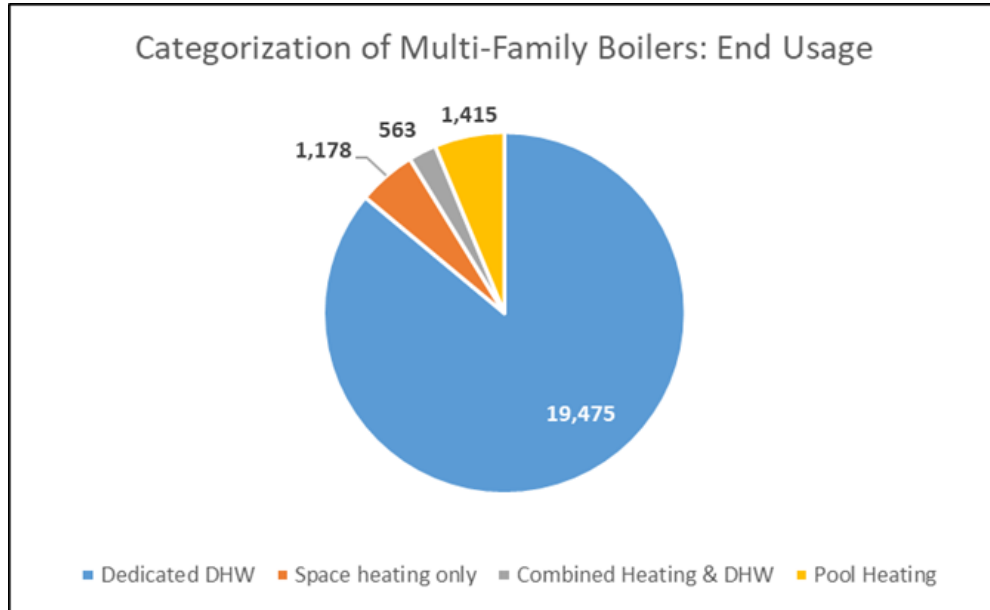
[1] Derived from Cadmus Multifamily Study (2019)

[2-4] Boiler Licensing Data (Publicly available information)

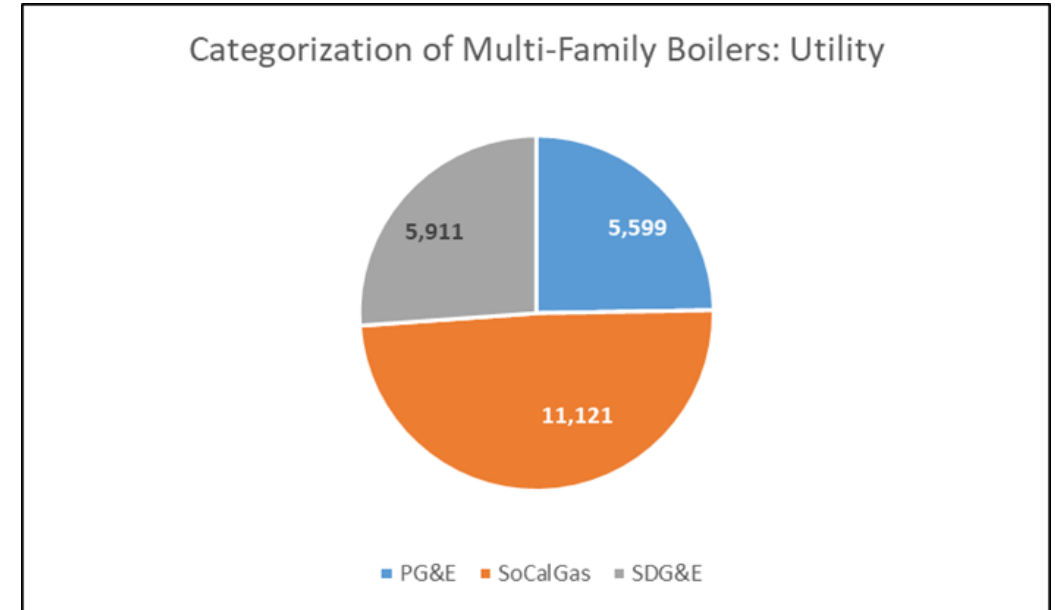
EPA GHG Datasets of Industrial Boilers for confirming [2]

Estimated number of Industrial Boilers in U.S. – **38, 537**

# ETO4 – Literature Review



*Reference: Multifamily Boiler Study by Cadmus (2019)*



- The end-usage most often served is domestic water heating. Pool heating is the next prevalent end use.
- SoCalGas territory has the highest number of Multifamily boilers among the three utilities in California.



# ETO4 – Literature Review

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## **Lessons Learned from Boiler Studies Conducted in Other States**

### **A) Findings from the Oregon Boiler Market Characterization**

Retrofitting the oversized boiler with modulating burner and digital controls would allow the boilers to operate more efficiently

Focus on improving the design and performance of condensing boilers rather than the purchase of new condensing boilers

### **B) Findings from the Minnesota Boiler Market Characterization**

The field monitoring of condensing boilers indicated that the on-field operation had better than expected space heating performance (Average AFUE of 13 condensing boilers was 94%)

# ETO4 – Literature Review

## Review of U.S. DOE Tip Sheets: Boilers and Accessories

Pipe Diameter (inches)	Energy Content, MMBtu/year*				
	Steam Velocity, feet/min				
	200	300	400	500	600
2	90	140	185	230	280
4	370	555	740	925	1,110
6	835	1,250	1,665	2,085	2,500
10	2,315	3,470	4,630	5,875	6,945

\*Assumes continuous operation, 70°F makeup water, and condensed steam at 100°F.

Energy Recovery Potential of Vent Condenser

Blowdown Rate, % Boiler Feedwater	Heat Recovered, Million Btu per hour (MMBtu/hr)				
	Steam Pressure, psig				
	50	100	150	250	300
2	0.45	0.5	0.55	0.65	0.65
4	0.9	1.0	1.1	1.3	1.3
6	1.3	1.5	1.7	1.9	2.0
8	1.7	2.0	2.2	2.6	2.7
10	2.2	2.5	2.8	3.2	3.3
20	4.4	5.0	5.6	6.4	6.6

Based on a steam production rate of 100,000 pounds per hour, 60°F makeup water, and 90% heat recovery.

Energy Recovery Potential of Boiler Blowdown

# ETO4 – Literature Review

## Review of U.S. DOE Tip Sheets: Boilers and Accessories

Energy Savings Due to Installation of an Energy-Efficient Burner		
Burner Combustion Efficiency Improvement, %	Annual Energy Savings, MMBtu/yr	Annual Dollar Savings, \$
1	6,250	50,000
2	12,345	98,760
3	18,290	146,320

Energy Recovery Potential of Burner Upgrades

System	Combustion Efficiency @ 4% Excess O <sub>2</sub> (%)	Stack Gas Temperature °F
Boiler	78 to 83%	350 to 550*
- with Feedwater (FW) Economizer	84 to 86%	250 to 300*
- with FW and Condensing Economizer	92 to 95%	75 to 150*

Energy Recovery Potential of Economizer

- Installation of turbulators: easy to install, low-cost design improvement substitute



# ET04 – Historical IOU Participation Data Analysis and Customer Surveys

# ETO4 – Historical IOU Participation Data Analysis

Year	Number of claims made	Measure(s)	Measure Classification		Commercial	Residential	Agricultural	Industrial	Measure type
			Deemed	Custom					
2022	18	Boiler Replacement: Commercial, Residential, Process	0	18	6	12	0	0	Add-on equipment measures: 0
2021	1190	Boiler Replacement: Commercial, Residential, Process Boiler upgrade to Condensing Tank-type Water Heaters, VSD DHW recirc controls Boiler Demand Controls Process Boilers, Feedwater Economizer, NC Process Boilers, Condensing Economizer, AOE MF Central Boiler Dual Setpoint Temperature Controller_OAT Reset	1148	48	1102	84	2	2	Add-on equipment measures: 33 % AOE: 3 % Economizers: 9 MF Central Boiler Dual Setpoint Controller: 20 Others: 4
2020	759	Boiler Replacement: Commercial, Residential, Process Replacement with Condensing Boilers	731	28	706	51	1	1	Add-on equipment measures: 4 % AOE: 1 % Economizers: 1 Others: 3
2019	676	Boiler Combustion Air Fan VFD W/H- Boiler Controllers Boiler Replacement: Commercial, Residential, Process Central Hydronic Boiler DHW Recirculation Controls	613	63	127	533	7	9	Add-on equipment measures: 478 % AOE: 71 % Boiler Combustion Air fan VFD: 1 W/H Boiler Controllers: 477
2018	69	W/H- Boiler Controllers Boiler Replacement: Commercial, Residential, Process Central Hydronic Boiler DHW Recirculation Controls	10	59	25	35	2	7	Add-on equipment measures: 9 % AOE: 13 % Economizers: 2 Steam traps: 1 Others: 6

- More than 90% of the claims submitted during the years 2019–21 were for deemed measures
- Existing deemed boiler related measures focus on the entire boiler retrofit
- Significant opportunity for measure package development related to boiler add-ons

# ETO4 – Customer Surveys

- Objective of conducting customer surveys
- Customer data screening and outreach
- Online survey instrument
  - a) Type of boiler
  - b) End usage of boilers
  - c) Year of installation
  - d) Measure(s) installed

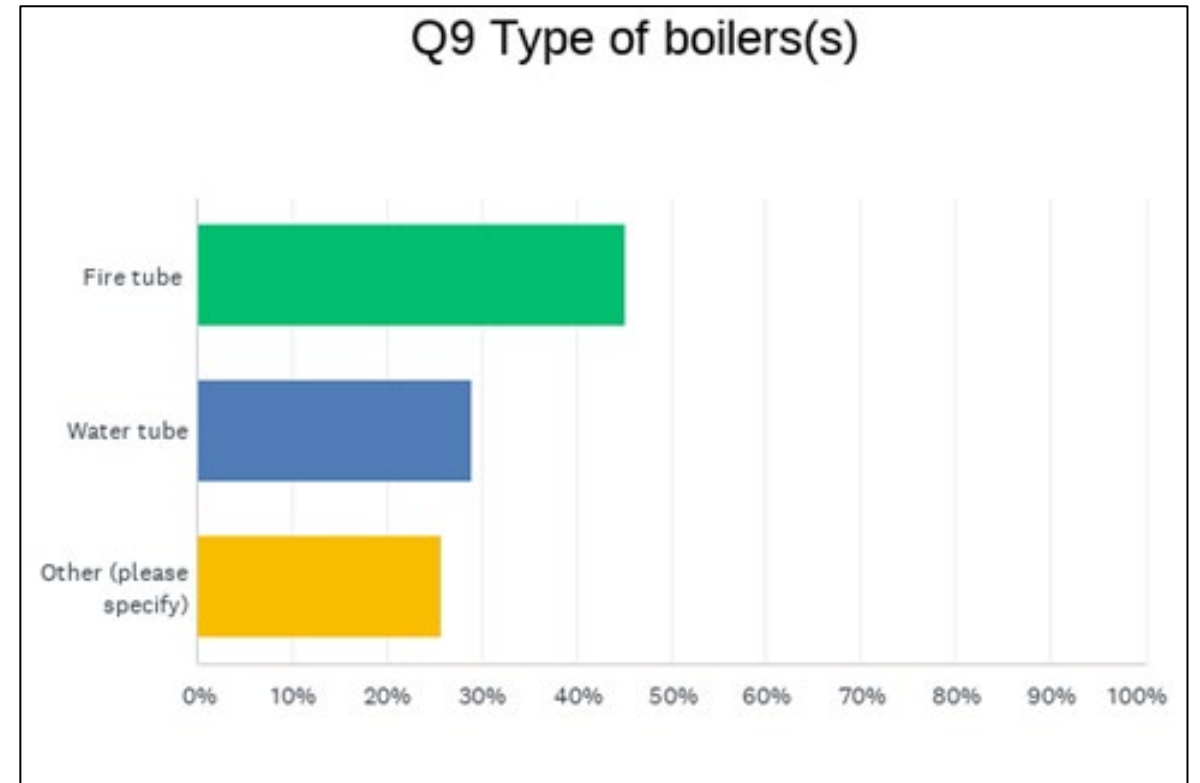
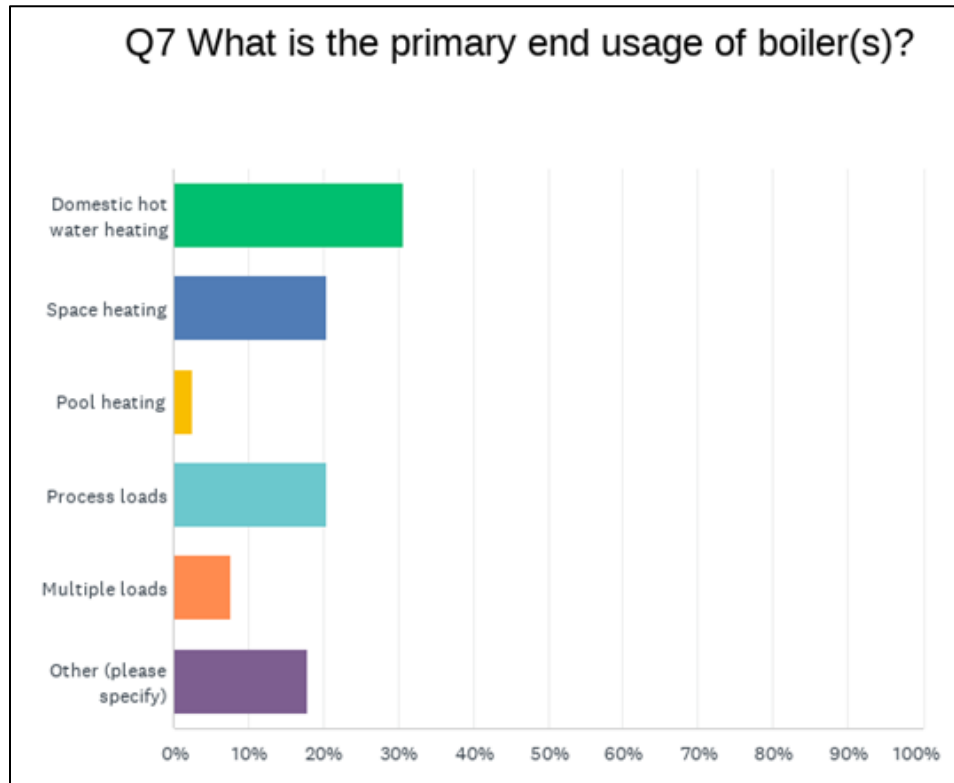
Source	Number of contacts
Bay Area AQMD	444
South Coast AQMD	2,962
SoCalGas	1,001
<b>Total</b>	<b>4,407</b>

*Note: Some of the contacts in the SoCalGas dataset may overlap with one or more AQMD datasets.*

<b>Total Contacts</b>	4,407
<b>Survey Responses</b>	46
<b>% Response Rate</b>	1%

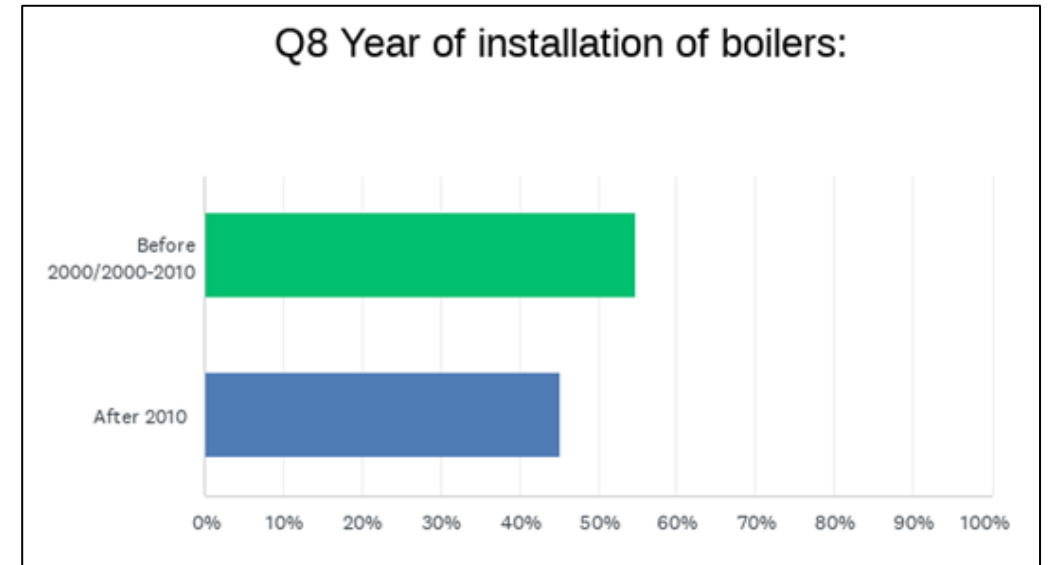
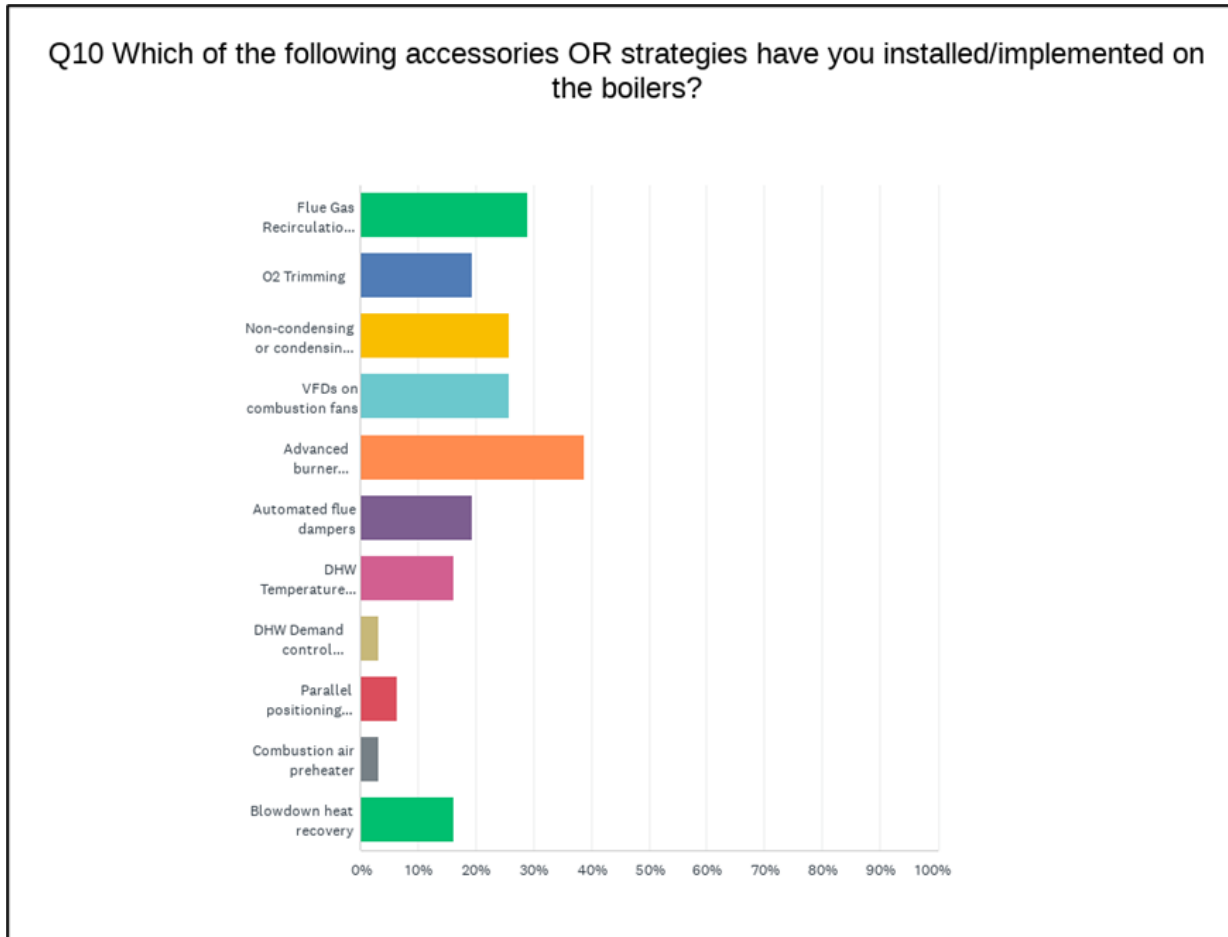
# ETO4 – Customer Surveys

- Customer Survey Results Discussion



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- Customer Survey Results Discussion

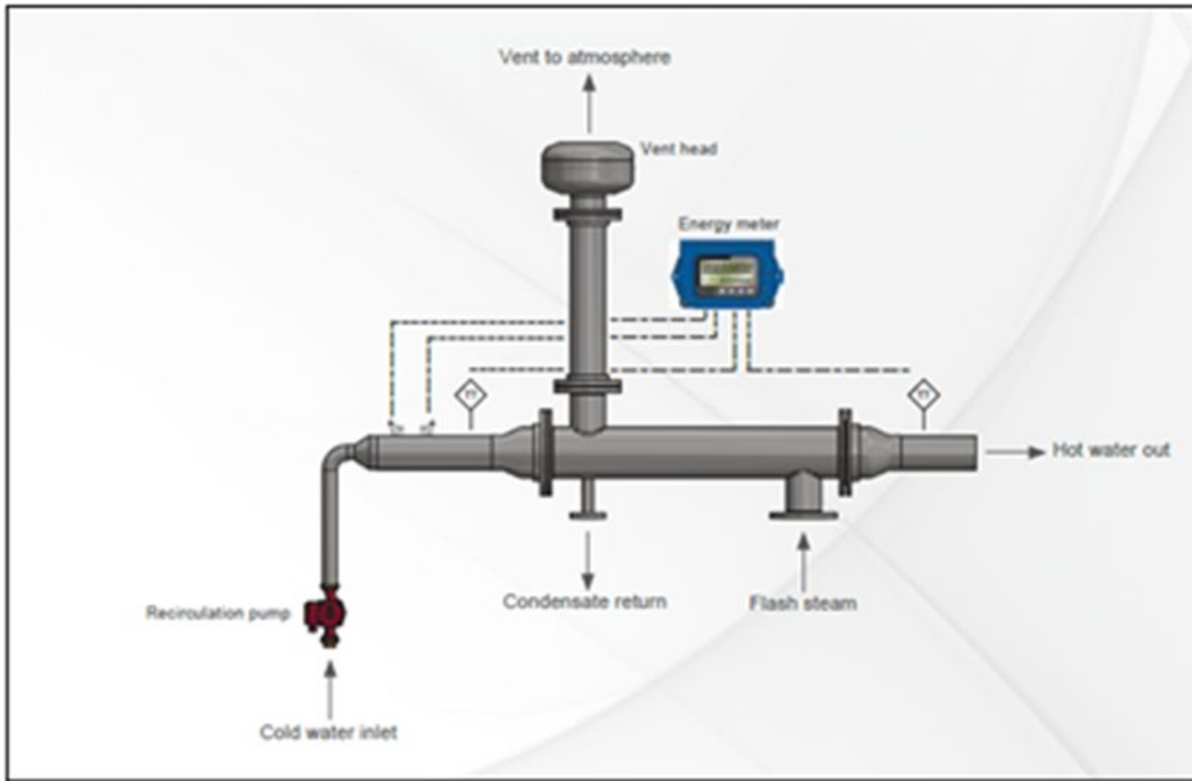




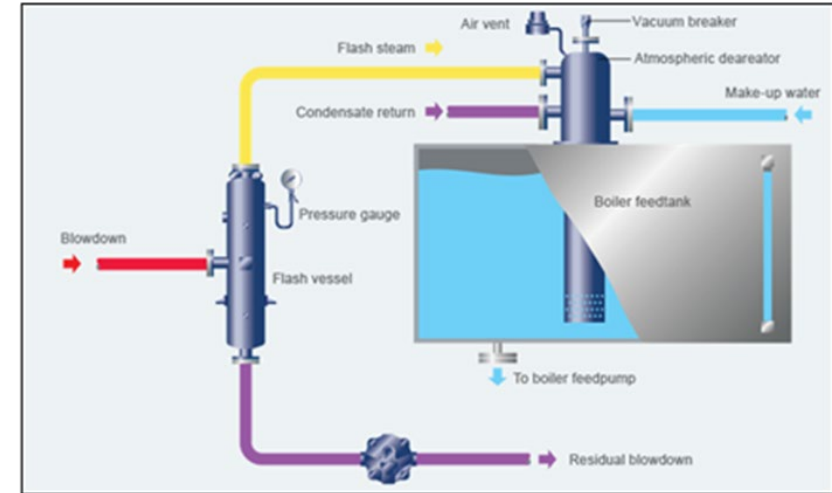


## ET04 – Manufacturer Interviews: Summary of Emerging Technologies

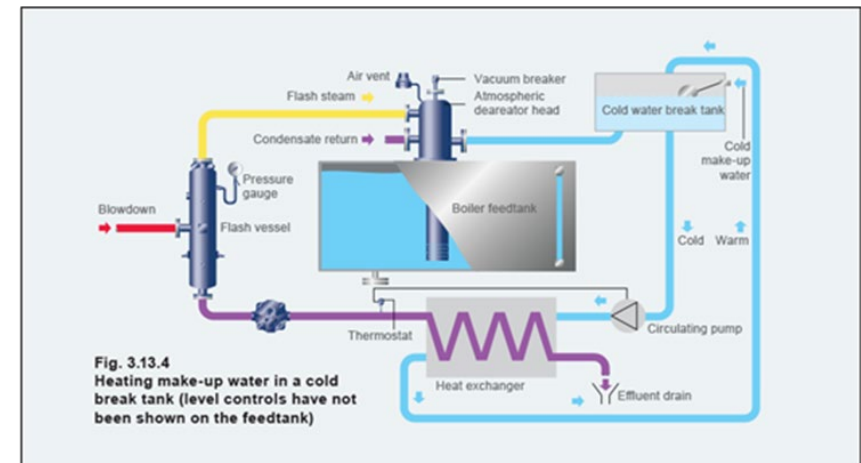
# ET04 – Manufacturer Interviews: Summary of Emerging Technologies



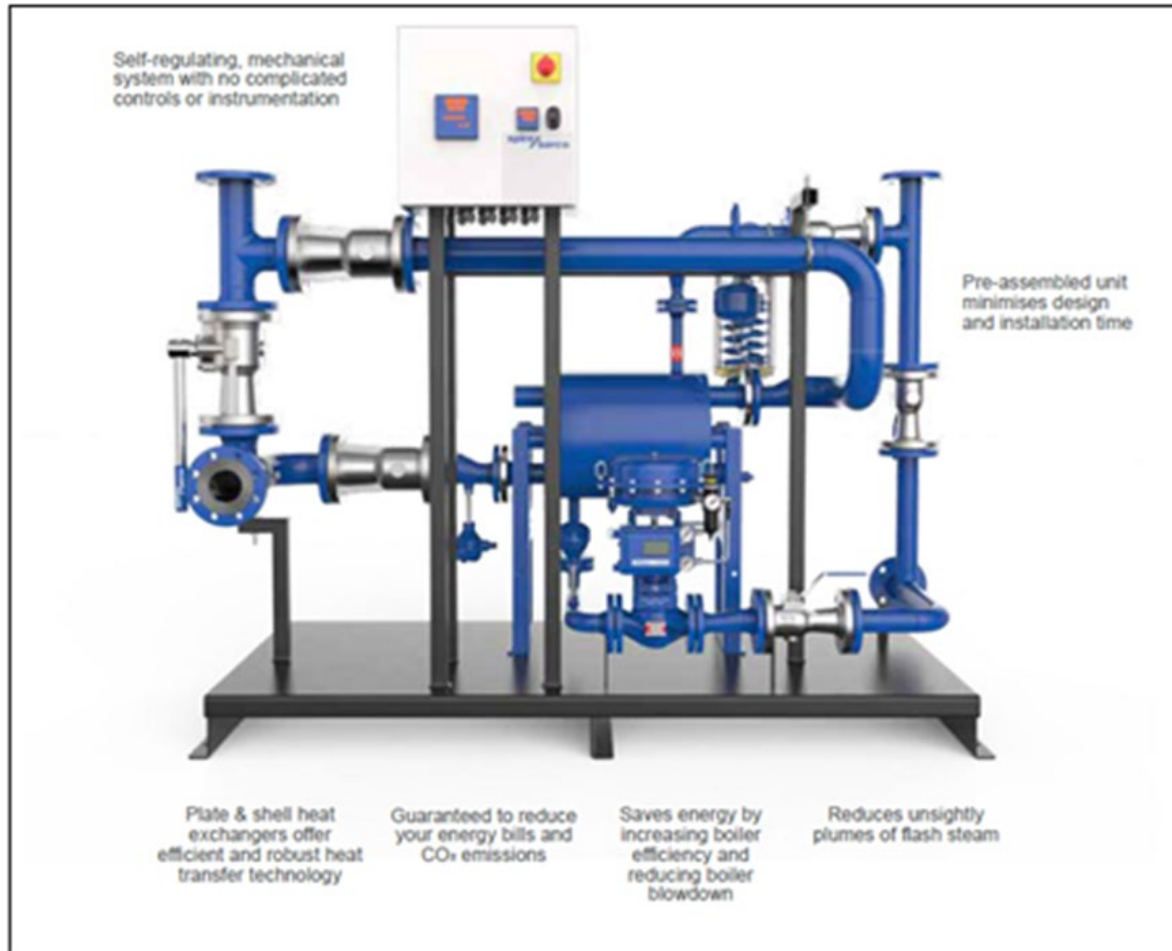
Exhaust Vent Condenser



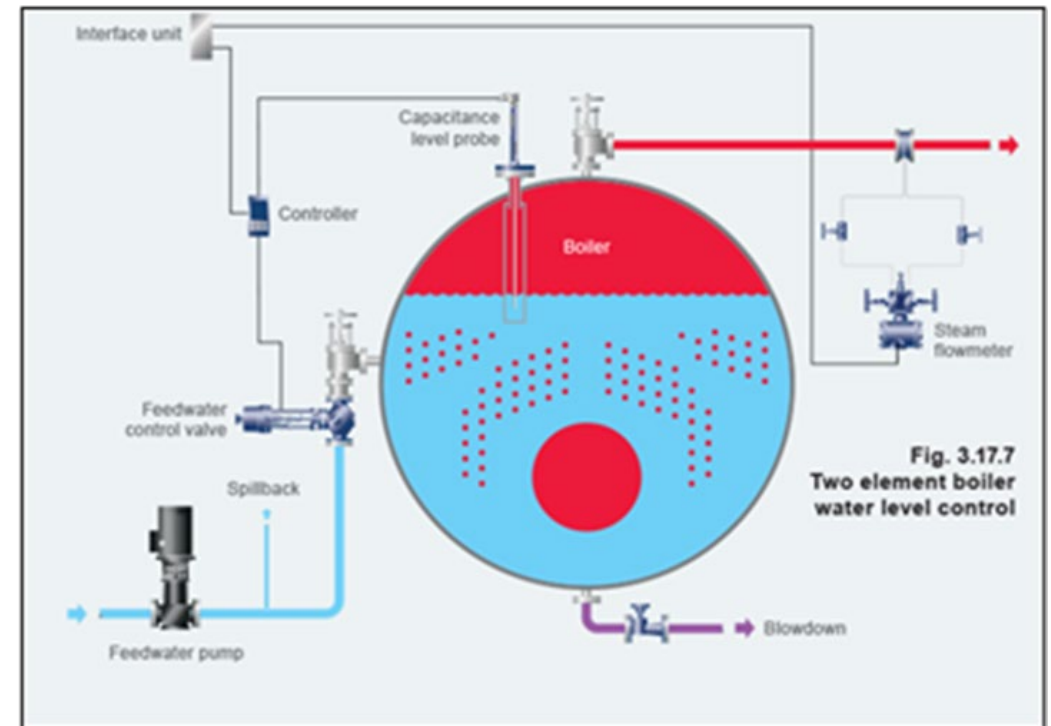
Energy recovery using a flash vessel



# ET04 – Manufacturer Interviews: Summary of Emerging Technologies



Flash Recovery Energy Management Equipment (FREME)

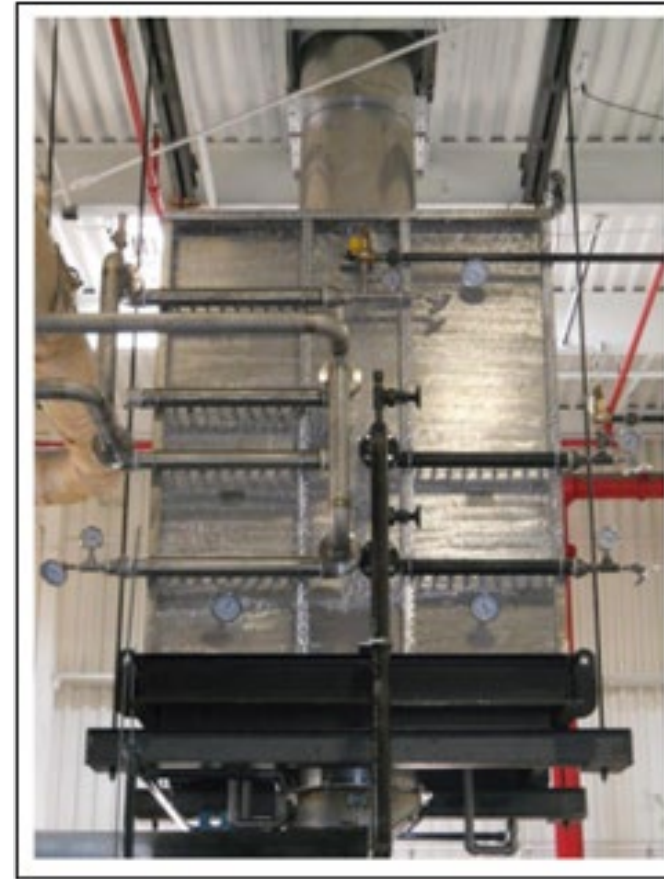


Two element water controller system

# ET04 – Manufacturer Interviews: Summary of Emerging Technologies



Economizer – Two stage stacked

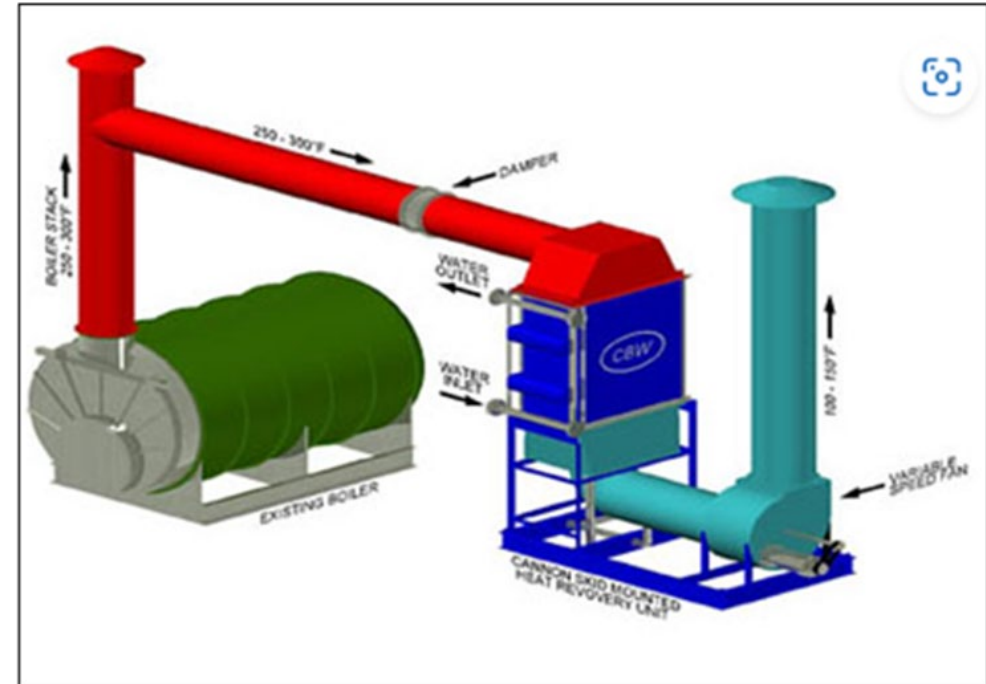


Economizer – Side by side design

# ET04 – Manufacturer Interviews: Summary of Emerging Technologies

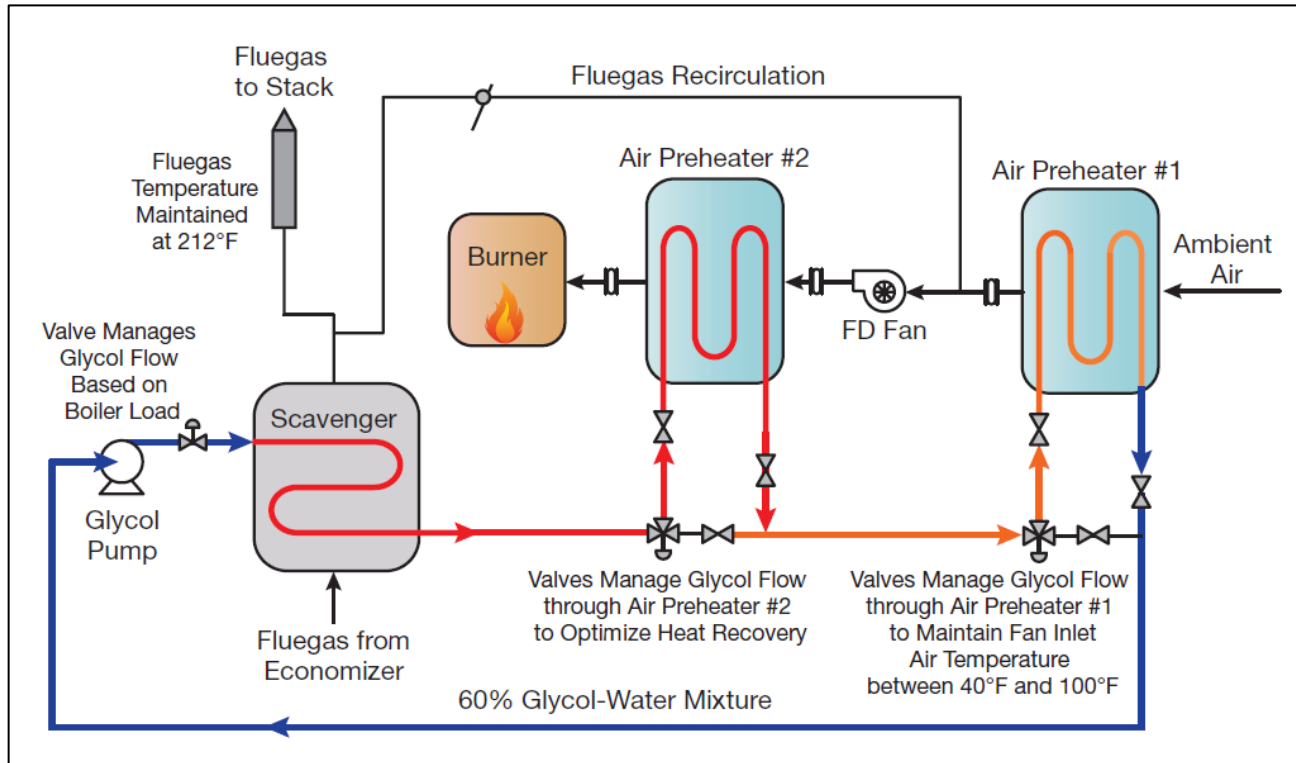


Transport Membrane Condenser Technology

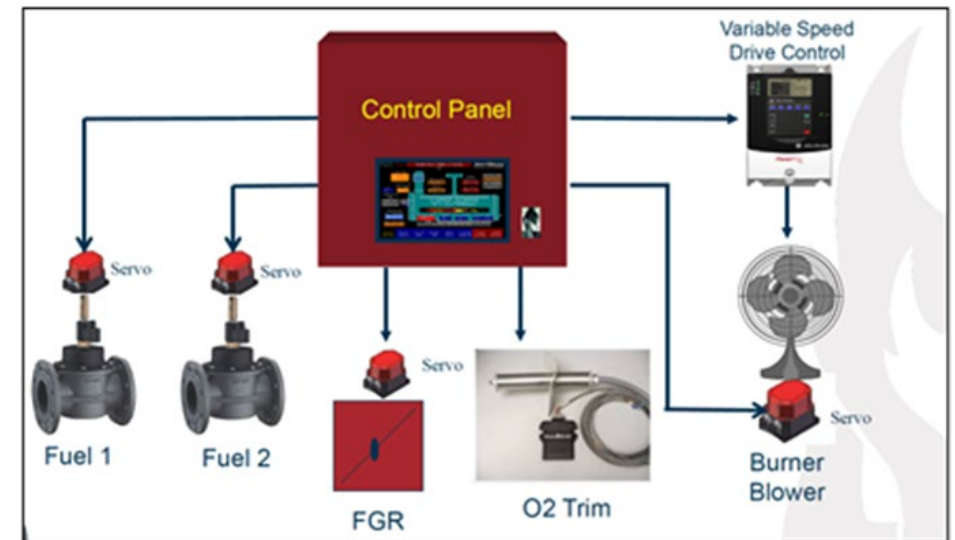


On-Demand Condensing Economizer

# ET04 – Manufacturer Interviews: Summary of Emerging Technologies

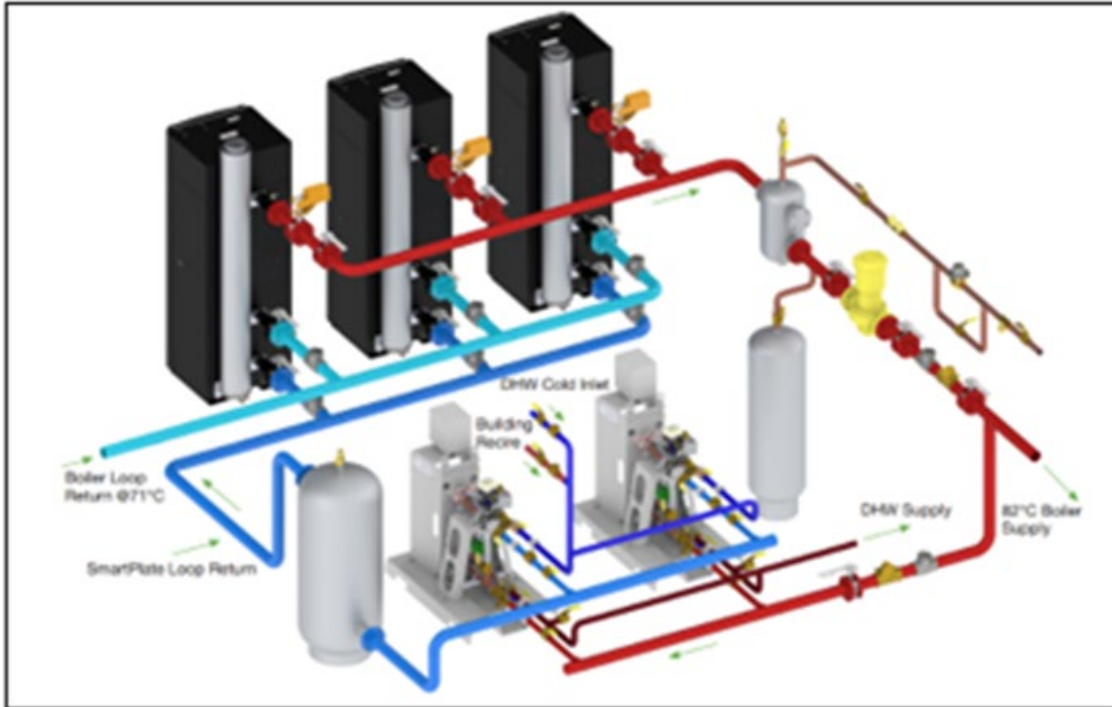


Glycol Scavenging System

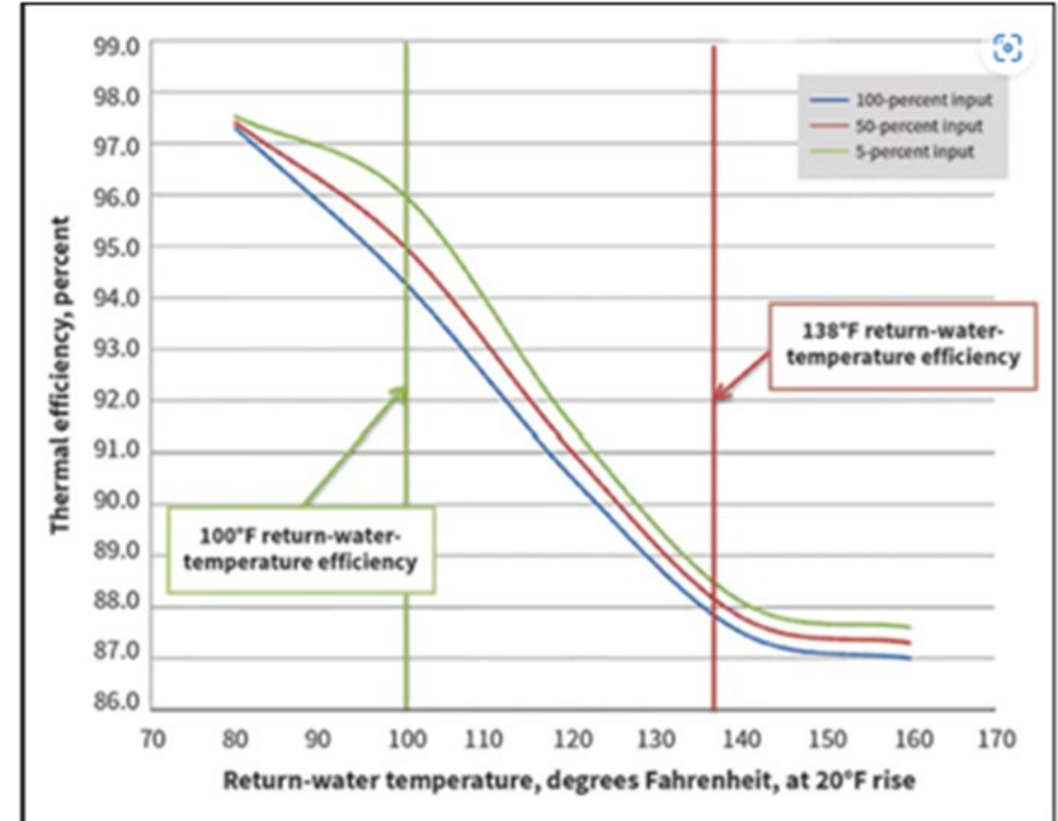


Burner related tech: Parallel Positioning

# ET04 – Manufacturer Interviews: Summary of Emerging Technologies



Combination plant with dual returns



# ET04 – Measure Table: Manufacturer Interviews

	Measure Description	Estimated Efficiency Improvement
1	On-demand economizer	May boost efficiency over 90%
2	Transport Membrane Condenser (TMC) Technology	May boost efficiency between 92-94%
3	Multi-stage economizer (for hot water boilers)	Increase in efficiency by 5-12%
4	Multi-stage economizers with side-by-side design (for hot water boilers)	-
5	Exhaust Vent Condenser	1% fuel savings
6	Energy recovery using a flash vessel	1.7% fuel savings
7	Flash Recovery Energy Management Equipment	Increase in efficiency by 5.5%
8	Installing two element water level control	Increase in efficiency by 1-2%
9	Remote boiler controller	No direct EE impact
10	Dual returns and smart plate heat exchanger	Increase in efficiency by 3-5.5%
11	Glycol Scavenging Systems	Increase in efficiency by 2-3% Negative impact on reducing NOx

*Note: The efficiencies of these measures are not additive; if there is a technology overlap*



# ET04 – Measure Table: Manufacturer Interviews

	Measure Description	Estimated Efficiency Improvement
1	Combustion air positive shutoff using automated flue damper	-
2	Combustion fan VFD	Increase in efficiency by 2-3%
3	Combustion air preheater	Increase in efficiency by 2-3% Negative impact on reducing NOx
4	Parallel positioning controls	Increase in efficiency by 2-3%
5	Dynamic staged entrainment burner technology for Commercial Boilers/Burner Retrofit	Increase in efficiency by 2%
6	O2 Trimming	Increase in efficiency by 2-3%
7	Flue Gas Recirculation (FGR)	No direct impact on EE
8	Blowdown Heat Recovery	-
9	Condensing economizer	Increase in efficiency by 7%
10	Installing turbulators in boiler tubes (for fire tube boilers)	Increase in efficiency by 2-3%



Microsoft Excel  
Worksheet

*Note: The efficiencies of these measures are not additive; if there is a technology overlap*



## Results and Reccomendations

# ETO4- Results

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- Estimated Boiler Count in California

Sector	Number of Estimated Boilers
Multifamily	22,631
Industrial	3,170
Commercial	3,483
Others	151

- Historical IOU Participation Data Analysis: **more than 90%** of the claims submitted during the years 2019–21 were for the deemed measures
- Customer survey results: **46** responses with an overall low response rate of **1%**; **5** completed site visits
- Measures such as Advanced burner technology, FGR and VFDs on combustion fans were found to be more prevalent compared to others
- Completed boiler manufacturer and distributor interviews: **25**
- Potential barriers in implementation of measures related to boiler add-ons: space constraint, variability in size of boilers, installation limitations, high upfront costs, and general adverse environment for implementing gas technologies

# ET04– Conclusions and Recommendations

**Following identified technologies are good candidates for near term hits for the deemed measure packages:**

1. Parallel positioning controls, Combustion fan VFD
2. O2 Trimming
3. Combustion air positive shutoff
4. Installing turbulators in boiler tubes (for fire tube boilers)

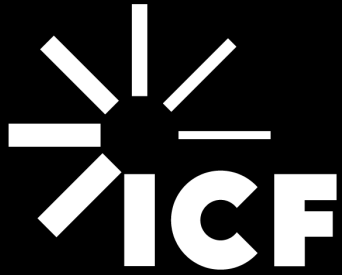
**Following measures or technologies are recommended for field or lab testing:**

1. On-demand economizer
2. Transport Membrane Condenser Technology
3. Multi-stage economizer (for hot water boilers)
4. Multi-stage economizers with side-by-side design (for hot water boilers)
5. Exhaust Vent Condenser
6. Energy recovery using a flash vessel
7. Flash Recovery Energy Management Equipment (FREME)
8. Installing two element water level control
9. Dual returns and smart plate heat exchanger

Metrics
Ease of installation
Energy saving potential
Installation limitations
Measure cost
Application, scope of process etc.

**Following measures or technologies are not viable for measure package development:**

1. Combustion Air Preheater
2. Flue Gas Recirculation (FGR)
3. Remote Boiler Controller
4. Glycol Scavenging Systems



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