Energy Research and Development Division
FINAL PROJECT REPORT

INDUSTRIAL NATURAL GAS ENERGY EFFICIENCY CALCULATOR TOOLS

Prepared for: California Energy Commission
Prepared by: Sempra Energy – Southern California Gas Company

APRIL 2013
CEC-500-2014-066

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Contract Number: 500-08-026

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ACKNOWLEDGEMENTS

The project manager Mr. Steven Ly and principal investigator Dr. Arvind Thekdi would like to thank many individuals and organizations who provided support and guidance during development and testing of the tools.

Special thanks to the following Energy Commission personnel who provided technical and administrative guidance to meet all project management requirements:

Pramod Kulkarni

Kiel Pratt

Michael Lozano

Linda Schrupp

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The authors also would like to thank the following from Sempra Energy – Southern California Gas Company:

Bryan Warren

Rebecca Martinez

Paden Cast

Chris Goff

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

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- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Industrial Natural Gas Energy Efficiency Calculator Tools is the final report for Contract Number 500-08-026, conducted by Sempra Energy. The information from this project contributes to Energy Research and Development Division's Industrial/Agricultural/Water End-Use Energy Efficiency Program.

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ABSTRACT

Software and tools for industrial system optimization can help California plant managers understand where energy is being used in its facility, identify and prioritize energy saving opportunities, and help justify energy efficiency improvement projects. This research project developed 12 web-based software and desktop tools, each with its own technical guide that explains the background of the tool and instructions for use. The software tools consisted of web-based calculators and list many natural gas energy efficiency measures with a proven track record of energy savings and cost reduction. The web-based tools enable industries to identify, natural gas energy savings opportunities in the areas of process heating and steam generation. These areas use about 85 percent of industrial natural gas and represent major opportunities to reduce natural gas use in California industries. The no-cost tools can be downloaded at:

http://www.gosolarcalifornia.ca.gov/tools/newCalcSys/CalculatorList.php

This report describes the research that was used to develop the tools and provides information about each tool.

Keywords: California Energy Commission, industrial energy savings, software tools, process heating systems, steam systems, Sempra Energy, E3M Inc.

Please use the following citation for this report:

Ly, Steven (Sempra Energy), Arvind Thekdi (E3M Inc.). 2013. ***Industrial Natural Gas Energy Efficiency Calculator Tools***. California Energy Commission. Publication Number: CEC-500-2014-066.

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Introduction

California's industrial sector is estimated to use about 23 percent of all natural gas consumed annually in the state. This sector is vital to California's economy and depends on affordable, reliable and sustainable energy supplies. They must keep operating costs low while maintaining environmentally clean and energy-efficient operations. Software tools can help industrial end users understand where energy is used and potential energy saving opportunities. These tools can help plant managers justify and prioritize energy efficiency improvements.

Project Objectives

This project developed web-based software and desktop tools that are easily downloaded by industrial end users to analyze current plant operations, identify energy-saving opportunities and reduce greenhouse gas emissions.

Description of Tools

These software tools consist of web-based calculators and include embedded computer functions that measure the total benefits of energy efficiency projects. The energy efficiency improvement measures or projects are those with a proven history of energy savings and cost reduction, and address process heating and steam systems. Combined, these two areas account for about 85 percent of industrial natural gas use and offer major opportunities for energy savings in California industries. The no-cost tools can be downloaded to personal computers by California industries.

Developed in a Microsoft Excel® spreadsheet format, the tools include 12 calculators designed to estimate energy savings for the most common efficiency measures for furnaces, ovens, dryers, and boilers including steam systems:

1. Available heat for gaseous fuels (natural gas)
2. Electric power generation using waste heat
3. Reducing excess air or oxygen in flue (exhaust) gases
4. Reducing wall losses
5. Using preheated combustion air
6. Eliminating or reducing opening heat loss
7. Load preheating
8. Lower explosion limit or lower flammability limit control for ovens
9. Humidity control for dryers
10. Reducing boiler blowdown water
11. Boiler blowdown water heat recovery

12. Using noncondensing economizer on a boiler

The 12 free tools and the technical guides can be downloaded at: http://www.gosolarcalifornia.ca.gov/tools/newCalcSys/CalculatorList.php

Each technical guide includes the following topics:

1. Executive Summary
2. Notes to Calculator Tool Users
3. Description of the Subject Area
4. Technical Approach and Calculations
5. The Effect of Different Parameters
6. Instructions on Calculator Use
7. References and Resources

Project Tasks and Work Performed

The specific tasks associated with this contract include:

1.1. Selection of technical back up and resources estimating energy savings and carbon dioxide emission reduction

1.2. Preparing individual Excel-based tools spreadsheets for each of the selected tools

1.3. Verifying results using alternate methods and check on accuracy and documentation in the form of work papers for each tool

1.4. Compiling tools into one "Tool Suite"

1.5. Converting the Tools Suite to Web-based Excel format with appropriate recordkeeping for usage

1.6. Preparing training material in the form of presentations with specific examples or cases for California industries

These tasks were completed successfully. Details of the tool development, description of the tools, and associated technical guide for each tool are included in this report.

Training and Tracking

More than 30 Account Executives from Southern California Gas Company attended a training session and provided feedback on the tools. User-friendly training materials were developed and a second training session for potential industrial users was held December 2012. A registration feedback system was implemented to track download activity. The calculators have been offered to engineers and account executives of Southern California Gas Company who plan to use the tool for evaluating energy efficiency and demonstrate these tools to their customers for future energy-saving activities. As of November 2012, there have been more than 50 tool downloads.

Benefits to California

The tool developed under this contract will help California's industrial facilities better understand how energy is used in their facilities and analyze energy savings opportunities from the convenience of a desktop computer. Using these tools will allow the engineers and operating plant personnel to provide economic and technical justificiation for implementing energy saving measures to their management.

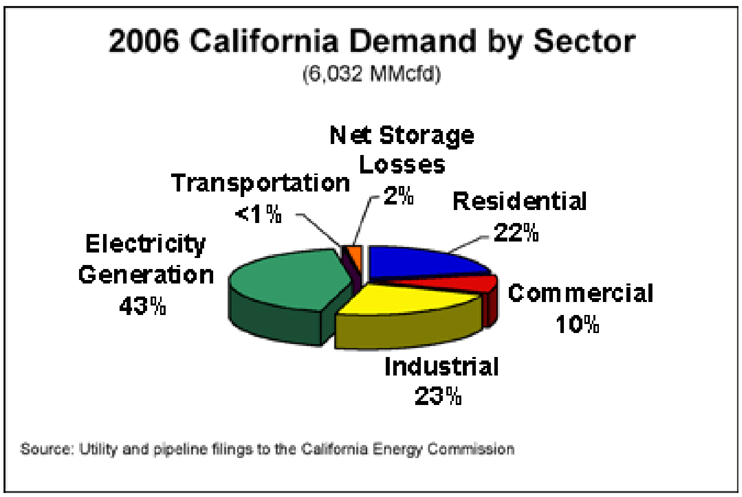
CHAPTER 1: Work Performed

1.1 Energy Use in California Industries

California industries consume 23 percent of the total natural gas used in the state (Figure 1). This is almost the amount of energy used in the residential sector (22 percent) and higher than energy consumed in the commercial sector (10 percent). The industrial sector uses almost 1,400 million cubic feet each day or 5,011 million therms annually.[1]

Figure 1: California Natural Gas Demand

California Natural Gas Demand By Sector 2006



	Million cubic feet per day
Residential	1,300 Mmcfd
Commercial	573
Industial	1,392
Electric Gen	2,613
Transportation	25
Net Storage/Loss	129
Total	**6,032**

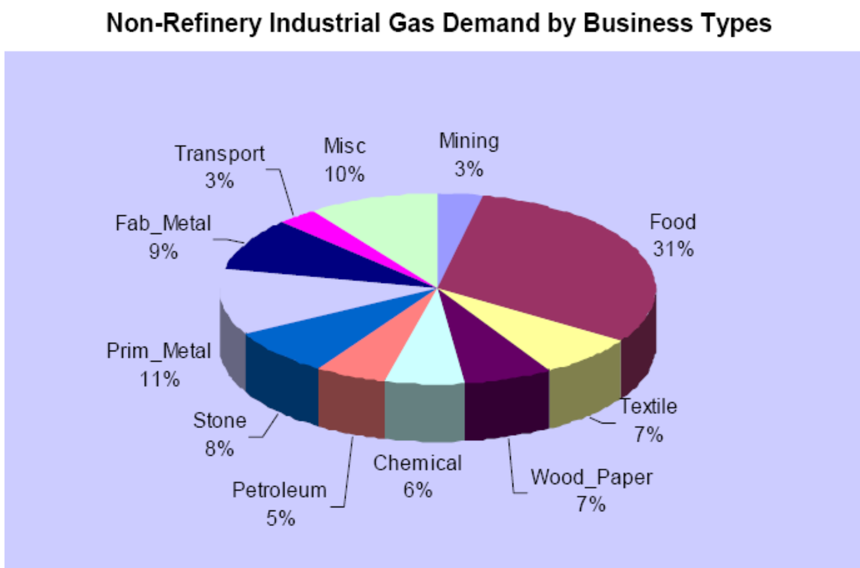
Source: California Energy Commission, Electricity and Natural Gas Office, from utility and pipeline f

[1] 1 therm of natural gas is equivalent to 100,000 British thermal units (Btu) and 1 cubic foot (cf) of natural gas typically contains 1,000 Btu. There are 1,000,000 Btu in one million cubic feet (MMcf) of gas or 10 therms.

In Southern California Gas Company's service area, the largest natural gas user excluding refineries is the food industry which accounts for 31 percent of consumption, mainly for steam generation (Figure 2). Primary metal using 11 percent is the second largest, mostly from process heating. Nearly all of the energy efficiency projects that save natural gas can be achieved in these two customer segments and include reducing excess air, steam system optimization and minimizing heat loss. This information was used to identify the industry needs and to develop a list of tools for this project.

Figure 2: Nonrefinery Industrial Gas Demand by Business Type

in Southern California Gas Service Area2



Source: 2008 California Gas Report – Prepared by the California Gas and Electric Utilities

[2] http://www.socalgas.com/regulatory/documents/cgr/2008_CGR.pdf, page 67

1.2 Selecting the Tools

The calculator tools (defined as a calculator in this study) were chosen to meet the industry needs and based on an Excel spreadsheet that accepts input data (measured, assumed, calculated, etc). The spreadsheet also provides results for a given energy savings measure for a defined boundary condition. For example, a tool that calculates savings from reducing excess air will identify possible energy savings for a given operating condition defined by the user. Other calculators are used to estimate potential savings under similar or different operating conditions.

Based on the background and other work performed for organizations such as the U.S. Department of Energy (DOE), the project team prepared a matrix (Figure 3). This matrix identifies large natural gas using industries and possible tools representing several energy saving measures for a plant's process heating and steam systems.

The matrix lists ten large energy using industries and seven major tool categories for various industrial processes:

1. Combustion system
2. Heat containment
3. Flue gas heat recovery
4. Control tool for specially designed ovens and dryers
5. Steam system tool for boiler operation
6. Heat to power conversion tool
7. Heat calculator

Blue represents primary application and orange represents secondary or low priority application. The selected tool can serve multiple industries with many serving all industries. These tools can be useful to all major industrial sectors in California.

The specific calculator tools developed for each of the seven categories are:

1. Available heat for gaseous fuels (natural gas)
2. Electric power generation using waste heat
3. Reducting excess air or oxygen (O_2) in flue (exhaust) gases
4. Reducting wall losses
5. Using preheated combustion air
6. Eliminating or reducing opening heat loss
7. Load preheating
8. Lower Explosion Limit (LEL) or Lower Flammability Limit (LFL) control for ovens

9. Humidity control for dryers
10. Reducting boiler blowdown water
11. Boiler blowdown water heat recovery
12. Using noncondensing economizer in a boiler

Figure 3: Matrix Showing Applicability of Tools to California Industries

Overview of Tools and Their Applications in Major California Industries

No.	Name of the Tools and Application Areas	Food	Primary metal	Fab metal	Stone/glass/ cement	Textile	Wood/ paper	Chemical	Mining	Transport	Petroleum	Misc
1	Combustion system tool - Fuel saving for:											
	Air/Fuel Ratio control	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary
	Preheat combustion air	Secondary	Primary	Secondary	Primary	Primary	Primary	Primary	Secondary	Secondary	Primary	Secondary
2	Heat Containment tool – Fuel saving for:											
	Minimize surface losses	Secondary	Primary	Primary	Primary	Secondary	Primary	Primary	Primary	Primary	Primary	Primary
	Eliminate opening losses	Secondary	Primary	Primary	Primary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary	Secondary
3	Flue Gas Heat Recovery tool - Fuel savings for:											
	Economize (gas-to-gas; gas-to-water)	Primary	Primary	Primary	Secondary	Primary	Primary	Primary	Secondary	Secondary	Primary	Primary
	Material preheat	Secondary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Secondary
4	Control tool - Fuel saving for:											
	Low explosion limit (LEL)	Primary	Primary	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Primary	Secondary
	Humidity control	Primary	Primary	Secondary	Primary	Primary	Primary	Primary	Primary	Primary	Secondary	Secondary
5	Available heat calculator for gaseous fuels	Secondary	Primary	Primary	Primary	Primary	Primary	Primary	Secondary	Secondary	Primary	Secondary
6	Steam system tool - Calculate fuel savings for:											
	Blowdown heat recovery	Primary	Primary	Secondary	Secondary	Primary	Primary	Primary	Secondary	Secondary	Primary	Primary
	Reduce blow down	Primary	Primary	Secondary	Secondary	Primary	Primary	Primary	Secondary	Secondary	Primary	Primary
7	Heat-to-power conversion tool											
	High temp. FG heat recovery - power generation*	Secondary	Primary	Secondary	Primary	Secondary	Secondary	Primary	Secondary	Secondary	Secondary	Secondary
	Rankin and similar cycles	Secondary	Primary	Secondary	Primary	Secondary	Primary	Primary	Secondary	Secondary	Primary	Secondary
	NH3 based cycle	Secondary	Primary	Secondary	Primary	Secondary	Primary	Primary	Secondary	Secondary	Primary	Secondary
	Kalina cycle	Secondary	Primary	Secondary	Primary	Secondary	Primary	Primary	Secondary	Secondary	Primary	Secondary
	* Includes a water heat recovery boiler and steam turbine											

Legend:
- Primary applications (blue)
- Secondary or low priority applications (orange)

Note: The secondary or low priority could be due to lack of the system use or small size that can make the application uneconomical

1.3 Selecting Technical Back-Up and Resources to Estimate Energy and CO_2 Savings

The tools use various resources to identify critical input and output parameters, and calculation methods that represent energy savings and carbon dioxide (CO_2) emission reduction for a given energy saving measure.

The equations and approach used to develop the Excel spreadsheets are discussed in detail in Technical Guides for each tool.

The following technical resources were used to prepare the matrix and technical background for the calculators.

- Reed, Richard. 1986. *North American Combustion Handbook,*" Vol. I and II, North American Mfg. Co., Cleveland, OH 44105, USA.
- Baukal, Charles Jr. 2001. *The John Zink Combustion Handbook*, CRC Press, New York, NY, USA.
- Industrial Heating Equipment Association, 1994. *Combustion Technology Manual*, Industrial Heating Equipment Association, Cincinnati, OH, USA.
- W. Trinks, M.H. Mawhinney, R.A. Shannon, R.J. Reed and J.R. Garvey, 2004. *Industrial Furnaces*, John Wiley & Sons, Inc., Hoboken, NJ, USA.
- The U.S. Department of Energy, 2005. *Improving Process Heating System Performance*, The U.S. Department of Energy, Washington D.C. USA.
- The U.S Department – Tip sheets publications
- *Steam: Its Generation and Use*, Babcock and Wilcox, Barberton, OH
- *Energy Efficiency Handbook*, Council for Industrial Boiler Operators (CIBO), Burke, VA
- *Steam Efficiency Improvement*, Boiler Efficiency Institute, Auburn, AL
- *Marks' Standard Handbook for Mechanical Engineers*, Mc Graw-Hill, NY
- *Steam Utilization − Design of Fluid System*, Spirax Sarco Application Engineering
- *ANSI/MSE 2000:2008, A Management System for Energy*, Georgia Institute of Technology, 2008

1.4 General Tool Descriptions

The tools are intended to help California industries with natural gas fired heating systems and developed in MicroSoft Excel format.

The user can select one calculator or can down load all calculators at the same time. The user must complete a registration form to provide minimum information to track use of the tool (Figure 4) such as:

- Customer first and last name

- Organization name
- Phone number
- E-mail

The registration form also includes the following disclaimer:

Disclaimer
Important: Information you provide will be used internally by the Southern California Gas Company and the California Energy Commission to evaluate user response and the success of this online calculator tools project. You may be contacted by Southern California Gas Company or California Energy Commission evaluators to provide feedback and comments on the calculators you downloaded. All personal information will be kept confidential and WILL NOT be distributed to any other government agency or any outside party. We hope that you will find these calculators useful and they help you to initiate energy efficiency projects within your organization. Thank you for your cooperation.

After completing the registration, the user can down load one or all calculators without any further interaction with the website.

Figure 4: Registration Form for Downloading of the Tools

Each tool includes a section where the user is required to provide information about the company, industry, application, contact information and other necessary details for reporting purposes (Figure 5). This information can be used as part of the report that the user can distribute or share with others in its organization. For privacy reasons, this information will NOT be available to staff of the Energy Commission or Sempra Energy (Southern California Gas Company.

Figure 5: User or Customer Information Screen

Calculator for Reduction in Wall Losses through Proper Insulation				
1	Company name	ABC Corporation		
2	Plant name or designation	LA Plant		
3	Plant address	12345 Main Street, Gabriel, CA 90878		
4	Contact name	Bob Smith		
5	Contact address	54321 First Street, North Warren, CA 90878		
6	Contact phone number and e-mail	Phone:	E-mail:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010		
Heating equipment description (where the energy saving measure is applied)				
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Oven		
9	Equipment use (e.g., textile drying, aluminum melting)	Metal coating		
10	Other comments if any	The oven is designed to run continuously		

Every tool includes several input and output cells, however, since there are 12 different calculators, each with its own input-output cells, one tool is used as an example to illustrate and explain various features of the other tools.

Calculator number 3 “Control Air-Fuel Ratio or Reduction of Excess Air (or Oxygen) in Flue Gases,” is used as an example (Figure 6). The technical guide for this calculator provides detailed information and is discussed later to assist the user.

The user is required to enable macros or proper settings to enable macros before using each calculator.

The calculator uses white colored cells for data input and yellow colored cells for calculator outputs or results. The yellow cells, title of the tool and description of the cell items are protected and cannot be changed.

The tool has two columns. The “current” and “new” columns are used to provide data and get results for current operating conditions. The data in white are collected and entered by the user. The second “New” or in some cases “Modified” column, is used to enter data that represents conditions selected, expected or desired after the energy saving measure is implemented.

The calculator then provides energy savings and CO_2 reductions resulting from the selected energy saving measures and parameters.

Figure 6: Example of a Calculator (#3)

Control Air-Fuel Ratio or Reduction of Excess Air (or Oxygen) in Flue Gases			
		Current	**New**
11	Furnace flue gas temperature (°F.)	1,200	1,200
12	Percent O2 (dry) in flue gases	8.00	3.00
13	% Excess air	55.08	14.92
14	Combustion air temperature (°F.)	70	70
15	Fuel consumption (MM Btu/hr) - Avg. current	20.00	17.32
16	Available Heat (%)	53.8%	62.2%
17	Fuel savings (%)	Base	13.39%
18	No. of operating hours (hours/year)	8000	8000
19	Heat energy used per year (MM Btu/year)	160,000	138,579
20	**Heat energy saved (MM Btu/year)**	**Base**	**21,421**
21	Cost of fuel ($/Million Btu)	$ 10.00	$ 10.00
22	**Annual savings ($/year)**	**Base**	**$ 214,210**
23	**CO2 savings (Tons/year)**	**Base**	**1,253**

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For example, the user provides data (measured, estimated or derived from other sources) on the following parameters:

a. Furnace flue gas temperature (degrees Fahrenheit [°F])

b. Percent O_2) (dry) in flue gases

c. Combustion air temperature (°F.)

d. Fuel consumption in millions of British thermal units per hour (MMBtu/hr) - Avg. current

e. Number of annual operating hours (hours/year)

f. Cost of fuel ($/Million Btu)

The following results are calculated for the modified conditions.

g. % Excess air

h. Available Heat (%)

i. Heat energy used per year (MM Btu/year)

After this is completed, the user moves to the "New" column and enters data that reflects the new operating conditions. For example, in Figure 6, the user has changed only one parameter, "Percent O_2 (dry) in flue gases" while all other parameters (a and c to f) remain unchanged. The calculator calculates corresponding results (g to i) for the "New" condition.

The results are used to calculate the following savings:

j. Fuel savings (%)

k. Heat energy saved (MMBtu/year)

l. Annual savings ($/year)

m. CO_2 savings (Tons/year)

Similar calculation methods are used for all calculators. The user will be required to save the calculator file as a separate file for future use.

1.5 General Description of Technical Guides

Technical guides were developed to provide detailed information for each of the 12 tools. The guides are included on the website for each calculator and can be downloaded as a portable document file (PDF) document. Chapter 3 describes the technical guides in more complete detail.

CHAPTER 2: Description of Calculators

This section provides descriptions of the twelve calculators developed under this project.

2.1 Available Heat for Gaseous Fuels (Natural Gas) – Tool #1

This calculator tool was developed to calculate available heat for gaseous fuels used in industrial heating processes. The term “available heat,” is used for the amount of heat that remains in the furnace and is usually expressed as a percentage of the total heat input for heating equipment as defined in the following equation whereas heat input and heat in flue gases can be represented in Btu/hr:

$$\text{Percent Available Heat} = \frac{(\text{Furnace Heat Input} - \text{Heat in flue gases})}{\text{Furnace Heat Input}}$$

The value of available heat depends on several factors such as composition of the fuel, amount of combustion air used, combustion air temperature, fuel temperature and flue gas temperature for the heating equipment. For heating systems, available heat is also affected by the amount of air leaks as represented by O_2 content of flue gases, addition of water vapor and other gases discharged from the material being processed or charged. In some cases, available heat can be called “combustion efficiency”.

The Available Heat Calculator Tool is shown in Figure 7. The data required to be input by the user includes the following items:

- Composition (by volume percentage) of the fuel
- Combustion air temperature
- Percentage oxygen (dry basis) in flue or exhaust gases. The calculator estimates approximate amount of excess air to get the calculations started
- Flue gas temperature measured at the exhaust of the heating system

A typical gas composition for natural gas used by California industries is included as an example. The user has the option of inputting other values for the natural gas or any other type of fuel gas.

If the sum of all fuel gas components is not equal to 100%, then the calculator makes adjustments to bring the total to 100%, and the adjusted fuel composition is used for further calculations.

The results of the calculator outputs are given in the form of a table as shown in Figure 7 and include the following parameters:

- Flue gas analysis by weight percentage – wet and dry basis
- Flue gas analysis by volume percentage – wet and dry basis

- Available heat as percentage of the total heat input
- Stoichiometric combustion air required for the fuel

This information is needed for most thermal balance calculations or heat savings estimate when an energy saving measure is used to calculate total energy savings.

Figure 7: Available Heat Calculator Tool Data Input Required

Calculate Available Heat

1	Company name	ABC Corporation			
2	Plant name or designation	LA Plant			
3	Plant address	12345 Main Street, Gabriel, CA 90878			
4	Contact name	Bob Smith			
5	Contact address	54321 First Street, North Warren, CA 90878			
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010			

Heating equipment description (where the energy saving measure is applied)

8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Furnace
9	Equipment use (e.g., textile drying, aluminum melting)	Metal heating
10	Other comments if any	The furnace was rebuilt recently.

Fuel Gas Analysis (See note below)

	Gas composition	By volume	Adjusted by volume	Comment
11	CH_4	96.36%	96.485%	
12	C_2H_6	1.44%	1.442%	
13	N_2 and other inert	0.32%	0.320%	
14	H_2	0.00%	0.000%	
15	C_3H_8	0.31%	0.310%	
16	$C_4H_{10} + C_nH_{2n}$	0.06%	0.060%	
17	H_2O	0.00%	0.000%	
18	CO	0.00%	0.000%	
19	CO_2	1.38%	1.382%	
20	SO_2	0.00%	0.000%	
21	O_2	0.00%	0.000%	
22	**Total of fuel components**	**99.87%**	**100.000%**	
23	**Difference**	0.13%	0.00%	

Note: The fuel gas composition is in volume %. The higher hydrocarbons in fuel are treated as same as C_4H_{10} and all other inert gases are treated as N_2.

24	Combustion air temperature (°F)	600
25	% Oxygen (O_2) in COMBUSTION AIR	20.9
26	% Oxygen (O_2) in flue gases	3.8
27	Calculated percentage excess air used	19.8
29	Exhaust (flue) gas temperature (°F)	1450
30	**Available Heat: (% of higher heating value of fuel)**	**64.38%**

Click here for detailed Results

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The results shown in Figure 8 give the higher heating value (HHV) of the fuel in Btu per standard cubic feet (Btu/scf) of fuel, stoichiometric air required for the fuel, value of available heat in percentages, and flue gas composition in terms of dry and wet values. This calculator can be used to evaluate relative combustion efficiency of different fuels and their use under different operating conditions of a heating system

Figure 8: Available Heat Calculator Tool Results or Output

Calculator for Available Heat and Flue Gas Analysis						
1	Company name	ABC Corporation				
2	Plant name or designation	LA Plant				
3	Plant address	12345 Main Street, Gabriel, CA 90878				
4	Contact name	Bob Smith				
5	Contact address	54321 First Street, North Warren, CA 90878				
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com	
7	Date (format mm/date/year)	May 12, 2010				
Heating equipment description (where the energy saving measure is applied)						
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Furnace				
9	Equipment use (e.g., textile drying, aluminum melting)	Metal heating				
10	Other comments if any					
11	Stoichiometric (theoretical) combustion air required	9.57	Std. cu. ft. of air per std. cu. ft. of fuel			
	Flue Gas Analysis By Weight					
	Flue gas composition - content →	CO2	H2O	O2	N2	Total
12	% By weight - wet analysis	12.9%	10.3%	3.6%	73.3%	100.0%
13	% By weight - dry analysis	14.3%	0.0%	4.0%	81.6%	100.0%
14	Heating value (Btu/std. Cu. ft.) of fuel					1,011.80
15	**Available Heat: (% of higher heating value of fuel)**	**64.38%**	As % of higher heating value of fuel			
	Flue Gas Analysis By Volume					
	Flue gas composition - content →	CO2	H2O	O2	N2	Total
16	Total volume of gases - Ft^3./cu.ft of fuel	1.01922	1.98838	0.39539	9.06426	12.47
17	% By volume - wet analysis	8.2%	15.9%	3.2%	72.7%	100.0%
18	% By volume - dry analysis	9.7%	0.0%	3.8%	86.5%	100.0%

Back to Data Input

2.2 Electrical Power Generation Using Waste Heat (Tool #2)

This calculator tool estimates annual energy savings, associated cost savings and reduction in CO_2 emissions through recovery of heat from flue gases or other type of waste heat streams in the form of liquid or gases to generate electric power. At this time, there are two basic types of systems used by the industry: (1) for high temperature waste heat streams, specifically high temperature (> approximately 800° F.) exhaust gases from high temperature heating processes; and (2) for low to medium temperature fluid streams (gases or liquids) in the temperature range of 300° F. to 800° F. from boilers, ovens, dryers, heat recovery systems etc. Schematics of these systems are shown in Figure 9 and Figure 10.

For high temperature flue gases it is common to use a steam boiler, commonly known as heat recovery steam generator (HRSG), to produce high pressure (usually >50 pounds per square inch gauge psig) steam and use this steam in a turbo generator to produce electrical power. In this case, the working fluid is steam. Figure 9 shows schematic of a typical steam based power generation system.

Figure 9: Power Generation System Using High Temperature (>~800 deg. F.) Exhaust Gases

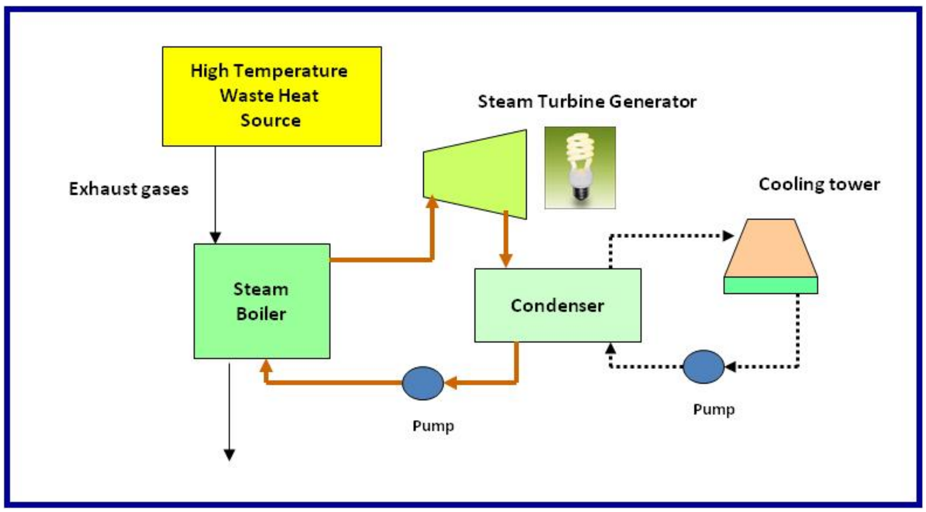
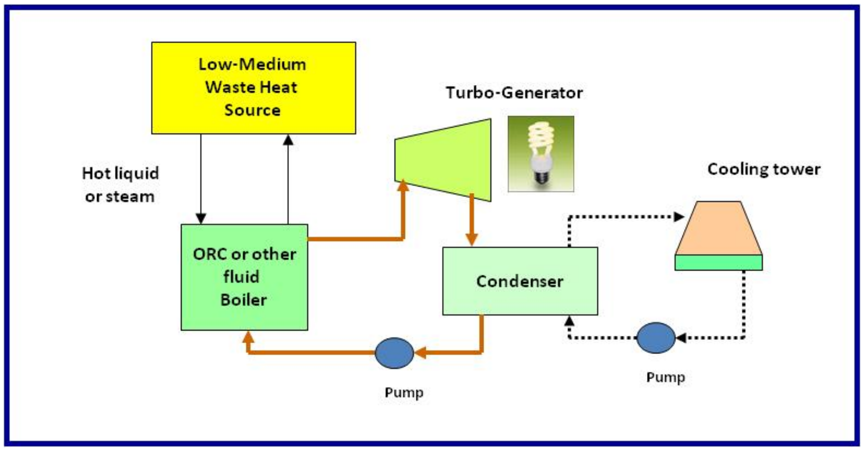


Figure 10 shows an organic Rankine cycle system that is used for electrical power production using heat from lower (300^0 F to 800^0 F) temperature flue gases. In this case, organic liquids or other types of fluids are used as working fluids. The high pressure liquid is heated and vaporized in a fluid boiler and the vapors are passed though a turbo generator to produce electrical power. The lower pressure vapors are condensed in a condenser using cooling water (or air in some cases) to condense the vapors into liquid. The liquid is pumped to a higher pressure before going to the boiler.

Figure 10: Power Generation System for Lower Temperature (>~300^0 F to 800^0 F) Exhaust Gases



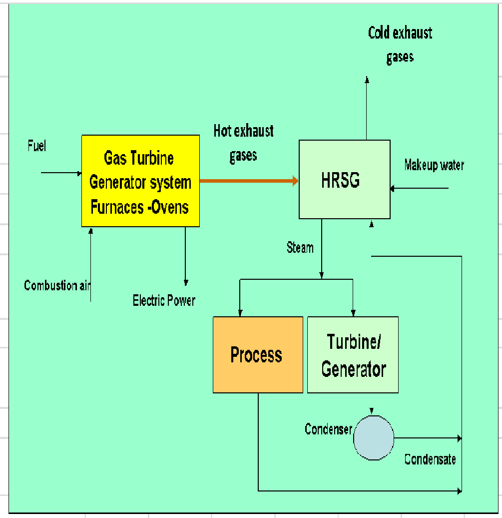
The calculator screens are shown in Figures 11 and 12. Figure 11 provides user information and Figure 12 represents the actual calculator.

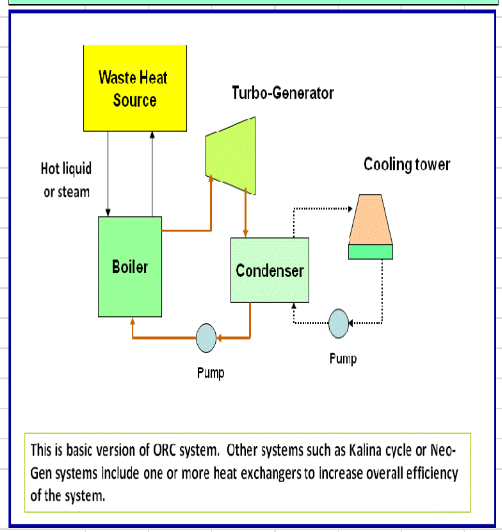
Figure 11: User Data for the Power Generation Tool

Generate Electrical Power Using Waste Heat						
1	Company name	ABC Corporation				
2	Plant name or designation	LA Plant				
3	Plant address	12345 Main Street, Gabriel, CA 90878				
4	Contact name	Bob Smith				
5	Contact address	54321 First Street, North Warren, CA 90878				
6	Contact phone number and e-mail	Phone:	916-756-9923		E-mail:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010				
Heating equipment description (where the energy saving measure is applied)						
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)		A furnace using a recuperator			
9	Equipment use (e.g., textile drying, aluminum melting)		Gas fired furnace used continuously			
10	Other comments if any	This is a preliminary evaluation for possible heat recovery and power generation using heat of exhaust gases.				

Figure 12: Calculator for Power Generation System Using Exhaust Gas Heat

	Electric Power Generation Using Waste Heat in Exhaust Gas			
11	Firing rate for the process generating waste heat (MM Btu/hr)	100		
12	Exhaust (flue) gas temperature (°F)	550		
13	O2 (dry) content in exhaust gases (%)	12		
14	Combustion air temperature (°F)	90		
15	Available heat (NG as fuel) (%)	69.2%		
16	Heat in exhaust gases - estimated based on natural gas as fuel (MM Btu/hr)	30.82		
	Typical power generation systems	**Steam turbine - generator**	**ORC based**	**Other system***
	Application feasibility	**Poor**	**Good**	**Good**
17	Heat in exhaust gases (MM Btu/hr) *(User Defined if necessary)*	30.82	30.82	30.82
18	Conversion efficiency **	27.5%	12.0%	18.0%
19	Heat - power equivalent (MM Btu/hr)	8.48	3.70	5.55
20	Equivalent power generation (kW)	2,484.05	1,083.95	1,625.92
21	Demand (peak) charge reduction credit if any ($/kW)	$ 10.00	$ 10.00	$ 10.00
22	Electricity cost savings ($/kWh)	$ 0.06	$ 0.06	$ 0.06
23	Annual operating hours (per year)	8,000	8,000	8,000
24	Electricity cost savings ($/year)	$ 1,217,184	$ 531,135	$ 796,702
25	Additional credits ($/year)	$ -	$ -	$ -
26	Other expenses - power generation ($/kWh)	$ 0.010	$ 0.010	$ 0.010
27	Other expenses - power generation ($/year)	$ 198,724	$ 86,716	$ 130,074
28	**Net energy savings ($/year)**	**$ 1,018,460**	**$ 444,419**	**$ 666,629**
29	Savings ($/kW)	$ 410.00	$ 410.00	$ 410.00
30	Expected cost for the package ($/kW)	$ 2,500	$ 3,500	$ 2,500
31	**CO2 savings for equivalent electricity (Tons/year)**	**13,315**	**5,810**	**8,715**
32	**Simple payback period (years)**	**6.10**	**8.54**	**6.10**
33	Lower temperature limit for the exhaust gas temperature (°F) specified by the supplier *	300.0		





* Define the lower temperature practical limit for the system applicability
** The conversion efficiency value must be obtained from the system supplier. This value depends on the system design and operating conditions such as the heat exchanger efficiency, cooling water (or air) temperature for the condenser, ambient conditions etc.

The calculator can be used to estimate power generated using a system that matches the temperature range for the waste heat stream. The user is required to give information such as temperature, mass flow rate etc. for the available heat sources. It is also necessary to provide the value of the power generation efficiency available from the systems supplier. The calculator includes a range of power generation efficiency values for various systems as they are reported by suppliers of currently available systems. The user is encouraged to check with the system supplier to get the most current values for the system under consideration. The calculator can be used to estimate power generated in terms of kilowatts (kW) or megawatts (MW) for the given source of heat.

Additional details are given in Technical Guide for the calculator.

2.3 Reduction of Excess Air or Oxygen (O_2) in Flue (Exhaust) Gases (Tool #3)

The primary objective of this calculator is to promote energy savings in industrial heating operations and to allow users to calculate potential savings. This calculator tool can be used to estimate annual energy savings, associated cost savings, and reductions in CO_2 emissions through control of air-fuel ratio for the combustion system. This includes burners used to supply heat to a furnace, boiler, oven or any other type of heating equipment used by the industrial plants. This calculator also determines savings (energy, cost and CO_2) for a case where O_2 in flue gases is reduced.

The user is required to give data for several operating parameters that can be measured or estimated during normal operating conditions, or from available records. Measurements should be performed during typical or average operating conditions.

Figure 13 shows an image of the air-fuel ratio control calculator.

Figure 13: Calculator for Savings by Adjusting Air-Fuel Ratio in a Combustion System

Control Air-Fuel Ratio (Reduction of Excess Air [or Oxygen] in Flue Gases)						
1	Company name	ABC Corporation				
2	Plant name or designation	LA Plant				
3	Plant address	12345 Main Street, Gabriel, CA 90878				
4	Contact name	Bob Smith				
5	Contact address	54321 First Street, North Warren, CA 90878				
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com	
7	Date (format mm/date/year)	May 12, 2010				
Heating equipment description (where the energy saving measure is applied)						
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)		Gas fired furnace			
9	Equipment use (e.g., textile drying, aluminum melting)		Continuous metal heating furnace			
10	Other comments if any	The burners are nozzle mix type with proper equipment to adjust fuel air ratio.				

Control Air-Fuel Ratio or Reduction of Excess Air (or Oxygen) in Flue Gases			
		Current	**New**
11	Furnace flue gas temperature (°F.)	1,200	1,200
12	Percent O2 (dry) in flue gases	8.00	3.00
13	% Excess air	55.08	14.92
14	Combustion air temperature (°F.)	70	70
15	Fuel consumption (MM Btu/hr) - Avg. current	20.00	17.32
16	Available Heat (%)	53.8%	62.2%
17	Fuel savings (%)	Base	13.39%
18	No. of operating hours (hours/year)	8000	8000
19	Heat energy used per year (MM Btu/year)	160,000	138,579
20	**Heat energy saved (MM Btu/year)**	**Base**	**21,421**
21	Cost of fuel ($/Million Btu)	$ 10.00	$ 10.00
22	**Annual savings ($/year)**	**Base**	**$ 214,210**
23	**CO2 savings (Tons/year)**	**Base**	**1,253**

The savings are estimated for cases where excess air or O_2 content of the combustion products or flue or exhaust gases is reduced while maintaining safe and efficient combustion conditions within the heating system. Reduction in O_2 in flue gases represents reduction in mass flow of exhaust gases and hence reduction in energy wasted from the heating system. Reduction in flue gas O_2 can be due to a reduction in excess combustion air, air leaks in the system, additional make up air etc.

Figure 14 shows a typical air-fuel ratio control system used by the industry in systems requiring constant air flow.

Figure 14: Constant Air Flow System

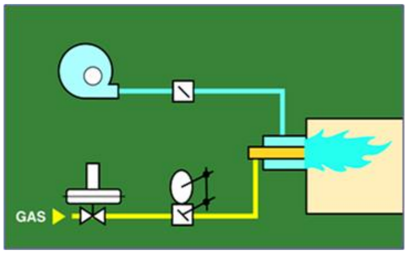


Figure 15 shows a controlled air and fuel flow system using linkages that is most commonly used for boilers and some ovens or dryers.

Figure 15: Controlled Air and Fuel Flow Type System Using Linkage

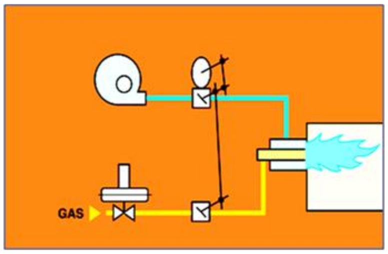
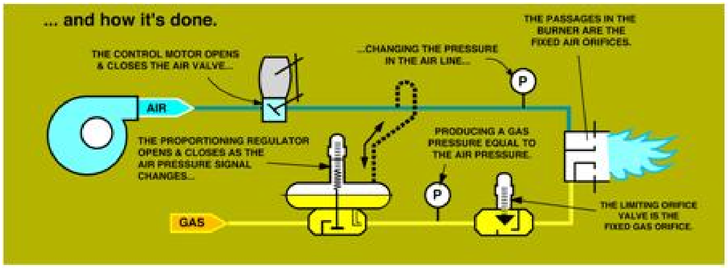


Figure 16 represents controlled air flow with a ratio regulator that uses a pressure signal from the air line downstream of the air control valve as is most commonly used for ovens, furnaces, dryers etc.

Figure 16: Controlled Air Flow and a Ratio Regulator System



The calculator estimates the expected energy savings in terms of MMBtu/year. It also estimates the energy cost reduction by using the given cost of fuel for the industrial application and the number of annual operating hours. This calculator also gives the reduction of CO_2 emissions that result from reduction in the combustion of natural gas.

The calculator's results should be considered preliminary and a starting point for more detailed technical and economic analysis. The results are to be used as a basis for a go/no go decision for further analysis. The accuracy of the calculator's results is expected to be within plus or minus 5 percent.

2.4 Reduction of Wall Losses (Tool #4)

This calculator tool allows a user to estimate annual energy savings, cost savings and reductions in CO_2 emissions through reduction in heat losses from the furnace walls of a heating system such as a furnace, boiler or oven. Wall losses are calculated by measuring the outside surface wall temperature and using appropriate correction factors. The wall loss is equal to heat loss through the walls at steady state conditions for a continuously operating furnace or oven. This calculator allows a user to change (reduce in most cases) the wall surface temperature achieved and estimate potential energy savings resulting from reduction in wall surface heat loss by convection and radiation. Potential energy saving measures can include improved insulation and furnace construction.

The calculator is shown in Figure 17.

Figure 17: Furnace Wall Loss Calculator

Minimize Wall Surface Heat Losses (Calculator for Reduction in Wall Losses through Proper Insulation)			
1	Company name	ABC Corporation	
2	Plant name or designation	LA Plant	
3	Plant address	12345 Main Street, Gabriel, CA 90878	
4	Contact name	Bob Smith	
5	Contact address	54321 First Street, North Warren, CA 90878	
6	Contact phone number and e-mail	Phone: 916-756-9923	E-mail: b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010	
Heating equipment description (where the energy saving measure is applied)			
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Oven	
9	Equipment use (e.g., textile drying, aluminum melting)	Metal coating	
10	Other comments if any	The oven is designed to run continuously	

	REDUCE FURNACE/OVEN WALL TEMPERATURE (Use proper insulation for the walls and doors)	**Current**	**New**
11	Surface temperature (°F)	200	140
12	Ambient temperature (°F)	60	60
13	Heat Loss [Btu/(hr.ft^2)]	299	185
14	Correction factor for surface orientation etc.	1.10	1.10
15	Estimated heat loss for the surfaces (Btu/(hr-ft^2)	329	203
16	Surface area (ft^2)	1,200	1,200
17	Furnace flue gas temperature (°F)	1,100	1,100
18	% Oxygen in flue gases	5.00	5.00
19	Combustion air temperature (°F)	80	80
20	Cost of fuel ($/Million Btu)	$6.00	$6.00
21	Operating hours/year	8,400	8,400
22	Energy used per year (MM Btu/year)	5,324	3,284
23	**Energy saved per year (MM Btu/year)**	**Base**	**2,040**
24	Cost of fuel used ($/year)	$29,039	$17,912
25	**Savings ($/year)**	**Base**	**$11,127**
26	**Energy cost savings ($/year-ft^2)**		**$9.27**
27	**CO2 savings (tons/year)**		**119**

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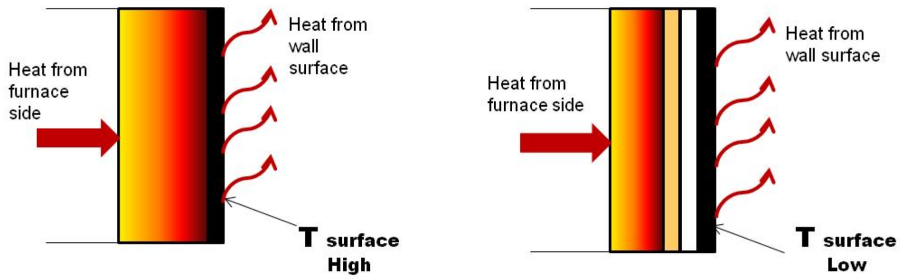
Typical furnace or oven/boiler wall construction is shown in Figure 18 and includes one or more layers of insulation material on the hot side of the wall and a steel plate to provide a structure for the heating equipment. Heat flows from hot side of the wall to the steel plate or colder side of the wall by thermal conduction. This raises the temperaure of the steel plate and heat is dissipated by convection (usually natural convection) and radiation. The final steel plate or cold side temperature shows an equilibrium temperature that can be used to calculate wall heat loss.

Figure 18: Typical Furnace Wall Construction and Heat Flow - Losses



The calculator does not require details of the wall insulation and construction since the surface heat losses are dependent only on external factors such as the wall outside surface temperature, other surface properties (i.e. emissivity) and external parameters such as the wind velocity. The calculator gives heat losses for near zero wind velocity and vertical surfaces. In most furnaces operating inside the plant, it is not necessary to account for wind velocity. Effect of surface emissivity, surface orientation and wind velocity can be accounted by using a correction factor in the calculator. The calculator estimates expected annual energy savings in terms of MMBtu/year. It also estimates the energy cost reduction by using the given cost of fuel for the industrial application and the annual operating hours. This calculator also estimates reduction of CO_2 emissions from the combustion of natural gas and other fuels.

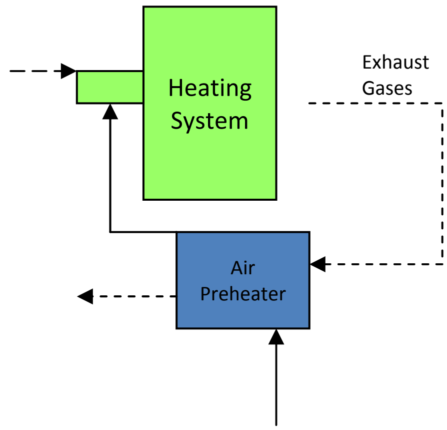
2.5 Use of Preheated Combustion Air (Tool #5)

This calculator tool allows a user to estimate annual energy savings, cost savings and reduction in CO_2 emissions through use of preheated combustion air for industrial heating applications and boilers. The savings are estimated for cases where heat from flue or exhaust gases is used to preheat combustion air. This pre-heated air is then used in burners installed on the heating system of furnaces, ovens, heaters, dryers, smelters, or boilers.

Combustion air can be preheated in heat recovery heat exchangers or air preheaters, commonly known as recuperators or regenerators. An air preheater is located in the exhaust gas passage so that heat from exhaust gases can be used to raise temperature of colder or ambient air used for combustion in one or more burners. Use of preheated air, particularly for high temperature (>1000^{O} F.) applications, can reduce energy consumption by 10% to 40% in a heating system.

A typical arrangement is shown in Figure 19.

Figure 19: Typical Arrangement for Use of Combustion Air Preheating

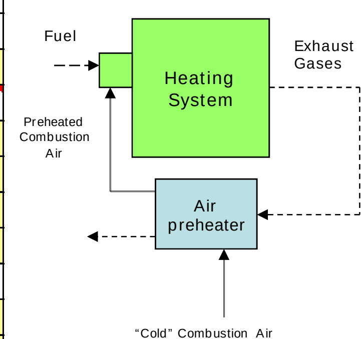


The calculator is shown in Figure 20. The calculator estimates annual energy savings in terms of MMBtu/year and cost reduction for a given combustion air preheat temperature and flue gas temperature and operating conditions for the heating equipment. This calculator also gives the reduction of CO_2 emissions that result from the combustion of natural gas. The use of preheated combustion air has very little or no effect on water consumption for the system.

Figure 20: Calculator for Savings with Use of Combustion Air Preheating

Use Preheated Combustion Air for Burners (Calculator for Preheated Combustion Air)						
1	Company name	ABC Corporation				
2	Plant name or designation	LA Plant				
3	Plant address	12345 Main Street, Gabriel, CA 90878				
4	Contact name	Bob Smith				
5	Contact address	54321 First Street, North Warren, CA 90878				
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com	
7	Date (format mm/date/year)	May 12, 2010				
Heating equipment description (where the energy saving measure is applied)						
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)		A furnace using a recuperator			
9	Equipment use (e.g., textile drying, aluminum melting)		Gas fired furnace used continuously			
10	Other comments if any	This is a preliminary evaluation for possible heat recovery and power generation using heat of exhaust gases.				

Use of Preheated Combustion Air **Note: The combustion air is heated by using heat from flue or exhaust gases.**			
		Current	**New**
11	Furnace flue gas temp. (°F)	1,000	1,000
12	Percent O2 (dry) in flue gases	3.00	3.00
13	% Excess air	14.92	14.92
14	Combustion air temperature (°F)	60	600
15	Fuel consumption (MM Btu/hr) - Avg. current	5.00	4.36
16	Volume of fuel gas scfh - based on fuel heating value	4,945.19	4,308.71
17	Available Heat (%)	66.89	76.77
18	Fuel savings (%)	Base	12.87%
19	No. of operating hours (hours/year)	6000	6000
20	Heat used per year (MM Btu/year)	30,000	26,139
21	**Heat saved per year (MM Btu/year)**	**Base**	**3,861**
22	Cost of fuel ($/Million Btu)	$ 6.00	$ 6.00
23	**Annual savings ($/year)**	**Base**	**$ 23,167**
24	**CO2 savings (tons/year)**	**Base**	**227**



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2.6 Eliminate or Reduce Opening Heat Loss (Tool #6)

This calculator estimates annual energy savings, cost savings and reduction in CO_2 emissions from reducing radiation heat loss from heating equipment such as a furnaces, ovens or process heaters by reducing openings, their size or time. The calculator is shown in Figure 21. The calculator allows the user to calculate heat loss for current conditions and then calculate heat loss when changes are made through the opening or when the discharge door is kept open.

Use of this calculator requires collection of data such as the type of opening (rectangular versus round), size of the opening (width and height or diameter) and the depth of the wall where the opening is located. The heat loss calculations account for the view factors associated with each opening and then allows calculations for the thermal radiation loss

Figure 21: Calculator for Reduction in Opening Heat Losses.

Eliminate or Reduce Opening Heat Loss
(Reduce Loss from a Furnace Door Opening)

1	Company name	ABC Corporation	
2	Plant name or designation	LA Plant	
3	Plant address	12345 Main Street, Gabriel, CA 90878	
4	Contact name	Bob Smith	
5	Contact address	54321 First Street, North Warren, CA 90878	
6	Contact phone number and e-mail	Phone: 916-756-9923	E-mail: b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010	
Heating equipment description (where the energy saving measure is applied)			
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Oven	
9	Equipment use (e.g., textile drying, aluminum melting)	Metal coating	
10	Other comments if any	The oven is designed to run continuously	

REDUCE LOSS FROM A FURNACE DOOR- OPENING

		Current	New
11	Average furnace temperature (°F)	1,750	1,750
12	Ambient temperature (°F) - Open door	80	80
13	Emissivity for the furnace interior *	0.90	0.90
14	Radiation heat Loss [Btu/(hr.ft^2)]	36,645	36,645
15	Furnace door - opening width (ft.)	10.25	10.25
16	Furnace door - opening height (ft.)	5.00	5.00
17	Surface area (ft^2)	51	51
18	View factor (if applicable)***	0.90	0.90
19	Furnace flue gas temp. (°F)**	1,800	1,800
20	% Oxygen in flue gases from FGA during open door	4.0	4.0
21	Combustion air temp. (°F)	80	80
22	Available heat (%)	46%	46%
23	Door - Opening - open time (minutes) per cycle or charge	15	5
24	No. of cycles or charges per day	12.0	12.0
25	Total net heat loss (MM Btu/day)	5.1	1.7
26	Operating days per year (days/year)	360	360
27	Cost of fuel ($/MM Btu)	$8.00	$8.00
28	Heat loss per year (MM Btu/year)	1,825	608
29	Heat input required for the losses per year (MM Btu/year)	3,998	1,333
30	**Gas Savings per furnace (MM Btu/year)**	**Base**	***2,665***
31	**Cost of fuel used for losses ($/year)**	**$31,983**	**$10,661**
32	**Savings ($/year per furnace)**	**Base**	**$21,322**
33	**CO2 savings (tons/year)**	**Base**	**156**

View Factor Chart
Use for openings other than doors

Notes:
* In most cases this can be assumed to be 0.9
** Assumed to be 50 deg. F. higher than furnace temp.
*** View factor depends on size and shape of the opening. **For furnace doors this can be assumed as 0.9.** See instructions for further information.

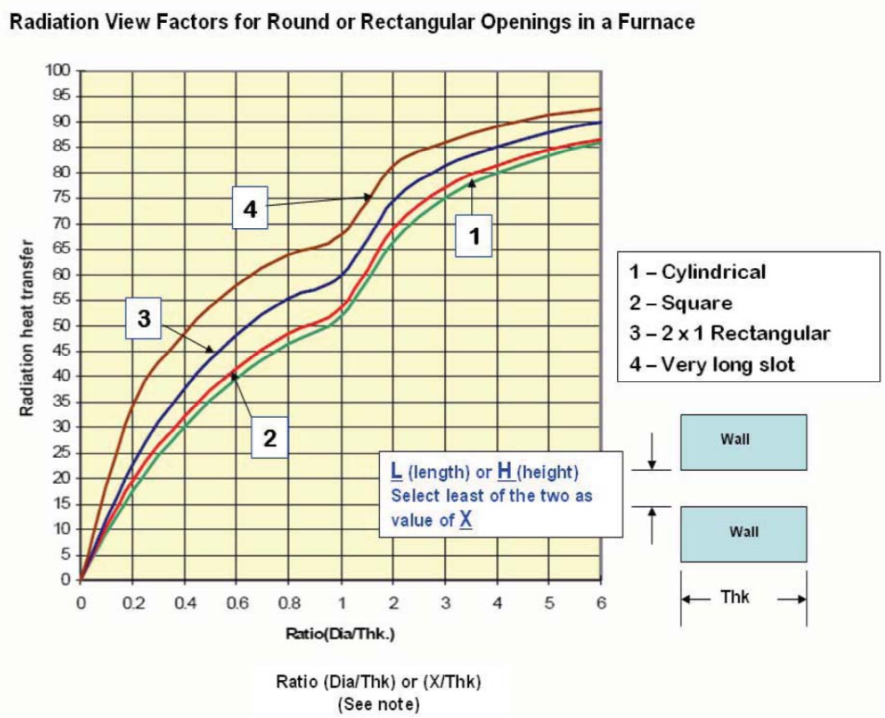
As shown in Figure 22, the opening can be fixed, such as a hole in the furnace wall or a stack opening. It can also be a variable opening. Variable opening heat losses are associated with a product charge or a discharge door where the door is kept open before, during or after the product is charged or discharged into the furnace. It can also occur when openings are used to pull a sample during operating conditions. For high temperature (>400 deg. F.) furnaces and ovens, the opening heat losses are due to thermal radiation from the opening. In some cases, the openings allow cold air to enter the furnace if the furnace pressure at the opening location is negative, or allow hot gases to escape from the furnace if the furnace pressure at the opening level is positive. This calculator *does not* account for these latter losses associated with cold air or hot gas exchange from a furnace.

Figure 22: Example of a Wall Opening or Furnace Door Opening.

A separate calculator, shown in Figure 23, is included with this tool to help the user calculate view factors for a given geometry of the opening. Energy savings resulting from the elimination or reduction of the opening size accounts for the "available heat" for the heating system.

Figure 23: Support Calculator to Calculate View Factor for Openings

Instructions on use of the chart for an openig in a furnace wall				
Round Opening			Current	New
1	Find or measure furnace wall thickness at the location of the opening	Inch	9.00	9.00
2	For round opening find or measure diameter of the opening	Inch	24.00	6.00
3	Ratio of Diameter to Thickness	Inch	2.67	0.67
4	Find "Radiation Heat Transfer - % of balck body radiation) using line 1 (Round Opening)		75.00	43.00
5	View factor - Use this number in cells		0.75	0.43
Square or Rectangular Opening			Current	New
1	Find or measure furnace wall thickness at the location of the opening	Inch	8.00	9.00
2	For square or rectangular opening find or measure length (width) of the opening	Inch	30.00	6.00
3	For square or rectangular opening find or measure height of the opening	Inch	6.00	3.00
4	Ratio of length/width to height or height to length/width- use for seelction of lines 1, 2, 3 or 4.		5.00	2.00
5	Smaller of the length (width) or height of the opening value	Inch	6.00	3.00
6	Ratio of value in line 4 to thickness; Use this for X axis	Inch	0.75	0.33
7	Find "Radiation Heat Transfer" - % of balck body radiation) using one of the lines 2 to 4 on the chart and values in line 4		62.00	45.00
8	**View factor - Use this number in line 18 of the calculator**		**0.62**	**0.45**



Note:
Dia – Diameter of round opening
Thk – Furnace wall thickness
X – Length (L) or Height (H) of rectangular-square opening, Use least of the length or height value.

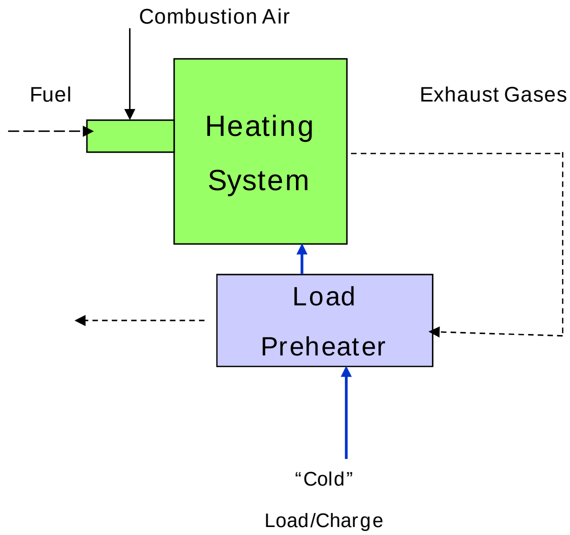
2.7 Load Preheating (Tool #7)

This calculator tool estimates annual energy savings, associated cost savings and reductions in CO_2 emissions from the use of heat from flue gases to preheat load or charge material for a furnace, oven or any type of heating equipment. Preheating reduces energy used to raise temperature of the load and reduces energy use for the heating system. Load preheating is one of the most widely considered methods of flue gas waste heat recovery and energy savings. In addition to energy savings, load preheating may decrease production time due to the need for shorter heating time.

The most commonly used method of load preheating is to use heat from exhaust or flue gases outside the heating equipment itself. In some cases, it may be possible to integrate the load heating system with the primary or main heating system (furnace, oven etc.) by redesigning an existing system.

A typical load preheating system, where the exhaust gas heat is used to preheat the load in a separate chamber, or preheater is shown in Figure 24. Exhaust gases from a furnace are sent to a preheater where the gases are recirculated using a fan. The recirculated gases supply heat to the load and walls of the preheater box mostly by convection. For higher temperature applications the walls would radiate to the load to supply additional heat. The box temperature is controlled to avoid overheating of the load.

Figure 24: Typical Load Preheating System Using Exhaust Gas Heat.



The load preheating calculator is shown in Figure 25.

This calculator estimates the annual expected energy savings in MMBtu/year. It also estimates the energy cost reduction by using the given cost of fuel for the industrial application and the number of operating hours per year. This calculator also gives the reduction of CO_2 emissions that result from the combustion of natural gas.

Details of data input, results and guidance on data acquisitions, are discussed in the Technical Guide for this calculator. The guide can be down loaded from the same website location as the calculators. The calculator has a built in list of commonly used materials and a table of average specific heat for these materials. The user can select materials not listed in the calculator and still use the calculator. The specific heat value for the material is given as one of the input parameters. Figure 26 shows the table of specific heat values for various materials. This table is associated with the calculator. In this table, specific heat values are given in English units as Btu per pound mass per degree Fahrenheit (Btu/lbm-^{O}F) or in International units as kiloJoules per kilogram per degree Kelvin (kJ/kg-^{O}K).

Figure 25: Load Preheating Calculator

Preheat Loads using Heat from Exhaust Gases
(Calculator for Furnace Charge Preheating using Exhaust Gases)

1	Company name	ABC Corporation			
2	Plant name or designation	LA Plant			
3	Plant address	12345 Main Street, Gabriel, CA 90878			
4	Contact name	Bob Smith			
5	Contact address	54321 First Street, North Warren, CA 90878			
6	Contact phone number and e-mail	Phone:	916-756-9923	Email:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010			
Heating equipment description (where the energy saving measure is applied)					
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Furnace			
9	Equipment use (e.g., textile drying, aluminum melting)	Gas fired furnace			
10	Other comments if any	The furnace exhaust gases are dischrged from a single stack			

Calculations for Savings - Furnace Charge Preheating using Exhaust Gases

		Base	New
11	Charge Material	Aluminum	
12	Charging rate (as charged with moisture) (Lbs./hr)	4,000	
13	*Base* Charge Initial temperature (°F)	82	
14	*New* Charge Preheat temperature (°F)		400
15	Specific heat of the charge in temp. range of preheat (Btu/lb. F)	0.21	0.21
16	*Base* % moisture content in the charge (cold)	1.00%	
17	*New* % moisture content in the charge (preheated)		0.25%
18	Net heat reduction due to preheat (Btu/hr)	300,269	
19	Flue gas temperature from oven/furnace (°F)	1100	1100
20	Air preheat temperature (°F)	80	80
21	Current O2 in flue gases (%)	4.50	4.50
22	Available heat (%)	63.00%	63.00%
23	Savings in gross heat supplied to oven/furnace (Btu/hr.)	Base	476,607
24	Total energy savings (MM Btu/hr)	Base	0.477
25	Energy Cost ($/MM Btu)	$8.00	$8.00
26	Operating Hrs (per year)	8000	8000
27	**Energy savings (MM Btu/year)**		**3,813**
28	**Savings - Energy cost ($/year)**	**Base**	**$30,502.82**
29	**CO2 savings based on fuel:natural gas(tons/year)**		**223**

Specific Heat Table

Disclaimer: The California Energy Commission (Energy Commission), its contractor, Southern California Gas Company, and its subcontractor, E3M Inc., have made reasonable efforts to ensure that all information in this publication is correct. Neither the Energy Commission, Southern California Gas Company, nor E3M Inc. shall be responsible for errors or omissions in this publication or for claims or damages relating to its use. No publications or verbal representations of the Energy Commission, Southern California Gas Company, or E3M Inc. constitute any statement, recommendation, endorsement, approval, or guaranty (either express or implied) of any product or service.

Figure 26: Specific Heat Values for Commonly Used Materials

Material	Specific Heat Capacity* - cp -	
	(Btu/lbm °F) (kcal/kg °C)	(kJ/kg K)
Aluminum, 0°C	0.21	0.87
Antimony	0.05	0.21
Apatite	0.20	0.84
Asbestos cement board	0.20	0.84
Asbestos mill board	0.20	0.84
Ashes	0.20	0.84
Asphalt	0.22	0.92
Augite	0.19	0.80
Bakelite. wood filler	0.33	1.38
Bakelite. asbestos filer	0.38	1.59
Barite	0.11	0.46
Barium	0.07	0.29
Basalt rock	0.20	0.84
Beeswax	0.82	3.40
Beryl	0.20	0.84
Bismuth	0.03	0.13
Bone	0.11	0.44
Borax	0.24	1.00
Boron	0.31	1.30
Brass	0.09	0.38
Brick, common	0.22	0.90
Brick, hard	0.24	1.00
Cadmium	0.06	0.25
Calcite 32 - 100F	0.19	0.80
Calcite 32 - 212F	0.20	0.84
Calcium	0.15	0.63
Carbon, Diamond	0.12	0.52
Carbon, Graphite	0.17	0.71
Carborundum	0.16	0.67
Cassiterite	0.09	0.38
Cement dry	0.37	1.55
Cement powder	0.20	0.84
Charcoal	0.24	1.00
Chalk	0.22	0.90
Chalcopyrite	0.13	0.54
Charcoal, wood	0.24	1.00
Chromium	0.12	0.50
Clay	0.22	0.92
Coal, anthracite	0.30	1.26
Coal, bituminous	0.33	1.38
Cobalt	0.11	0.46
Coke	0.20	0.85

Material	Specific Heat Capacity* - cp -	
	(Btu/lbm °F) (kcal/kg °C)	(kJ/kg K)
Concrete, stone	0.18	0.75
Concrete, light	0.23	0.96
Copper	0.09	0.39
Corkboard	0.45	1.90
Corundum	0.10	0.42
Diamond	0.15	0.63
Dolomite rock	0.22	0.92
Earth, dry	0.30	1.26
Fiberboard, light	0.60	2.50
Fiber hardboard	0.50	2.10
Firebrick	0.25	1.05
Fluorite	0.22	0.92
Fluorspar	0.21	0.88
Galena	0.05	0.21
Garnet	0.18	0.75
Glass	0.20	0.84
Glass, crystal	0.12	0.50
Glass, plate	0.12	0.50
Glass, Pyrex	0.18	0.75
Glass, window	0.20	0.84
Glass, wool	0.16	0.67
Gold	0.03	0.13
Granite	0.19	0.79
Graphite	0.17	0.71
Gypsum	0.26	1.09
Hairfelt	0.50	2.10
Hematite	0.16	0.67
Hornblende	0.20	0.84
Hypersthene	0.19	0.80
Ice 32°F (0°C)	0.49	2.09
India rubber min	0.27	1.13
India rubber max	0.98	4.10
Iridium	0.03	0.13
Iron, 20°C	0.11	0.46
Labradorite	0.19	0.80
Lava	0.20	0.84
Limestone	0.20	0.84
Lead	0.03	0.13
Leather, dry	0.36	1.50
Lithium	0.86	3.58
Magnetite	0.16	0.67
Malachite	0.18	0.75
Manganese	0.11	0.46

Material	Specific Heat Capacity* - cp -	
	(Btu/lbm °F) (kcal/kg °C)	(kJ/kg K)
Magnesia (85%)	0.20	0.84
Marble	0.21	0.88
Mercury	0.03	0.14
Mica	0.12	0.50
Mineral wool blanket	0.20	0.84
Oligocose	0.21	0.88
Orthoclose	0.19	0.80
Paper	0.33	1.40
Paraffin wax	0.70	2.90
Peat	0.45	1.88
Plaster, light	0.24	1.00
Plaster, sand	0.22	0.90
Plastics, foam	0.30	1.30
Plastics, solid	0.40	1.67
Platinum, 0°C	0.03	0.13
Porcelain	0.26	1.07
Potassium	0.13	0.54
Pyrex glass	0.20	0.84
Pyrolusite	0.16	0.67
Pyroxylin plastics	0.36	1.51
Quartz mineral 55 - 212°F	0.19	0.80
Quartz mineral 32°F (0°C)	0.17	0.71
Rock salt	0.22	0.92
Rubber	0.48	2.01
Salt	0.21	0.88
Sand	0.19	0.80
Sandstone	0.22	0.92
Sawdust	0.21	0.90
Serpentine	0.26	1.09
Silica aerogel	0.20	0.84
Silk	0.33	1.38
Silver, 20°C	0.06	0.23
Sodium	0.30	1.26
Soil, dry	0.19	0.80
Soil, wet	0.35	1.48
Stone	0.20	0.84
Stoneware	0.19	0.80
Sulphur	0.17	0.71
Tar	0.35	1.47
Tellurium	0.05	0.21
Tile hollow	0.15	0.63
Topaz	0.21	0.88
Tungsten	0.04	0.17
Vanadium	0.12	0.50
Vermiculite	0.20	0.84
Vulcanite	0.33	1.38
Wood, balsa	0.70	2.90
Wood, oak	0.48	2.00
Wood, white pine	0.60	2.50
Wool, loose	0.30	1.26
Wool, felt	0.33	1.38

2.8 Lower Explosion Limit or Lower Flammability Limit Control for Ovens (Tool #8)

This calculator tool estimates annual energy savings, associated cost savings and reductions in CO_2 emissions through monitoring and control of LEL or LFL for industrial process ovens.

LEL is defined as lowest concentration (percentage) of a flammable (volatile) gas or vapor in air, capable of producing a flash or fire in presence of an ignition source (flame, spark, arc, heat). Concentrations lower than LEL are "too lean" to burn or ignite. LEL is also referred to as LFL. The value of LEL depends on the gas or vapor properties, the air – gas (vapor) mixture temperature and presence of certain inert gases in the mixture. In most industrial heating applications, it is customary to use LEL values in air at ambient temperature as a first guide.

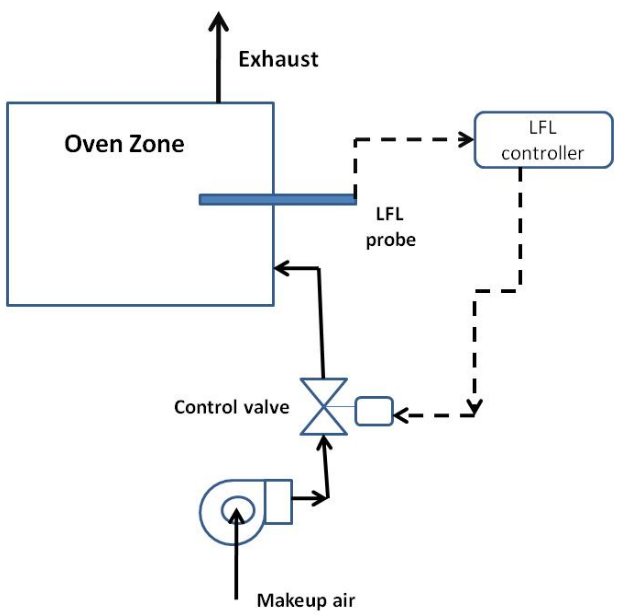
For safety reasons (i.e. avoiding ignition and explosion of the mixture), it is absolutely necessary to maintain flammable gas – vapor concentrations well below the corresponding LEL value. In most cases, it is recommended that the flammable gas or vapor concentration be maintained below 25% of the LEL value unless certain safety measures, such as continuous monitoring of LEL is incorporated in the process control system.

It is recommended that guidelines from National Fire Protection Association (NFPA) and the plant insurance company be used.

In many process heating ovens, flammable solvent removal from a product is used as part of the heating process. Mixing solvent vapors, which are flammable, with air or other oxygen bearing gases can create a flammable mixture. It is necessary to maintain a safe level of solvent concentration within the oven by introducing the appropriate amount of make-up or dilution air. This air has to be heated to the oven exhaust, and in some cases to even a higher temperature in a downstream emission control system such as a thermal oxidizer. Use of excessive air, above the required value by the safety regulations, increases energy use for the ovens. This tool allows the user to calculate energy savings associated with reducing extra make-up or dilution air, over and above the required level to maintain safe operating conditions.

A typical system used to monitor and control LEL in an oven is shown in Figure 27.

Figure 27: Typical System Used to Measure, Monitor, and Control LEL in an Oven



The calculator is shown in Figure 28. One of the important parameters required for use of the calculator, is the amount of air required to achieve LEL for any mixture. The calculator includes a table of commonly used solvents and air required to maintain LEL for the solvent. The table is shown in Figure 29.

The calculator can be used to estimate expected energy savings in terms of MMBtu/year. It also estimates the energy cost reductions by using the given cost of fuel for the industrial application and the annual operating hours. This calculator also gives the reduction of CO_2 emissions that result from the combustion of natural gas.

A list of input parameters required for the calculator, source of the required data (parameter values) and calculation methods are described in the Technical Guide for this calculator. A complete list of data required for the calculator is given in Technical Guide that can be down loaded from the Energy Commission website at the same location as the calculators.

Figure 28: Calculator for LEL or LFL Control

Monitor and Control Lower Explosive or Flammability Limit
(Calculator of LEL or LFL Control for the Ovens)

1	Company name	ABC Corporation			
2	Plant name or designation	LA Plant			
3	Plant address	12345 Main Street, Gabriel, CA 90878			
4	Contact name	Bob Smith			
5	Contact address	54321 First Street, North Warren, CA 90878			
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010			
Heating equipment description (where the energy saving measure is applied)					
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Paint drying oven			
9	Equipment use (e.g., textile drying, aluminum melting)	Continuous coil coating line			
10	Other comments if any	The oven does not have any type of LEL or LFL monitoring system at this time.			

LEL or LFL Control for the Ovens

	Items	Values	Comments - Suggestions
11	LEL reading - current reading or value	5.1%	Measured value using probe.
12	Current *average hourly* fuel consumption (MM Btu/hr)	4.00	
13	Excess air used for burners % *	10	Default can be 10%
14	Temperature of flue gases (°F)	350	
15	Combustion air temperature (°F)	80	
16	Ambient temperature (°F)	70	
17	Available heat for burners (%)	83%	
18	% O2 in exhaust air or flue gases	19.0	Dry basis
19	Estimated makeup air or air leaks (scfh)	347,984	
20	SCF air at LEL per gallon of solvent	2,885	See table or use default value 2,500 as approximation
21	Heat used in the oven/dryer (Btu/hr) - estimated	1,823,247	
22	Total volume of exhaust air (scfh)	388,706	
23	Gallons of solvent used (per hour)	6.8	Estimated based on given data for LEL etc.
24	New suggested value for LEL or LFL (%)	40	
25	New volume of exhaust air required - estimated	49,074	
26	Reduction in exhaust volume (scfh)	339,632	
27	Net heat savings (Btu/hr)	1,834,012	
28	Total or gross heat savings @ burner tip (Btu/hr)	2,197,024	
29	Fuel cost ($/Million Btu)	$ 6.00	
30	Operating hours (hours per year)	7,200	
31	**Annual fuel cost savings ($/year)**	**$ 94,911**	
32	**CO2 savings (tons/year)**	**$ 925**	
33	**Annual fuel savings (MM Btu/year)**	**13,205**	

→ LEL Table

* Note: This is NOT excess air in exhaust or stack gases. It represents how the burners are adjusted for air-fuel ratio. In many cases the users are advised to adjust burners for 10% to 20% excess air (2% to 4% Oxygen) in combustion products.

Figure 29: LEL or LFL Values and Additional Information for Industrial Solvents

Solvent Name	Molecular Weight	Flash Point °F	Auto-ignition °F	LEL % by Volume	UEL % by Volume	Specific Gravity Water =1	Vapor Density Air = 1	Boiling Point °F	lb per Gal	scf Vapor per gal	scf Vapor per lb	**scf Air at LEL per gal**
Acetone	58	-4	869	2.5	12.8	0.79	2	133	6.58	43.9	6.67	**1712**
n-Amyl Acetate	130	60	680	1.1	7.5	0.88	4.5	300	7.33	21.8	2.98	**1961**
sec-Amyl Acetate	130	89		1	7.5	0.88	4.5	249	7.33	21.8	2.98	**2159**
Amyl Alcohol	88	91	572	1.2 at 212°F	10.0 at 212°F	0.82	3	280	6.83	30	4.4	**2472**
Benzene	78	12	928	1.2	7.8	0.88	2.8	176	7.33	35	4.78	**2885**
Benzine	Mix	0	550	1.1	5.9	0.64	2.5		5.33	28.5	5.35	**2566**
n-Butyl Acetate	116	72	797	1.7	7.6	0.88	4	260	7.33	24.4	3.34	**1413**
n-Butyl Alcohol	74	98	650	1.4	11.2	0.81	2.6	243	6.75	35.3	5.23	**2484**
sec-Butyl Alcohol	74	75	761	1.7 at 212°F	9.8 at 212°F	0.81	2.6	201	6.75	35.3	5.23	**2039**
Butyl Cellosolve	118	148	472	1.1 at 200°F	12.7 at 275°F	0.9	4.1	340	7.5	24.6	3.28	**2209**
Butyl Propionate	130	90	799			0.88	4.5	295	7.33	21.8	2.98	
Camphor	152	150	871	0.6	3.5	0.99	5.2	399	8.24	21.1	2.55	**3489**
Carbon Disulfide	76	-22	194	1.3	50	1.26	2.6	115	10.49	53.4	5.09	**4056**
Cellosolve	90	110	455	1.7 at 200°F	15.6 at 200°F	0.93	3	275	7.75	34.6	4.46	**1998**
Cellosolve Acetate	132	124	715	1.7	13	0.98	4.7	313	8.16	23.1	2.84	**1338**
Chlorobenzene	113	82	1099	1.3	9.6	1.11	3.9	270	9.24	31.6	3.42	**2403**
Corn Oil	Mix	490	740			0.9			7.5			
Cottonseed Oil	Mix	486	650			0.9			7.5			
m-Cresol or p-Cresol	108	187	1038	1.1 at 302°F		1.03	3.7	395	8.58	30.7	3.58	**2763**
Cyclohexane	84	-4	473	1.3	8	0.78	2.9	179	6.5	29.9	4.61	**2271**
Cycloheanone	98	111	788	1.1 at 302°F	9.4	0.95	3.4	313	7.91	31.2	3.95	**2808**
p-Cymene	134	117	817	0.7 at 212°F	5.6	0.86	4.6	349	7.16	20.7	2.93	**2933**
Dibutyl Phthalate	278	315	757	0.5 at 456°F		1.04	9.6	644	8.66	12.1	1.41	**2399**
o-Dichlorobenzene	147	151	1198	2.2	9.2	1.31	5.1	356	10.91	28.7	2.67	**1276**
Diethyl Ketone	86	55	842	1.6		0.81	3	217	6.75	30.3	4.56	**1866**
n-Dimethyl Formamide	73	136	833	2.2 at 212°F	15.2	0.94	2.5	307	7.83	41.5	5.37	**1844**
p-Dioxane	88	54	356	2	22	1.03	3	214	8.58	37.7	4.45	**1848**
Ethyl Acetate	88	24	800	2	11.5	0.9	3	171	7.5	33	4.45	**1615**
Ethyl Alcohol	46	55	685	3.3	19	0.79	1.6	173	6.58	55.3	8.52	**1621**
Ethylbenzene	106	59	810	0.8	6.7	0.87	3.7	277	7.25	26.4	3.7	**3279**
Ethyl Ether	74	-49	356	1.9	36	0.71	2.6	95	5.91	30.9	5.3	**1596**
Ethyl Lactate	118	115	752	1.5 at 212°F		1.04	4.1	309	8.66	28.4	3.32	**1865**
Ethyl Methyl Ether	60	-35	374	2	10.1	0.7	2.1	51	5.8	37.6	6.53	**1842**
Ethyl Propionate	102	54	824	1.9	11	0.89	3.5	210	7.4	28.1	3.84	**1452**
Ethylene Dicholride	99	56	775	6.2	16	1.3	3.4	183	10.8	42.3	3.96	**640**
Gasoline	Mix	-45	536	1.4	7.6	0.8	3.0- 4.0		6.7	29.7	4.46	**2094**
n-Heptane	100	25	399	1	6.7	0.68	3.5	209	5.7	21.9	3.92	**2169**
n-Hexane	86	-7	427	1.1	7.5	0.66	3	156	5.5	24.7	4.56	**2223**
Kerosene (Fuel Oil #1)	Mix	100- 162	410	0.7	5	0.83			6.9			
Linseed Oil - Raw	Mix	432	650			0.93		600	7.7			
Magiesol 47	203	215	428	0.5		0.8	7	464	6.7	12.7	1.91	**2527**
Magisol 52	236	265	428	0.5		0.81	8.2	518	6.7	11.1	1.64	**2201**
Methyl Acetate	74	14	850	3.1	16	0.93	2.8	140	7.7	37	5.3	**1157**
Methyl Alcohol	32	52	725	6	36	0.79	1.1	147	6.6	79.5	12.25	**1246**
Methyl Carbitol	120	205	465	1.4	22.7	1.01	4.1	389	8.4	27.2	3.27	**1945**
Methyl Cellosolve	76	102	545	1.8	14	0.96	2.6	255	8	40.7	5.16	**2220**
Methyl Celloosolve Acetate	118	111		1.7	8.2	1.01	4.1	292	8.4	27.6	3.32	**1595**
Methyl Ethyl Ketone	72	16	759	1.4 at 200°F	11.4 at 200°F	0.8	2.5	176	6.7	35.8	5.44	**2521**
Methyl Lactate	104	121	725	2.2 at 212°F		1.1	3.6	293	9.2	34.1	3.77	**1515**
Mineral Spirites #10	Mix	104	473	1.8 at 212°F	6	0.8	3.9	300	6.7	22.9	3.43	**2836**
Naphtha (VM&P Regular)	Mix	28	450	0.9	5.9			203-320				
Naphthalene	128	174	979	0.9		1.1	4.4	424	9.2	27.7	3.06	**3049**
Nitrobenzene	123	190	900	.8 at 200°F		1.25	4.3	412	10.4	32.7	3.19	**1786**
Nitroethane	75	82	778	3.4		1.04	2.6	237	8.7	44.7	5.23	**1269**
Nirtromethane	61	95	785	7.3		1.13	2.1	214	9.4	59.7	6.43	**758**
Nitropropane-1	89	96	789	2.2		1	3.1	268	8.3	36.2	4.4	**1609**
Nitropropane-2	89	75	802	2.6	11	0.99	3.1	248	8.2	35.8	4.4	**1343**
Paraffin Oil	Mix	444				0.83-0.91						
Peanut Oil	Mix	540	833			0.9			7.5			
Perchloroethylene	166	None	None	None		1.62	5.8	250	13.5	31.1	2.36	
Petroleum Ether	Mix	<0	550	1.1	5.9	0.66	2.5		5.5	29.4	5.35	**2646**
Propyl Acetate	102	55	842	1.7 at 100°F	8	0.89	3.5	215	7.4	38.1	3.84	**1626**
n-Propyl Alcohol	60	74	775	2.2	13.7	0.8	2.1	207	6.7	43	6.53	**1910**
i-propyl Alcohol	60	53	750	2	12.7 at 200°F	0.78	2.1	181	6.5	41.9	6.53	**2052**
n-pPropyl Ether	102	70	370	1.3	7	0.75	3.5	194	6.2	23.7	3.84	**1798**
Pryridine	79	68	900	1.8	12.4	0.98	2.7	239	8.2	40	4.96	**2180**
Rosin Oil	Mix	266	648			1		680	8.3			
Soy Bean Oil	Mix	540	833			0.9			7.5			
Tetrahydrofuran	72	6	610	2	11.8	0.89	2.5	151	7.4	39.8	5.44	**1952**
Toluene	92	40	896	1.1	7.1	0.87	3.1	231	7.2	31.1	4.26	**2800**
Turpentine	136	95	488	0.8		0.87	4.7	300	7.2	20.6	2.88	**2556**
Vinyl Acetate	86	18	756	2.6	13.4	0.93	3	161	7.7	34.8	4.56	**1305**
o-Xylene	106	88	867	0.9	6.7	0.88	3.7	292	7.3	26.7	3.7	**2945**

2.9 Humidity Control for a Dryer (Tool #9)

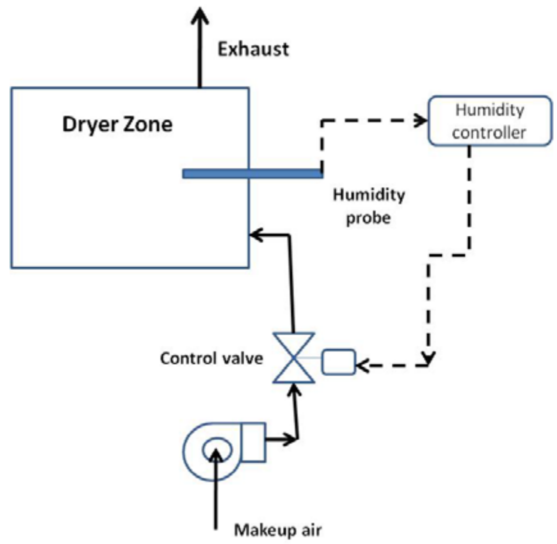
This calculator tool estimates annual energy savings, associated cost savings and reductions in CO_2 emissions through monitoring and control of humidity in industrial dryers.

Industrial dryers are used to remove moisture from products such as paper, grain, textile, and food processing. In these processes, a large amount of water is removed from the products and as a result, the amount of water present is much larger than would be in natural gas combustion products. As a result, the humidity in the dryer environment could be very high.

It is necessary to maintain the required or optimum moisture content or humidity in the dryer to maximize the drying rate. The moisture level is maintained by introduction of makeup or dilution air in the dryer. The make-up or dilution air is mixed with combustion products from the dryer burners and needs to be heated to the dryer zone temperature before it can be discharged from the dryer as exhaust air or flue gas. Air heating can consume a large percentage of the total heat required for drying. It is advisable to control the make-up air mass flow and keep it to a minimum required value, without adversely affecting the product drying rate. Too little air can raise the moisture level in the dryer and retard the drying rate while too much air uses extra, unnecessary energy. Humidity in exhaust air can be measured and monitored by using a humidity sensor and calculator available from several vendors. The humidity sensor must be selected to withstand the exhaust air temperature in the presence of any other gases present in the exhaust air.

Typical humidity measuring, monitoring and control system is shown in Figure 30. A humidity sensor is used to measure humidity level, usually measured in terms of relative humidity. This information is processed in a humidity controller which will compare the measured value with a given set point. Based on the difference, the controller signal is used to increase or reduce make-up air in the dryer.

Figure 30: Typical System Used to Measure, Monitor, and Control Humidity in a Dryer



The calculator shown in Figure 31 can be used to calculate differences in make-up air and corresponding changes in energy requirement for the dryer. The calculator allows the user to change humidity in the exhaust or dryer air and estimate the expected energy savings in terms of MMBtu/year. It also estimates the energy cost reduction by using the given cost of fuel for the industrial application and the annual operating hours per year. This calculator also gives the reduction of CO_2 emissions that result from reduced natural gas use.

The calculator's results should be considered preliminary starting point for more detailed technical and economic analysis. The results are to be used as a basis for a go/no go decision for further analysis. The accuracy of the calculator's results is expected to be within plus or minus 5 percent.

Figure 31: Humidity Control Calculator

Humidity Control in Dryers and Ovens				
1	Company name	ABC Corporation		
2	Plant name or designation	LA Plant		
3	Plant address	12345 Main Street, Gabriel, CA 90878		
4	Contact name	Bob Smith		
5	Contact address	54321 First Street, North Warren, CA 90878		
6	Contact phone number and e-mail	Phone:	916-756-992	E-mail: Email: b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010		
Heating equipment description (where the energy saving measure is applied)				
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Drying oven		
9	Equipment use (e.g., textile drying, aluminum melting)	Gas fired oven		
10	Other comments if any	The oven exhaust gases are discharged from a single stack		
	Humidity Control in Dryers and Ovens			
11	Dry bulb temperature of flue gas or exhaust air	Deg. F.	200	200
12	Relative humidity (RH) value - measured	%	5	10
13	Oxygen (O_2) content of flue gas or exhaust air (dry %)	%	18	
14	Absolute humidity of exhaust gases	lb. Water vapor/lb. dry air	0.0252	0.0526
15	Heat content of exhaust gases	Btu/lb. wet mixture	74.7	103.7
16	Burner combustion air temperature	Deg. F.	75	75
17	Excess air used for burners	%	10	10.0
18	Average firing rate (heat input) from burners	MM Btu/hour	4.50	
19	Total mass flow of exhaust gases	Lbs./hour	23,163	11,433
20	Number of operating hours per year	Hours/year	6,000	6000
21	Heating value of natural gas	Btu/scf	1,020.00	
22	Mass flow of dry gases (lb./hr.)	Lbs./hour	22,579	10,831
23	Heat content of exhaust air (Btu/hr.)	Btu/hour	1,731,263	1,186,095
24	Available heat for the heating system **	%	87%	87%
25	Reduction in heat demand in the dryer (Btu/hr.)	Btu/hour	Base	627,091.83
27	Energy saved for process equipment (boiler/furnace/oven)	MM Btu/year	3,763	
28	Cost of energy (natural gas)	$/MM Btu	$6.00	
29	Energy cost savings	$/year	**$22,575.31**	
30	CO_2 emission reduction	Tons/year	**220.11**	

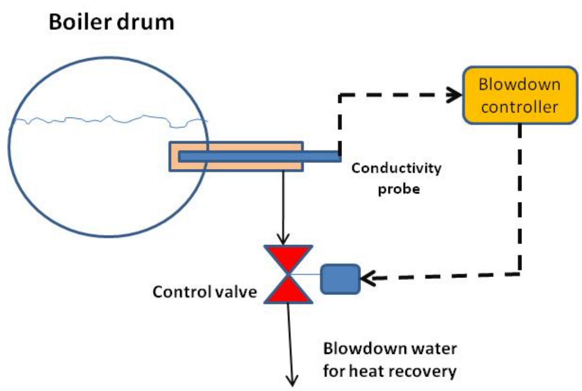
2.10 Reduction of Boiler Blowdown Water (Tool #10)

This calculator tool estimates annual energy savings and associated cost savings, including reductions in CO_2 emissions through the reduction or minimization of boiler blowdown water. This calculator can identify steam drum water quality. Minimizing blowdown rate can substantially reduce energy losses, reduce the hot blowdown liquid sent to the sewer and reduce make-up water and chemical treatment costs.

As water evaporates in the boiler steam drum, solids present in the feed water are left behind. The suspended solids form sludge or sediments in the boiler. These materials degrade heat transfer. Dissolved solids promote foaming and carryover of boiler water into the steam. To reduce the levels of suspended and total dissolved solids (TDS) to acceptable limits, water is periodically discharged or blown down from the boiler. Removing mud or bottom blowdown is usually a manual procedure done for a few seconds over intervals of several hours and is designed to remove solids that settle out of the boiler water. Surface or skimming blowdown is designed to remove the dissolved solids that concentrate near the liquid surface. Surface blowdown is often a continuous process.

Insufficient blowdown may lead to carryover of boiler water into the steam, and the formation of deposits. Excessive blowdown will waste energy, water, and chemicals. The optimum blowdown rate is determined by various factors including the boiler type, operating pressure, water treatment, and quality of makeup water. Blowdown rates typically range from 4% to 8% of boiler feed water flow rate, but can be as high as 10% when make-up water is high. Reducing and controlling blowdown rate to an optimum value can substantially reduce energy losses.

Figure 32: Typical Boiler Blowdown Control System



The blowdown rate can be controlled by using an automatic blowdown control system similar to one shown in Figure 32. An automatic system uses a conductivity probe in the boiler drum and a controller that controls the boiler water quality in the drum by controlling boiler water blowdown. The blowdown-control system optimizes blowdown rates by regulating the volume of water discharged from the boiler in relation to the concentration of dissolved solids present. Automatic control systems maintain water chemistry within acceptable limits, while minimizing blowdown and reducing energy losses. Cost savings come from the significant reduction in the consumption, disposal, treatment, and heating of water.

The boiler blowdown control calculator, shown in Figure 33, can be used to estimate expected energy savings in terms of MMBtu/year by controlling and reducing blowdown water from a boiler. It also gives reduction in water use, CO_2 reduction and total cost savings, including cost of water and chemicals.

It is necessary to collect data on current boiler operating conditions. The data includes parameters such as the steam pressure, temperature, steam production rate, current boiler blowdown rate, boiler operating hours. A complete list of data required for the calculator is given in Technical Guide that can be down loaded from the Energy Commission website at the same location as the calculators.

It is also necessary to give steam properties for the given operating conditions. These can be obtained from any standard reference book, or can be selected from the steam tables given as an attachment to the tool. Figure 34 shows images of steam tables included. The user can also use the following website for getting steam properties required for the use of this tool.

The website for steam properties calculations is:

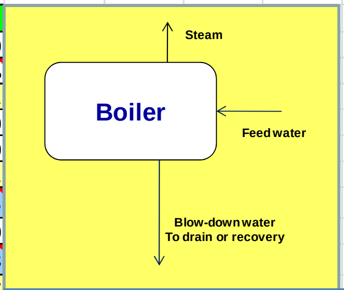
http://www.spiraxsarco.com/esc/SS_Properties.aspx?lang_id=ENG&country_id=US

Note: It may be necessary to copy and paste this link into your browser.

Figure 33: Boiler Blowdown Control Calculator

	Reduce Boiler Blowdown Water			
1	Company name	ABC Corporation		
2	Plant name or designation	LA Plant		
3	Plant address	12345 Main Street, Gabriel, CA 90878		
4	Contact name	Bob Smith		
5	Contact address	54321 First Street, North Warren, CA 90878		
6	Contact phone number and e-mail	Phone: 916-756-9923	E-mail:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010		
	Heating equipment description (where the energy saving measure is applied)			
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Boiler		
9	Equipment use (e.g., textile drying, aluminum melting)	Steam supply to process heating dryer		
10	Other comments if any	Theboiker doe not use blowdown control.		

	Reduction of Blow Down Water	
11	Steam production **(lb./day)**	300,000
12	% Reduction in Boiler blow down rate (% of steam production)	2%
14	Feedwater (steam + blowdown) lb./day	306,122
15	Boiler Pressure (psig)	600
16	Feedwater Temperature (°F)	240
17	Reduction in blow down water (lb./day)	6,122
18	Enthalpy in blow down water at boiler pressure, h_f (Btu/lb.) * from steam table	475
19	Make up water temperature (°F)	60
20	Enthalpy in make up water at temperature, h_f (Btu/lb.)* from steam table	28
21	Net heat addition in blow down water (Btu/lb.)	447
22	Boiler efficiency	75%
23	Gross heat input required for the water (Btu/lb.)	596.0
24	Total heat savings for the boiler (MM Btu/day)	3.65
25	No. of operating days per year (days/year)	360
26	**Energy savings (MM Btu/year)**	**1,314**
27	Cost of fuel ($/MM Btu)	$ 7.00
28	Annual fuel cost savings ($ per year)	$ 9,195
29	Cost of water and chemicals for make up water ($/gallon of water)	$ 0.0050
30	**Total cost savings ($/year)**	**$ 10,518**
33	**CO_2 savings (Tons/year)**	**77**
34	**Water savings (Gallons/year)**	**264,278**



Use steam tables attached to the tool

Steam Tables

or

Use other source such as a website

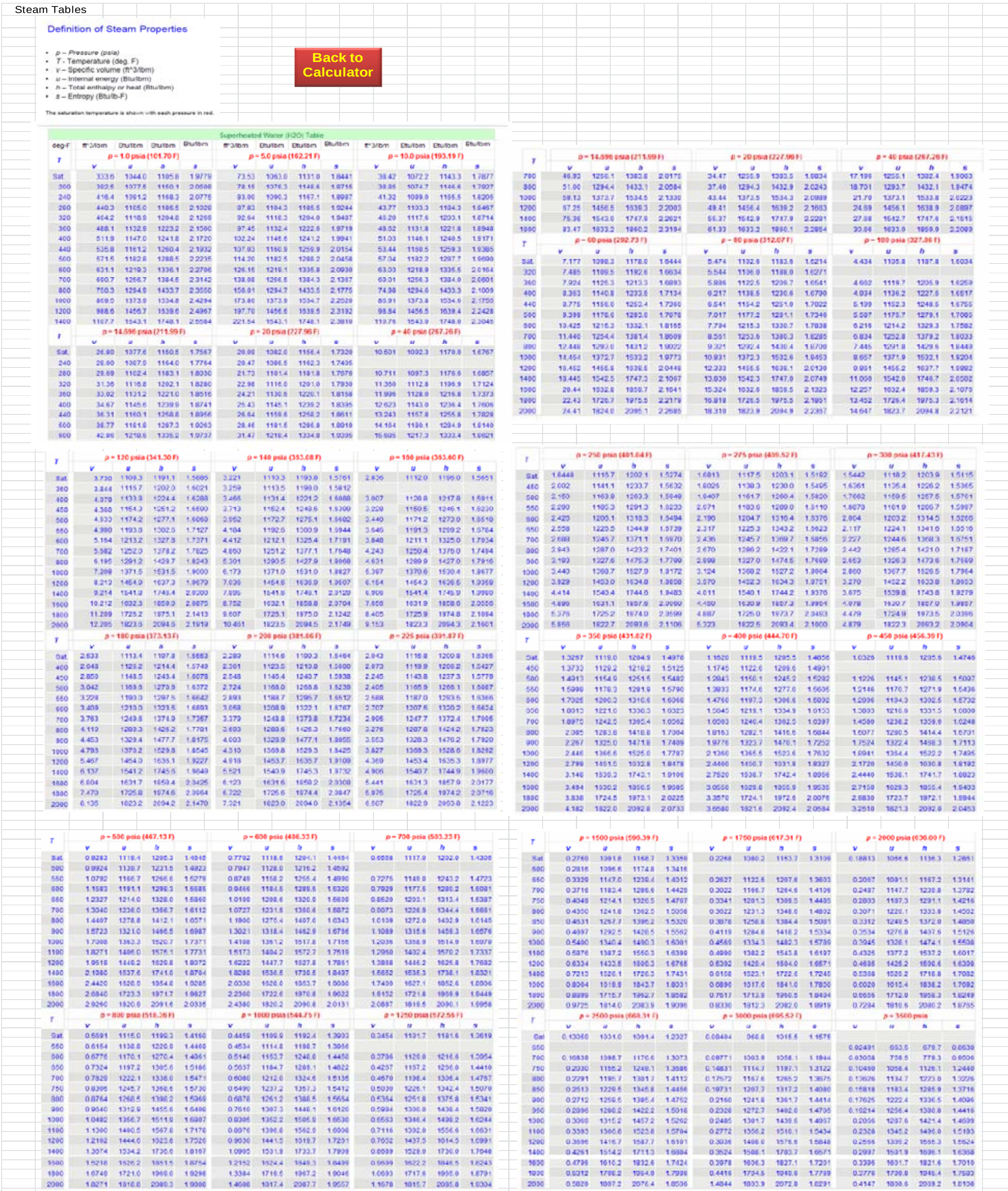
Website

Website—http://www.spiraxsarco.com/esc/SS_Properties.aspx?lang_id=ENG&country_id=US

* Note: Inputs with this color are obtained from steam tables. Make sure to use absolute pressure for looking up values (absolute pressure [psia] = psig + 14.7) while looking up this value in a steam table.

Disclaimer: The California Energy Commission (Energy Commission), its contractor, Southern California Gas Company, and its subcontractor, E3M Inc., have made reasonable efforts to ensure that all information in this publication is correct. Neither the Energy Commission, Southern California Gas Company, nor E3M Inc. shall be responsible for errors or omissions in this publication or for claims or damages relating to its use. No publications or verbal representations of the Energy Commission, Southern California Gas Company, or E3M Inc. constitute any statement, recommendation, endorsement, approval, or guaranty (either express or implied) of any product or service.

Figure 34: Steam Tables Included With the Calculator Tool



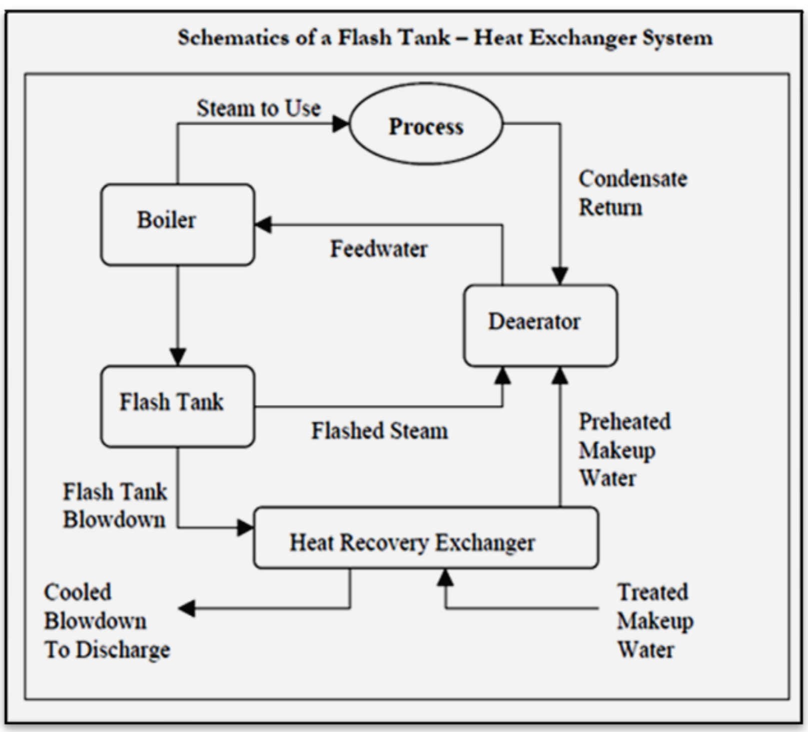
2.11 Boiler Blowdown Water Heat Recovery (Tool #11)

This calculator tool allows a user to estimate annual energy savings, associated cost savings, and reduction in CO_2 emissions through recovery of heat from boiler blowdown water.

As indicated in the previous section (2.10), blowdown water from a boiler drum is at the same temperature and pressure as the steam temperature and contains considerable heat that could be recoverable. The exact amount of recoverable heat depends on the steam pressure and the pressure at which the water is discharged from the recovery system. The waste heat can be recovered by reducing the steam pressure and recovering heat to produce lower pressure steam with residual heat in condensate discharged from the recovery system.

The blowdown heat can be recovered by a system shown in Figure 35. In this system blowdown water is collected in a flash tank where pressure is lower than the steam or blowdown water pressure. This results in generation of lower pressure steam and reduction in water mass flow since part of the water is converted to steam. Flash steam is sent to deaerator tank while the remaining water from the flash tank goes to a heat recovery heat exchanger where some heat from the water is recovered. The recovered heat is used to heat treated make-up water and preheated make-up water is used in deaerator. Cooled blowdown water is discharged in the drain or appropriate location.

Figure 35: Heat Recovery System for Continuous Boiler Blowdown Water



The boiler blowdown heat recovery calculator, shown in Figure 36, can be used to estimate expected energy savings in terms of MMBtu/year by using a heat recovery system. It also gives reduction in water use, CO_2 reduction and total cost savings, including cost of water and chemicals.

It is necessary to collect data on current boiler operating conditions. The data includes parameters such as the steam pressure, temperature, steam production rate, current boiler blowdown rate, boiler operating hours etc. A complete list of data required for the calculator is given in Technical Guide that can be down loaded from the Energy Commission website at the same location as the calculators.

It is necessary to give steam properties for the given operating conditions. These can be obtained from any standard reference book or can be selected from steam tables given as an attachment to the tool. Figure 37 shows images of steam tables included. The user can also use the following website for getting steam properties required for the use of this tool.

Website for steam properties calculations:

http://www.spiraxsarco.com/esc/SS_Properties.aspx?lang_id=ENG&country_id=US

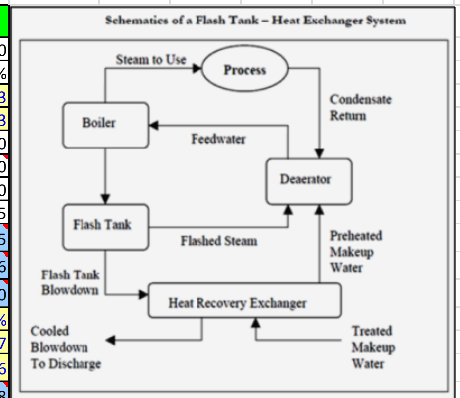
Note: It may be necessary to copy and paste this link into your browser.

Figure 36: Boiler Blowdown Water Heat Recovery Calculator

Recover Heat from Boiler Blowdown Water
(Heat recovery from continuous boiler blowdown)

1	Company name	ABC Corporation			
2	Plant name or designation	LA Plant			
3	Plant address	12345 Main Street, Gabriel, CA 90878			
4	Contact name	Bob Smith			
5	Contact address	54321 First Street, North Warren, CA 90878			
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010			
	Heating equipment description (where the energy saving measure is applied)				
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Steam boiler			
9	Equipment use (e.g., textile drying, aluminum melting)	Gas fired boiler			
10	Other comments if any	The boiler is used continuously.			

	Heat recovery from continuous boiler blowdown		
11	Steam production (lb./day)		240,000
12	Boiler blow down rate (% of steam production)		3%
13	Blowdown (lb./day)		7,423
14	Feed water (steam + blowdown) (lb./day)		247,423
15	Boiler Pressure (psig)		200
16	Feed water Temperature (live steam used) (°F)		240
17	Makeup water temperature (°F)		60
18	Flash tank pressure (psig)		5
19	Heat of blow down water at boiler pressure, h_f (Btu/lb)* from steam table		475
20	Heat of blow down water at flash pressure, h_f (Btu/lb)* from steam table		196
21	Latent heat of vaporization at flash pressure, h_{fg} (Btu/lb)* from steam		960
22	% flashed steam		29.1%
23	Flashed steam available at flash tank pressure (lb./day)		2,157
24	Heat of flashed steam at flash tank pressure (Btu/lb)		1,156
25	Heat of makeup water at temperature, h_f (Btu/lb) * from steam table		28
26	Heat available in flashed steam (Btu/lb)		1,128
27	Heat savings in flashed steam (Btu)		2,433,340
28	Temperature of flash steam condensate discharged (Deg. F.)		80
29	Heat of flash steam condensate at temperature, h_f (Btu/lb)* from steam		48
30	Heat recovery (Btu/lb)		148
31	Blowdown not flashed		70.9%
32	Heat savings from heat exchanger (Btu/day)		779,289
33	Heat savings in flashed steam (Btu/day)		2,433,340
34	Total heat savings: (Btu/day)		3,212,629
35	Boiler efficiency		75%
36	Operating days (per year)		360
37	Fuel cost ($ per MM Btu)	$	7.00
38	Savings in boiler fuel energy ($/day)	$	29.98
39	**Energy savings (MM Btu/year)**		**1,542**
40	**Annual energy cost savings ($/year)**	**$**	**10,794.43**
41	**CO2 savings (for n. gas as fuel) (Tons/year)**		**90**



Use steam tables attached to the tool

Steam Tables

or

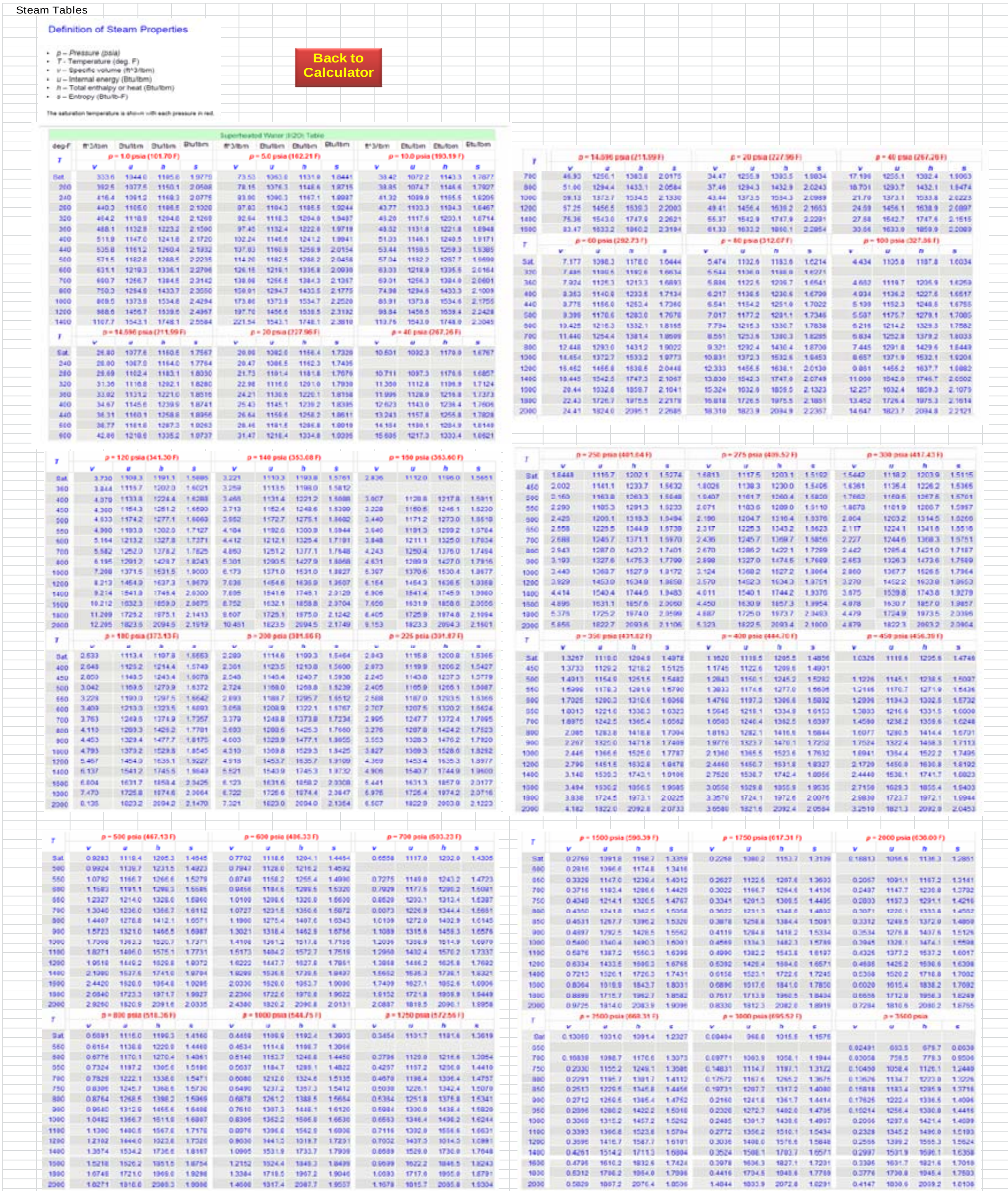
Use other source such as a website

Website

Website—http://www.spiraxsarco.com/esc/SS_Properties.aspx?lang_id=ENG&country_id=US

* Note: Value inputs with this color are obtained from steam tables. Make sure to use absolute pressure for looking up values (absolute pressure [psia] = psig + 14.7) while looking up this value in a steam table.

Figure 37: Steam Tables Included With the Calculator Tool



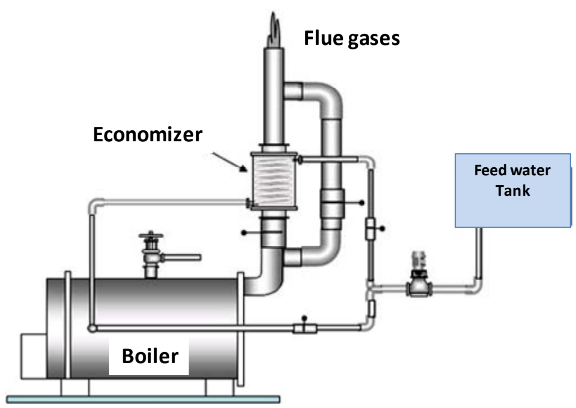
2.12 Use of Noncondensing Economizer on a Boiler (Tool #12)

This calculator tool estimates annual energy savings, associated cost savings and reduction in CO_2 emissions through use of an economizer on a boiler. An economizer is used to raise the temperature of the boiler feed water using heat from the boiler flue gases. This would lead to energy savings since the heat requirement for the boiler is reduced with use of higher temperature boiler feed water.

The calculator allows the user to estimate the savings for use of a conventional non-condensing economizer where flue gas temperature at the outlet of the economizer is maintained high enough to avoid condensation of water vapor in the flue gases. A conventional economizer is box or cylindrical shaped, and it contains finned metal tubes. Cold feed water enters on one side of the tubes and gets heated by hot flue gases passing over the tubes. Heat from flue gases is transferred to outer surface of the tubes and then to feed water in the tubes. The flue gas temperature drops as they transfer heat to the tubes and feed water.

Typical rearrangement for installation of an economizer is shown in Figure 38. In this case, an economizer is installed on a flue gas stack so flue gases pass though the economizer. Usually a bypass for flue gas is used when it is not possible to use the economizer.

Figure 38: Typical Economizer Installation for Boilers



The calculator shown in Figure 39 allows the user to estimate expected energy savings in terms of MMBtu/year for a given increase in feed water temperature or the corresponding reduction in flue gas temperature. It also estimates the energy cost reduction based on cost of fuel for the boiler and the annual operating hours. This calculator also gives the reduction of CO_2 emissions that result from the combustion of natural gas.

It is necessary to collect data on current boiler operating conditions. The data includes parameters such as the steam pressure, temperature, steam production rate, boiler flue gas temperature, current boiler blowdown rate, boiler operating hours etc. A complete list of data required for the calculator is given in Technical Guide that can be down loaded from the Energy Commission website at the same location as the calculators.

Figure 39: Boiler Economizer Calculator

Use of Non-Condensing Economizer for a Boiler			
1	Company name	ABC Corporation	
2	Plant name or designation	LA Plant	
3	Plant address	12345 Main Street, Gabriel, CA 90878	
4	Contact name	Bob Smith	
5	Contact address	54321 First Street, North Warren, CA 90878	
6	Contact phone number	Phone: 916-756-9923	E-mail: b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010	
Heating equipment description (where the energy saving measure is applied)			
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)		Boiler
9	Equipment use (e.g., textile drying, aluminum melting)		Gas fired boiler
10	Other comments if any	The boiler is used continuously.	

Use of a Non-Condensing Economizer for a Boiler

The tool is applicable to economizers and other flue-gas-to-water heat exchangers ***when the water vapor in flue gas is not condensed and heat exchanger effectiveness is known*** **.**

11	Current boiler energy use - ***average value***	25	MM Btu/hr
12	Boiler operating hours per year	7,000	Hrs./year
13	Flue gas temperature (hot-side inlet) to the economizer	450	Deg. F.
14	Oxygen in flue gas (%, dry basis) from the boiler	5.0%	%
15	Excess air (%)	29.4%	%
16	Feed water (cold-side) water flow rate	15,000	lbs./hr
17	Feed water (cold-side) water flow rate	29.99	gpm
18	Feed water (cold-side) pressure	150	psig
19	Feed water (cold-side) inlet temperature	60	Deg. F.
20	Displaced hot water (deaerator) heater efficiency (%)	80%	%
21	Economizer (Heat exchanger) effectiveness (%)	60%	%
22	Heat transferred to cold feed water	1,662,671	Btu/hr.
23	Flue gas (hot-side) outlet temperature	216	Deg. F.
24	Feed water outlet temperature	171	Deg. F.
25	Energy savings (%)	8.3%	%
26	**Annual energy savings**	**14,548**	**MM Btu/year**
27	Energy (natural gas) cost	$6.00	$/MM Btu
28	**Annual cost savings**	**$87,290**	**$/year**
29	**Annual CO2 savings based on natural gas as fuel**	**851**	**Tons/year**

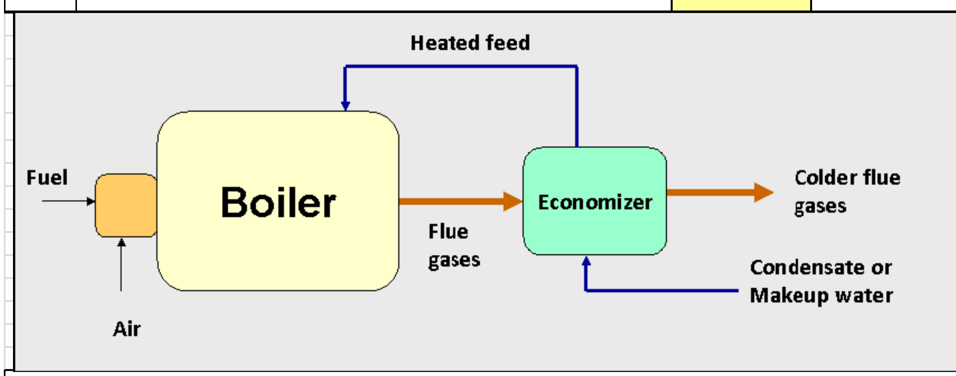


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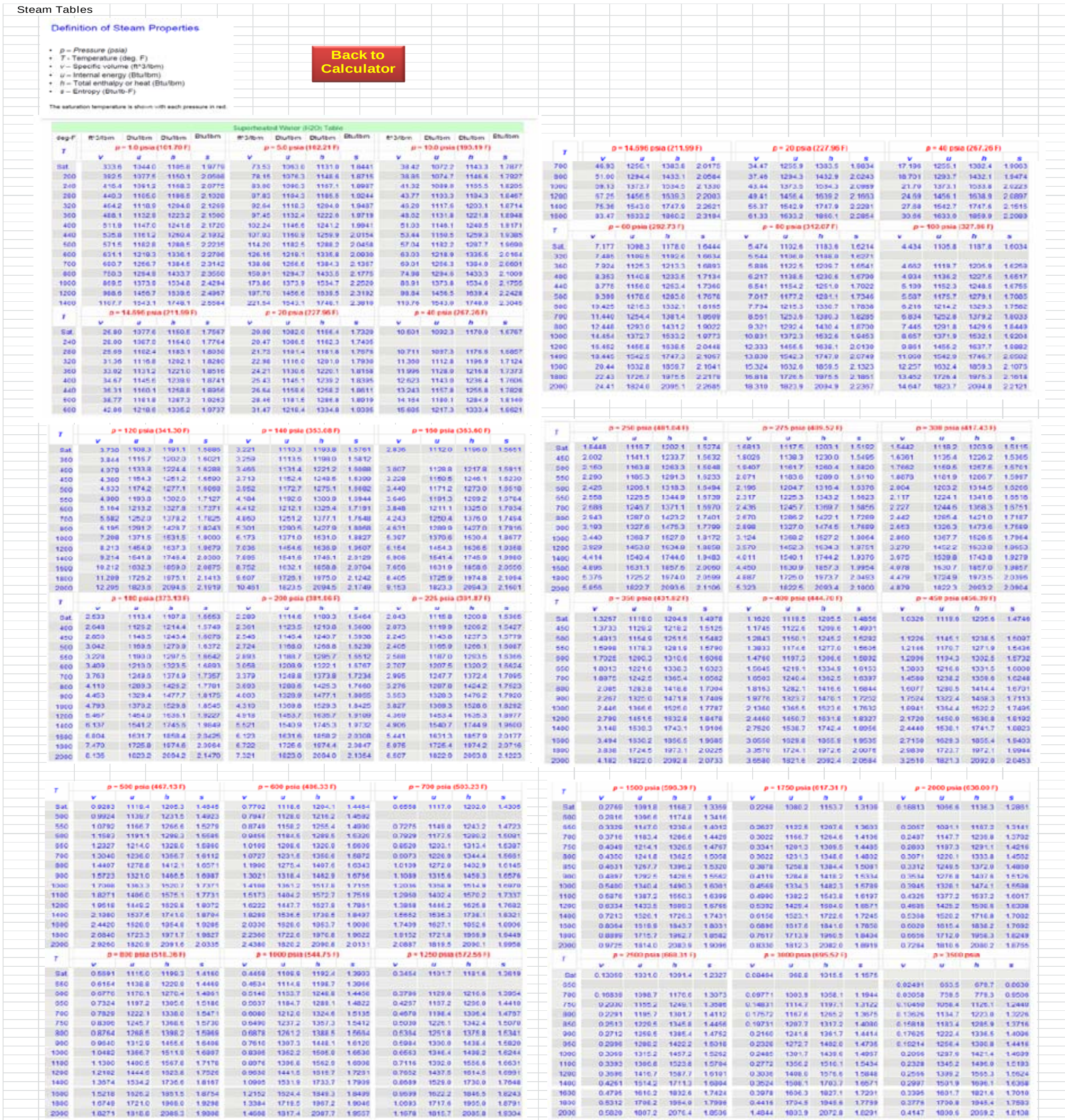
Figure 40: Steam Tables Included With the Calculator Tool



Steam properties used for the calculator can be obtained from any standard reference book or can be selected from steam tables given as an attachment to the tool. Figure 40 shows images of steam tables included with the tool.

The user can also use the following website for getting steam properties required for the use of this tool:

http://www.spiraxsarco.com/esc/SS_Properties.aspx?lang_id=ENG&country_id=US

Note: It may be necessary to copy and paste this link into your browser.

CHAPTER 3:
Description of the Technical Guides for Calculators

Technical Guides were developed to provide details on the background, technical information, input-output requirements and help on use of each of the twelve calculators. Each guide, an example of which has been provided in Appendix B, has the same format but different content that relates to the specific calculator for which the guide is developed. Each guide is structured to include the following sections.

i. Executive summary

   This section summarizes the information presented in the tool. It provides information on use of the calculator, specific results and its application areas.

ii. Note to the User of this Calculator Tool

   This note states that the user should have knowledge of certain subjects and understating of the terms used in the calculator so that correct information can be inputted during its use. References are given at the end of each guide so the user can get more information on the background for each calculator

iii. Description of the subject area.

   This section provides technical and other background information required for the tool. For example for tool no. 3, “Control Air-Fuel Ratio or Reduction of Excess Air (or Oxygen) in Flue Gases,” this section explains the importance of air-fuel ratio and its effect on energy efficiency and CO_2 emissions. This section also provides information on factors that affect air-fuel ratio and provides an explanation of important input parameters. For calculator no. 3, this section provides the impact of reducing excess air or flue gas oxygen on energy consumption and CO_2 emissions. The section may include equations or graphs necessary to understand the subject of the calculator.

iv. Discussion on the technical approach and the calculations

   This section discusses technical approach taken for calculations used for the calculator. For calculator no. 3, this section shows a typical heating system and its components with a description of the factors that affect energy consumption at different air-fuel ratios or oxygen content in exhaust gases.

v. Discussion of the effect of different parameters

   The next several sections discuss the effect of appropriate parameters on energy savings and CO_2 reduction. For Calculator 3, the sections include a discussion of energy savings through (a) control of air and fuel flow to the burners; (b) reduction of air leaks into the heating system; and (3) control or reduction of makeup air to the ovens or other heating systems. The number of sections depends on the type of calculator.

These sections include equations and other types of calculations, data sources for the parameters used in calculations and approach taken for final calculations of the resulting parameters.

vi. Instruction on use of the calculator

This section provides step-by-step instructions on how to use the tool with information on required data and where to collect or obtain it. . A list of output parameters or results is given at the end.

vii. References and Resources

A list of references and resources for the information used in the development of the calculator is given in this section.

The Technical Guide is included on the website for each calculator and it can be down loaded as a PDF document by the user.

A sample of one Technical Guide is given in Appendix A. All other guides can be accessed on the website:

http://www.gosolarcalifornia.ca.gov/tools/newCalcSys/CalculatorList.php

CHAPTER 4: Verification of the Results

The results of the tools were verified by using several methods of calculations.

For example, the result of the Available Heat tool was verified by using graphs in the most commonly used and well recognized reference book, "North American Combustion Handbook," Volume 4. The results were in good agreement (i.e. within 5%) for temperature ranges of 350^0 F to $2{,}500^0$ F. However, the low temperature range results were within 10% of the above mentioned reference. There may be many reasons for deviation, such as differences in latent heat content used in calculations.

In most cases, the results were compared with hand calculations by using equations given in several references given in the "Reference" section of each Technical Guide.. The results were in good agreement, within plus or minus 5%.

CHAPTER 5:
Compilation of Tools in One "Tool Suite"

The tools were compiled in a Tool Suite by using macros and support from the Energy Commission Information Technology team that is responsible for maintaining the Energy Commission website. The tool suite was then converted into a web-based format that allowed downloading of the calculators in Excel format. The web version included provisions for appropriate record keeping.

The Tool Suite is posted on the following website.

http://www.gosolarcalifornia.ca.gov/tools/newCalcSys/CalculatorList.php

The tool suite page includes:

1. Names of the twelve calculators;
2. A short description of each calculator with a link to the Technical Guide;
3. Registration before the calculator can be downloaded. Figure 41 shows an image of the registration form. It is also possible to download all calculators by using the link "Register to Download." The registration information required is minimal, and it is used to keep a record of how many times the calculators are downloaded and who has downloaded it. The information is transmitted to Energy Commission and Sempra project managers.

The tools can be downloaded as an individual calculator or as a complete set of tools.

Figure 41: Registration Form Image

Registration

Customer Registration Form (needs to be filled out to download Excel file)

	First Name	Last Name
Customer :		
Organization Name :		
Phone No :		
Email :		

Submit Reset

Disclaimer :

Important: Information you provide will be used internally by the Southern California Gas Company and the California Energy Commission to evaluate user response and the success of this online calculator tools project. You may be contacted by Southern California Gas Company or California Energy Commission evaluators to provide feedback and comments on the calculators you downloaded. All personal information will be kept confidential and WILL NOT be distributed to any other government agency or any outside party. We hope that you will find these calculators useful and they help you to initiate energy efficiency projects within your organization. Thank you for your cooperation.

CHAPTER 6
Preparation of Training Material

The training material was prepared in the form of PowerPoint presentations and includes details of each tool with reference to Technical Guides. The PowerPoint presentation can be used during training of technical and management personnel who can use these tools for a variety of purposes.

The presentation has been used in training workshops for the Sempra – Southern California Gas Company account executives and engineers on a trial basis. It also provides an opportunity to receive feedback and suggestions for revisions by the workshop attendees.

The presentation includes the following topics:

- Training objectives
- Training schedule
- List of tools
- Common items for all tools
- Tools presentation: Topics for each tool
- Technical background for the tool
- Demonstration of the tool with discussion on input parameters and sources of data
- Results, output parameters and use of results
- Hands on exercise for selected tools (time permitting)

The basic training is designed for delivery in one session of 7 to 8 hours. Typically a session may start at 8:00 to 8:30 AM and end at 4:30 PM to 5:00 PM, with one hour break for lunch and two breaks of 15 minutes each.

The attendees are required to download the tools from the Energy Commission website mentioned earlier. The attendees are also encouraged to use one or more tools during the training session.

The presentation can also be used for future web casts where the session length is limited to 1.5 to 2 hours and the entire training is delivered in 3 to 4 sessions.

Figure 42 shows an overview of the tools provided on the Energy Commission website.

Figure 42: List of Calculators on the Energy Commission Website

List of Industrial Energy Efficiency Calculators

This site will provide you access to various hands-on calculators. You will find technical descriptions of each calculator and links to download actual calculator as MS Excel file

Register to Download All

Calculator Name	Short Description	
Control-Air-fuel ratio control	This calculator tool allows user to estimate annual energy savings and the associated money (US dollars) savings, and reductions in CO2 emissions through control of air-fuel ratio for the combustion system or burners used to supply heat to a furnace, boiler, oven or any other type of heating equipment. More...	Register to Download
Calculate available heat	This calculator tool allows user to calculate available heat for gaseous fuels used in industrial heating processes. More...	Register to Download
Eliminate or reduce opening heat loss	This calculator tool allows a user to estimate annual energy savings and the associated money (US dollars) savings and reduction in CO2 emissions when radiation heat loss from heating equipment is reduced. More...	Register to Download
Control humidity for a dryer	This calculator tool can be used to estimate annual energy savings and the associated money (US dollars) savings and reductions in CO2 emissions through monitoring and control of humidity in a dryer zone for industrial dryers. More...	Register to Download
Preheat loads using heat from exhaust gases	This calculator tool allows user to estimate annual energy savings and the associated money (US dollars) savings and reductions in CO2 emissions for a case where heat from flue gases is used to preheat load or charge material for a furnace. More...	Register to Download
Monitor and Control lower explosion or flammabilit	This calculator tool allows user to estimate annual energy savings and the associated money (US dollars) savings and reductions in CO2 emissions through monitoring and control of lower flammability or explosion limits, commonly referred to as LFL or LEL. for industrial process ovens. More...	Register to Download
Minimize wall surface heat losses	This calculator tool allows a user to estimate annual energy savings and the associated money (US dollars) savings and reductions in CO2 emissions through reduction in heat losses from the outside wall surfaces of a heating system such as a furnace, boiler, or oven. More...	Register to Download
Use preheated combustion air for burners	This calculator tool allows a user to estimate annual energy savings and the associated money (US dollars) savings and reduction in CO2 emissions through use of preheated combustion air for industrial heating applications and boilers. More...	Register to Download
Recover heat from boiler blowdown water	This calculator tool allows a user to estimate annual energy savings and the associated money (US dollars) savings and reduction in CO2 emissions through recovery of heat from boiler blowdown water. More...	Register to Download
Reduce boiler blowdown water	This calculator tool allows a user to estimate annual energy savings and the associated money (US dollars) savings, reduction in CO2 emissions and reduction in makeup water requirenment through control and reduction of of boiler blowdown water. More...	Register to Download
Use an economizer for a boiler	This calculator tool allows a user to estimate annual energy savings and the associated money (US dollars) savings and reduction in CO2 emissions through use of an economizer on a boiler. More...	Register to Download
Generate power from waste heat	This calculator tool allows a user to estimate annual energy savings and the associated money (US dollars) savings and reduction in CO2 emissions through recovery of heat from flue gases or other types of waste heat streams in the form of liquid or gases to generate electric power. More...	Register to Download
Develop sankey (heat balance) diagram	This diagram generates Sankey diagram with the percentage of duty as a mean of various sizes of arrows. Selectable Mono-color or Multi-color arrows can be made via API called. More...	Register to Download

CHAPTER 7: Summary and Recommendations

This project resulted in development and demonstration of software tools for energy savings and reduction of greenhouse gases, specifically CO_2 emissions, from natural gas fired heating systems extensively used by California industries.

The project resulted in the development of 12 web-based software and desktop tools to aid California industries to identify, analyze and prioritize energy (i.e. natural gas and other alternate energy sources) savings opportunities. Each of the tools has a Technical Guide that explains the background of the tool and gives guidance on use of the tool. The software tools are a compilation of web-based calculators and are posted on the Energy Commission website and are available for use by all California industries.

The tools list contains many energy efficiency improvement measures or projects with a proven history of energy savings, cost reduction, and CO_2 reductions. These tools address the areas of process heating and steam generation. These two areas represent the primary uses of natural gas in California industry. Combined, these two uses account for about 85 percent of industrial natural gas use and represent major opportunities to reduce natural gas use in California industries.

The tools are available for downloading at the Energy Commission website

http://www.gosolarcalifornia.ca.gov/tools/newCalcSys/CalculatorList.php

This website contains brief instructions on the tools and associated technical guides.

It is recommended that the Energy Commission, in collaboration with California utilities, develop and execute plans for on-line training and support using these tools to stakeholders such as industrial companies, energy consultants and academic professionals. Knowledge and use of these tools can provide a simple and effective method of identifying energy opportunities and associated energy saving measures. Use of these tools will allow the engineers and operating plant personnel to present a case for implementation of energy saving measures with economic and technical support to their management.

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APPENDIX A:
Energy Efficiency Calculator Tools: First Critical Project Review Meeting
March 9, 2010 – The Southern California Gas Company (Downey, California, facility)

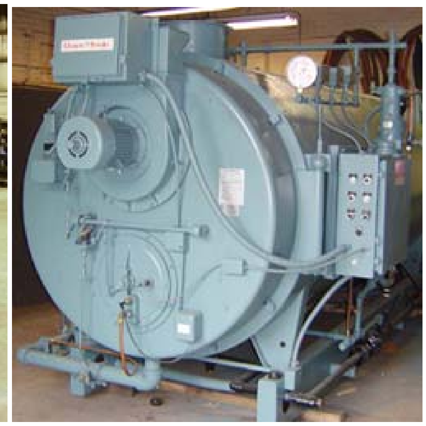
Agenda

1. Agenda check
2. Updates on calculator tools / project progress
3. Any foreseeable problems w/ project schedule, deliverables, or budget
4. Applicability of this tool suite to on-site industrial assessments by Energy Commission staff
5. Other items
6. Summary of any actions identified during the meeting, due dates for these actions, and identification of responsible parties

APPENDIX B:
Example of a Technical Guide for Calculator No. 3

Reduction of Oxygen (O_2) in Oven or Furnace Exhaust (Flue) Gases

For Industrial Heating Equipment and Boilers



Prepared for California Energy Commission (Energy Commission)

Prepared By:

Southern California Gas Company

(A Sempra Energy Utility)

E3M Inc.

May 2012

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Executive Summary

This calculator tool can be used to estimate annual energy savings and the associated cost (US dollars) savings, and reductions in CO_2 emissions through reduction of oxygen (O_2) level (also known as excess air) within the flue gases from burners that supply heat to a furnace, boiler, oven or other type of heating equipment used by industrial facilities. Energy savings estimates apply for cases where the oxygen (O_2) level of the flue gases is reduced while maintaining safe and efficient combustion conditions within the heating system. A reduction in O_2 level within flue gases represents a reduction in the total mass flow of exhaust gases and a reduction in energy wasted from the heating system. Flue gas O_2 levels can be reduced through reductions in excess combustion air, air leaks in the system, additional make up air, etc.

This calculator estimates the annual expected energy savings in terms of million British thermal units per year (MMBtu/year). It also estimates the energy cost reduction by using the cost of fuel for the industrial application and the operating hours per year. The amount of CO_2 emissions reduced is also estimated using natural gas as the sole fuel source.

The primary objective of this calculator is to identify energy savings potential in industrial heating operations to make a go / no go decision on further detailed engineering and economics analysis. The user is required to give data for several operating parameters that can be measured or estimated from normal operating conditions using available records. All data should be collected at typical or average unit operating conditions.

The calculator's results should be considered preliminary estimates of energy savings potential and a starting point for more detailed technical and economic analysis. The accuracy of the calculator's results is expected to be within ±5%.

Note to the User of this Calculator Tool

Use of this tool requires knowledge of combustion and operation of heating systems such as a furnace, oven, heater, boiler, kiln, dryer etc. The user is referred to several training programs and references quoted at the end of his document for further information on the available resources for getting trainings that would provide additional knowledge for the subject matters discussed in this document.

The following terms are used interchangeably in this document. The terms furnace or heating system represent many different types of equipment used by the industry. They include furnaces, boilers, heaters, ovens, kilns etc. The term combustion system is also used to represent fuel firing systems including burners and furnaces as defined above. The term flue gas can be used interchangeably with combustion products and stack gas.

Description of the Subject Area

This work paper describes a calculator tool that will allow a user estimate annual energy (fuel) savings, reductions in CO_2 emissions, and energy cost savings ($/year) by controlling the air-fuel ratio (and corresponding excess air) entering a heating system (boiler, furnace, oven, heater, kiln etc.) the system from any other source.

The air-to-fuel ratio refers to the proportion of air and fuel present during combustion. The chemically optimal point at which combustion is most efficient is called the stoichiometric air-to-fuel ratio (also referred to 100% theoretical air). In theory, a stoichiometric mixture has just enough oxygen available to completely burn the available fuel. In practice, complete combustion at 100% theoretical air is never quite achieved, due to incomplete mixing of the fuel and the air and requires additional air to complete combustion. Excess air is defined as the air flow in excess of the stoichiometric air-to-fuel ratio. This value is expressed as a percentage of 100% theoretical air, i.e., if the air-to-fuel ratio is 1.1 times the stoichiometric air-to-fuel ratio, the excess air is 10% of theoretical air.

Reducing excess air offers an opportunity to save energy. Operating a heating system with an optimum amount of excess air will minimize heat loss via the flue gases. The flue gas temperature and flue gas oxygen (or carbon dioxide) concentrations are primary indicators of the combustion efficiency (or available heat) of the system. Given complete mixing, a precise or stoichiometric amount of air is required to completely react with a given quantity of fuel. In practice, combustion conditions are never ideal, and additional or “excess” air must be supplied to ensure complete combustion of the fuel. The current level of excess air within the flue gas can be determined from analyzing the flue gas oxygen or carbon dioxide concentrations. Inadequate excess air levels result in unburned hydrocarbons, soot, and carbon monoxide; while too much excess air results in heat loss due to excessive flue gas flow -- thus lowering the overall efficiency. On well-designed natural gas-fired systems, an excess air level of less than 10% is attainable.

The focus of this tool is on the reduction of natural gas consumption for industrial processes by reducing excess air present in the flue gasses. There are three main strategies to reduce excess air:

- Control of air-fuel ratio to the burners – This strategy focuses on reducing the excess flow of combustion air to the burner while maintaining the required air-fuel ratio for complete combustion of the fuel.
- Control or reduce of air leaks – This strategy involves blocking leaks in the envelope of the furnace, oven, or other process heating system that allows ambient air to be drawn into the system due to a negative pressure within the system.
- Control of makeup air – This strategy involves increasing the control over the amount of makeup air allowed into a heating unit. This strategy only applies for specific systems (certain types of ovens, kilns, etc.).

A brief summary of the important calculation parameters follows:

- Flue gas temperature – The temperature of the flue gases exiting the process before and after implementation of the efficiency measure.
- Oxygen concentration in flue gas – The percentage of oxygen in the flue gas (measured on a dry basis) before and after implementation of the energy saving measure.
- Combustion air temperature – The temperature of the combustion air (which is the air mixed with fuel in the burner) before and after implementation of the efficiency measure.
- Fuel consumption per hour (MMBtu/hour) – The average estimated hourly consumption of natural gas (or other type of fuel) by the baseline combustion system (furnace, oven, kiln, etc.). This should be based on a recent 12-month consumption period (MM Btu/year).
- Number of operating hours (hours/year) – The number of hours for which the equipment is operated. This cumulative amount of operational hours should be based on a recent 12-month period.
- Cost of fuel – The average fuel cost ($/MM Btu) based on the past history and, if possible, future projected cost based on contacts with the energy supplier.

Impact of excess air reduction on energy savings and CO_2 emissions

This calculator allows a user to estimate energy (fuel) savings that can be achieved by reducing and controlling the amount of excess O_2 in the flue gases discharged from a heating system. These fuel savings result in a reduction of CO_2 emissions. The combustion of all commonly used fossil fuels (such as natural gas) results in the formation of CO_2. The amount of CO_2 emissions reduced is directly proportional to the natural gas reduction of an energy saving measure.

This calculator is designed to give energy savings estimates with the assumption that the industrial process uses natural gas as fuel. The actual savings in fuel consumption and the associated energy costs depend on several operating parameters. Parameters include:

- Average firing rate (fuel used per hour)
- Temperature of exhaust gases leaving the heating unit
- Amount of excess air used for combustion (as represented by presence of oxygen on a dry basis) in the exhaust gases
- Number of operating hours per year
- Average temperature of the combustion air entering the heating system
- Cost of fuel in terms of $/MMBtu

The energy savings estimates can vary from 5% for low-temperature processes to as high as 20% for high-temperature processes by controlling the air-fuel ratio at the burner. However, it should be noted that savings can be substantial for measures that reduce or eliminate air leaks into the heating system and measures that control the amount of makeup air used in processes that require large supplies of air. The exact value of the energy savings at specific values can be estimated using this calculator.

The CO_2 savings are directly related to energy savings. According to U.S. Environmental Protection Agency (EPA) estimates (Reference 5), the combustion of natural gas used in USA produces 116.39 lbs. of CO_2 per MM Btu heat input. For convenience, most calculations use 117 lbs. CO_2 emission per MM Btu heat input from natural gas. If the natural gas composition is available, it is advisable to carry out detailed combustion calculations to estimate more accurate values for the CO_2 produced by the combustion of natural gas. Reduction in CO_2 emissions is calculated by using the value of reduction in energy (fuel) used for the furnace.

Annual energy cost savings depends on the cost of energy, expressed as US dollars per MM Btu, and the total energy savings estimated using the calculator.

Discussion on the technical approach and the calculations

Reducing the amount of excess air within the flue gas will result in energy savings while maintaining the desired heat output or temperature (whichever is desired) within the heating unit. The annual energy savings (MM Btu/year) is the difference between the annual energy use by the baseline system and the annual energy use by the heating system after the implementation excess O_2 control measures. In all cases involving excess air reduction, an essential step is to determine the amount of excess O_2 present in the flue gas during normal operating conditions before and after implementation of the measure. This requires the measurement of the combustion air temperature, flue gas temperature, and oxygen concentration with a flue gas analyzer.

The excess air reduction calculator (tool) can be used to estimate energy savings. This calculator also calculates the combined gas savings resulting from reducing the excess air levels within the stack in addition to preheating the combustion air.

A schematic diagram of the combustion system considered in the excess air calculation is illustrated in Exhibit 1. In this analysis, the excess air includes the combustion air entering through the burner, make up air if used, and air leaks into the system. The flue gas (including combustion products and extra air that has not been used for combustion of the fuel) exits the heating system chamber through the stack. Amount of O_2 in flue gas is an indication of excess air. This tool allows the user to calculate excess air combined from all sources, available heat (or "combustion efficiency"), and potential energy savings.

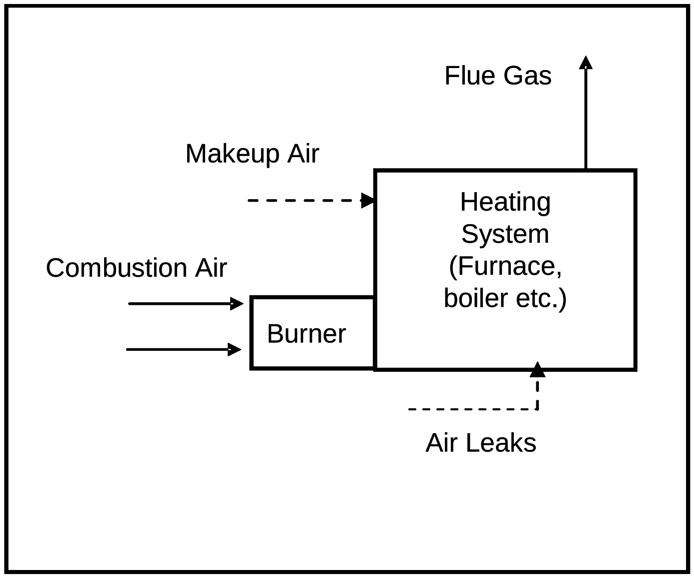

Exhibit 1: Combustion system diagram

In the following section we discuss how to control or reduce excess air for a process heating system and energy savings associated with each source of excess air.

Burner air-fuel ratio adjustment for excess air control

The simplest method to reduce excess air for a burner is to adjust flow of natural gas and/or the combustion air flow rate to the point that CO emissions are near the upper limit acceptable for flue gas emissions while still containing excess O_2 in combustion products. In practice this means controlling air and gas (or other fuel) flow so that the air flow is approximately 10% higher than the stoichiometric amount of air required for the fuel to completely burn. Note that it may not always be possible to adjust a burner to get low value of CO and use 10% excess air for a burner by measuring O_2 content of flue gas, particularly for multi-burner systems, since it is not possible to distinguish combustion products from each burner and the flue gas may contain additional air from other sources. Exact method of the burner air-fuel ratio adjustment depends on the type of burner used and the method of air – flow metering, if any, available for the system. Due to complexity of the adjustments and safety considerations it is strongly advised that the adjustment is made only by the heating system supplier, the burner or combustion system supplier or the experienced and qualified personnel.

Energy savings from reducing air infiltration or air leaks

The pressure in a heating system can be slightly negative (also known as draft) which results from the use of a chimney (or stack) or through the use of an induced draft (ID) fan. This results in ambient air flowing into the system through openings in the system's envelope (inspection ports, doors, feeders, cracks in the walls, bad seals etc.). This air is mixed with combustion products from the burner and increases O_2 content of flue gas. The air also has to be heated to the flue gas temperature before it leaves the system. The heat needed to raise the infiltration air from ambient temperature to the flue gas temperature is provided by the burner. By reducing the infiltration air flow rate, fuel can be saved at the burner. Several methods are used to reduce or eliminate air leaks. They include installing pressure controls, reducing or eliminating openings, and minimizing usage of doors or other operations that result in air leaks in the system.

Energy savings through controlling makeup air

Certain types of ovens or dryers used for processes in which organic solvent or water vapors are formed require makeup air to control the concentration of vapors within the heating system. The required amount of makeup air depends on various vapor characteristics including vapor discharge rate, lower flammability limit, etc. Makeup air mixes with combustion products from the burner and increases O_2 content of flue gases. The makeup air has to be heated to the flue gas temperature before it leaves the system. The heat needed to raise the makeup air temperature from ambient temperature to the flue gas temperature is provided by the fuel used in the burners. Controlling makeup air, will reduce mass of air entering the process and ultimately reduce energy usage.

Several methods are available to control make up air for ovens and dryers that have process or safety requirements. They include:

i. Using LEL (Lower Explosion Limit) or LFL (Lower Flammability Limit) probes that are used measure LEL levels in order to control makeup air for heating units that produce flammable vapors

ii. Using a humidity probe to control relative humidity or dew point within exit flue gases

    For most heating units, it is necessary to use some amount of makeup air and it is not possible to maintain 2% O_2 in flue gases while still operating safely. In such cases it may be possible to adjust the burners to operate at 2% O_2 in combustion products; however, the oxygen content of flue gases will be significantly higher than 2% due to make up air requirements. Adjusting the burners to achieve 2% O_2 in the stack while makeup air is being supplied to the unit can result in fuel rich operation of the burners and cause unsafe operating conditions. Any equipment supplier should be contacted to determine that sufficient air is being used to meet the process and safety requirements.

The energy savings and associated CO_2 emission reduction are calculated for most commonly used hydrocarbon fuels such as natural gas. The savings are calculated for a system in which excess air (represented by O_2) content in the flue gases is reduced. In these calculations, the system heat demand consists of several areas of heat requirement in a typical heating system (listed in the figure) that must remain constant.

The energy savings are based on changes in the reduction of heat contained within the flue gases and hence change (increase) in "available heat" for the heating system.

The term "available heat" is defined as difference in heat input and the heat content of exhaust gases leaving the furnace system. It is usually expressed as percentage (%) and represents the amount of heat remaining in a furnace as a fraction of the heat input to the furnace.

The following symbols are used in the equations below:

H_f = Furnace heat demand (Btu/hr)

H_{av} = Available heat (Btu/hr)

H_{in} = Heat input in the furnace (Btu/hr)

H_{ex} = Heat content of exhaust gases leaving the heating system or furnace (Btu/hr)

$Avht(\%)$ = Percent available heat

The total heat input is: $H_{in} = H_f + H_{ex}$

The available heat is: $H_{av} = H_{in} - H_{ex}$

$$H_{ex} = H_{in} - H_f$$

$$H_{av} = H_f$$

Available heat is expressed as a percentage is used as a good indication of performance of a heating system and it is given as

$$Avht(\%) = 100\% \times \frac{H_f}{H_{in}}$$

Therefore $H_{in} = 100\% \times \frac{H_f}{Avht(\%)} \left(\frac{Btu}{hr}\right)$

With the use of reduction in flue gas O_2, we can consider two different operating conditions. One condition is when the O_2 content of flue gases is high resulting in lower available heat [$Avht_{h_l}(\%)$ or H_{ex_l}] and another condition when the O_2 content of flue gases is lower resulting in higher available heat [$Avht_h(\%)$ or H_{ex_h}]. Correspondingly, the heat input will be higher heat input (H_{in_h}) or lower heat input (H_{in_l}) and the available heat percentages will be $Avht_l(\%)$ and $Avht_h(\%)$.

Note that in each case, the furnace heat demand is considered constant at H_f. For each case, the exhaust gas heat content is defined as H_{ex_c} and H_{ex_h} respectively.

Hence

$$H_{in_h} = 100\% \times \frac{H_f}{Avht_{h_l}(\%)}$$

$$H_{in_l} = 100\% \times \frac{H_f}{Avht_h(\%)}$$

The change in heat input (fuel) in terms of Btu/hr between the two different conditions is

$$H_{save} = H_{in_h} - H_{in_l} = 100\% \times H_f \times \left(\left(\frac{1}{Avht_l(\%)} \right) - \left(\frac{1}{Avht_h(\%)} \right) \right)$$

So the change in the heat input, or fuel, in terms of percentages is

$$H_{save}(\%) = \left(\frac{[H_{in_h} - H_{in_l}]}{H_{in_h}} \right) \times 100\%$$

$Avht(\%)$, the available heat expressed as a percentage, depends on the following variables:

- Fuel composition
- Exhaust gas temperature
- Combustion air temperature
- Percent oxygen (dry) within the exhaust gases.

Available heat can be calculated by using combustion calculations for a given fuel. For this excess air calculator tool, these calculations use a typical natural gas composition as found in California.

The natural gas composition used for calculations in this tool is given below. Note that the user gives the composition in the column marked “By Volume”. If the values in column “By Volume” do not add up to 100% the program will adjust the percentages under column “Adjusted by Volume” to total to 100% by changing the value of each component proportionately. In most cases the total under column "By Volume" is not equal to 100% due to rounding error.

Fuel Gas Analysis (See note below)		
Gas composition	**By volume**	**Adjusted by volume**
CH4	94.10%	94.241%
C2H6	2.40%	2.404%
N2 and other inert	1.41%	1.412%
H2	0.03%	0.030%
C3H8	0.49%	0.491%
C4H10 + CnH2n	0.29%	0.290%
H2O	0.00%	0.000%
CO	0.42%	0.421%
CO2	0.71%	0.711%
SO2	0.00%	0.000%
O2	0.00%	0.000%
Total of fuel components	99.85%	100.000%
Difference	0.15%	0.00%
Note: The fuel gas composition is in volume %. The higher hydrocarbons in fuel are treated as same as C4H10 and all other inert gases are treated as N2.		

Exhibit 2: Composition of natural gas used for calculations

For this calculator, the "higher heating value" or "gross heating value" of the fuel is used. The higher or gross heating value for commonly used natural gas with the composition shown in Exhibit 2 is 1,020 Btu per standard cubic foot (scf). The natural gas heating value varies from 970 Btu/scf to as high as 1,200 Btu/scf depending on location and time of year. In many situations 1,000 Btu/scf is considered a good approximation. Note that minor changes in the heating value have very little effect on the savings achieved with changes (usually reduction) in excess air.

It is recognized that natural gas composition may vary somewhat during the year or from location to location. However, a series of calculations shows that the variation in natural gas composition has a very small effect on the available heat as a percentage of the heating value. The changes in available heat are within a narrow range and the error for this value is relatively small (within ±5%). Thus, we advise users of this calculator that the accuracy of its estimates will be in the same order of magnitude, i.e. ±5%. A separate calculator is available to calculate the exact value of available heat when the fuel composition is known or when the natural gas composition is significantly different than the composition shown in Exhibit 2. Further discussion on available heat and the effect of fuel composition is discussed in References 1 and 2.

The reduction in energy or heat used for a furnace by reducing excess air level can be estimated by calculating changes in available heat temperature. The following equations show the calculation method used for this calculator.

The annual energy cost savings can be calculated with the following equation.

$$Energy\ cost\ savings\ = \frac{H_{annual} \times *\ Cost\ of\ fuel\ expressed\ in\ terms\ of\ \left(\frac{\$}{MMBtu}\right)}{1{,}000{,}000\ \frac{Btu}{MMBtu}}$$

The CO_2 savings can be calculated by using the fuel combustion calculations or by using the EPA guidelines for CO_2 generation calculations. Reference 5 gives details of United States Environmental Protection Agency guidelines.

$$Estimated\ CO_2\ savings\ \left(\frac{short\ tons}{year}\right) = \frac{\left(117\ \times Annual\ energy\ savings\ \left(\frac{MMBtu}{year}\right)\right)}{2{,}000}$$

Instruction on use of the calculator

The following list summarizes the user inputs that are required. The user should collect this information before using this calculator tool.

- Company name, plant location and address
- Customer name and contact information
- Heating equipment description (where the energy-saving measure is applied)
- Equipment type (furnace, oven, kiln, heater, boiler)
- Equipment use (e.g., textile drying, aluminum melting, food processing)

  Note that some of this information may be optional for the web-based calculators due to users' concerns about privacy.
- Flue gas temperature at the stack where flue gas analysis is taken (°F)
- Oxygen in flue gas (%, dry basis)
- Combustion air temperature (°F)
- Current fuel energy input (MM Btu/hr)
- Fuel (energy cost) in terms of $ per MMBtu
- Number of operating hours per year

The calculator gives following results:

- Excess air in flue gases (%)
- Available heat for the furnace (%)
- Heat (energy) used per year (MMBtu/year)
- Heat (energy) savings per year (MMBtu/year)
- Energy cost savings per year ($/year)
- CO_2 savings per year (tons/year)

Note that the CO_2 savings are based on natural gas as the fuel for the heating equipment. A correction factor must be applied if any other fuel is used.

The excess air reduction calculator requires the following input parameters describing the heating process in order to estimate the savings. Exhibit 3 shows the user information screen and Exhibit 4 shows the calculator screen.

The first section requires information about the user, equipment, and process.

Control Air-Fuel Ratio **(Reduction of Excess Air [or Oxygen] in Flue Gases)**						
1	Company name	ABC Corporation				
2	Plant name or designation	LA Plant				
3	Plant address	12345 Main Street, Gabriel, CA 90878				
4	Contact name	Bob Smith				
5	Contact address	54321 First Street, North Warren, CA 90878				
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com	
7	Date (format mm/date/year)	May 12, 2010				
Heating equipment description (where the energy saving measure is applied)						
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)		Gas fired furnace			
9	Equipment use (e.g., textile drying, aluminum melting)		Continuous metal heating furnace			
10	Other comments if any	The burners are nozzle mix type with proper equipment to adjust fuel air ratio.				

Exhibit 3: Required information for the calculator user

Line 1 – Name of the company

Line 2 – Name or known designation such as "main plant" or "secondary plant" if applicable

Line 3 – Plant address

Line 4 – Contact name for the plant – This is the individual who is main contact and is responsible for collecting and providing the required information.

Line 5 – Address for the contact person

Line 6 – Contact phone number and e-mail to be used for all future communications

Line 7 – Date when the calculations are carried out.

Line 8 – Type of heating equipment – This is the heating equipment where data is collected and the given energy saving measure is to be applied.

Line 9 – Process or function for which the heating equipment is used – This can be name of the process such as drying, melting, water heating, etc.

Line 10 – Any additional information or comments that can be useful

The second section of the calculator is used for collecting the necessary data and reporting the estimated savings.

As shown in Exhibit 4, there are two columns for the calculator. The "Current" column represents the conditions or data collected as average values for each of the parameters. Details of the data are given below. Data for the "Modified" conditions represents the values for each of the inputs after excess air control measures are implemented. The cells in the calculator are color coded. The white cells are used for data input by the user. The colored (yellow and light blue or green) cells are protected and give results of the calculations. The user is not allowed to change the numbers shown in the colored cells.

In most cases, the only input parameter that will change is combustion air temperature. All other values will be the same as the "Current" conditions.

Control Air-Fuel Ratio or Reduction of Excess Air (or Oxygen) in Flue Gases			
		Current	New
11	Furnace flue gas temperature (°F.)	1,200	1,200
12	Percent O2 (dry) in flue gases	8.00	3.00
13	% Excess air	55.08	14.92
14	Combustion air temperature (°F.)	70	70
15	Fuel consumption (MM Btu/hr) - Avg. current	20.00	17.32
16	Available Heat (%)	53.8%	62.2%
17	Fuel savings (%)	Base	13.39%
18	No. of operating hours (hours/year)	8000	8000
19	Heat energy used per year (MM Btu/year)	160,000	138,579
20	**Heat energy saved (MM Btu/year)**	**Base**	**21,421**
21	Cost of fuel ($/Million Btu)	$ 10.00	$ 10.00
22	**Annual savings ($/year)**	**Base**	**$ 214,210**
23	**CO2 savings (Tons/year)**	**Base**	**1,253**

Exhibit 4: Example of calculator inputs and results

Line 11 – Furnace flue gas temperature (°F) –Give the flue gas temperature as measured as close to the exit of the furnace as possible. Note that when preheating is done in an extended furnace section or unfired preheat section, this represents flue gas temperature coming out of the furnace and entering the preheat section. Obtain flue gas temperature measurements as close to the exit of the furnace as possible. The flue gas temperature should be taken when the furnace is operating at normal operating conditions from the middle of the stack. Measuring the temperature at the top of the stack or very close to the wall of the discharge duct can give erroneous reading.

Readings taken at non-average production or operating conditions can give unreliable results. Make sure that the flue gases are NOT mixed with cold air before the temperature is measured. Note that in almost all cases the flue gas exit temperature does not change when using load preheating since the furnace zone temperatures are controlled to meet the required process conditions.

Line 12 – Percent oxygen (dry) in flue gases – This value is obtained from a flue gas analysis using commonly available flue gas analyzers. These analyzers give measurements of flue gas components on dry basis in addition to other. The gas analysis sample should be taken when the furnace is operating at normal operating conditions. Readings taken at non-average production or operating conditions can give unreliable results. It is necessary to make sure that the flue gases are not mixed with cold air before the temperature is measured. Care should be taken to locate the sampling probe in the middle of the stack or area from where the flue gases are discharged.

Line 13 – Percent excess air –This is the calculated value of excess air present in the flue gases. It is calculated assuming natural gas is used as the sole fuel. However, this result is considered valid for different compositions of natural gas and for most hydrocarbon fuels.

Line 14 – Combustion air temperature (°F) – The temperature of combustion air entering the burners. In many cases it is not feasible to obtain exact air temperatures at the burner. A common practice is to use air temperature entering the combustion air blower or ambient temperature as the combustion air temperature if no air preheater is installed. If an air preheater is installed, use the air temperature exiting the recuperator or entering the burner.

Line 15 – Average current fuel consumption (MM Btu/hr) – This value should be a value based on fuel measurements over a period of time or at "average" operating conditions. It is possible to get this value if the fuel consumption data is available for a certain period of time (monthly, annual etc.) for the furnace being considered. Meter data (if used to calculate the fuel usage) must be corrected for pressure and temperature at the meter and the heat input should be calculated using gross heating value of the fuel. For most commonly used or average quality natural gas a heating value of 1,020 Btu per standard cubic foot (scf) will be a good approximation.

Line 16 – Available heat (%) – This is calculated value based on the data given above. The calculation uses the "Available Heat" tool developed as part of this tool set and assumes natural gas as fuel. The natural gas composition used for this calculation is same as that given in Exhibit 3 above.

Line 17 – Fuel savings (%) – This term is calculated using available heat and heat input data for the excess air and combustion air temperature at the current and modified conditions. The equations used for this calculation are discussed in a previous section.

Line 18 – Number of operating hours (per year) – This value represents annual operating hours of the equipment at the average firing conditions stated above.

Line 19 – Heat energy used per year (MM Btu/year) – This is calculated using the fuel consumption and the operating hours per year given in Line 15 and Line 18.

Line 20 – Heat energy saved per year (MM Btu/year) – This is the difference between the heat used per year with the current excess air and heat used per year with the excess air used after implementation of the modified conditions.

Line 21 – Cost of fuel ($/MM Btu) – The cost should include all charges related to use of fuel at "the burner tip". This value can be obtained from the monthly or annual gas bill or by dividing the total annual cost by the annual fuel used.

$$\text{Gas Cost}\left(\frac{\$}{\text{MMBtu}}\right)=\frac{\text{Total cost of gas or heat used}\left(\frac{\$}{\text{year}}\right)}{\text{Total amount of gas used}\left(\frac{\text{MMbtu}}{\text{year}}\right)}$$

If necessary contact the fuel (natural gas) supplier or distributor for more information.

Line 22 – Annual savings ($/year) – This line gives the estimated annual dollar savings resulting from reduced fuel cost.

Line 23 – Reduction in CO_2 emissions (Tons/year) – These savings are calculated based on annual fuel savings, assuming the fuel used is natural gas. The savings are in Short (US) tons, not in metric tons.

References and Resources

1. *North American Combustion Handbook,* Third Edition, 1986. Published by North American Mfg. Company, Cleveland, OH.

2. *Combustion Technology Manual*, Fifth Edition, 1994. Published by Industrial Heating Equipment Association, Cincinnati, OH.

3. *Improving Process Heating System Performance: A Sourcebook for Industry,* U.S. Department of Energy and Industrial Heating Equipment Association. Available online at

   http://www1.eere.energy.gov/industry/bestpractices/pdfs/process_heating_sourcebook2.pdf

4. *Tip sheets and Technical Briefs,* published by The U.S. Department of Energy. Available online at

   http://www1.eere.energy.gov/industry/utilities/steam_tools.html

5. *Unit Conversions, Emission Factors and Other Reference Data,* published by the U.S. EPA, November 2004. Available online at http://www.epa.gov/cpd/pdf/brochure.pdf

6. Additional information for process heating technology

   - The U. S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE) Office of Industrial Technologies (ITP) website. http://www1.eere.energy.gov/industry/
   - Sempra Energy – Southern California Gas Company website www.socalgas.com.
   - California Energy Commission website www.energy.ca.gov

APPENDIX C: Glossary

^0F	Degrees Fahrenheit
Btu	British thermal unit
Btu/scf	British thermal unit per standard cubic foot
Cf	cubic foot
CO^2	Carbon Dioxide
DOE	Department of Energy
HHV	higher heating value
HRSG	Heat recovery stram generator
Kw	kilowatts
LEL	Lower explosion Limit
LFL	Lower Flammability Limit
MMBtu/hr	Million British thermal units per hour
MMcf	one million cubic foot
MW	megawatt
NFPA	National Fire Protection Association
O^2	Oxygen
PDF	Portable Document File
PIER	Public Interest Energy Research
Psig	pounds per square inch gauge
RD&D	Research, Development and Demonstration
TDS	Total Dissolved Solids