

# Humidity Control for Drying Ovens



**Prepared for California Energy Commission (CEC)**

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## Executive Summary

This calculator tool can be used to estimate annual energy savings, associated cost (US dollars) savings, and reduction in CO<sub>2</sub> emissions through monitoring and control of humidity in a dryer zone for industrial dryers. The dryers are used to remove moisture from products in drying processes such as paper drying, grain drying, and food drying amongst others. It is necessary to maintain the optimum moisture content or humidity in the dryer to maximize the drying rate at a given fuel consumption rate. The moisture level is maintained by the introduction of makeup air (often known as ventilation air or dilution air) in a dryer. This air is mixed with combustion products from the dryer burners to heat the makeup air to the dryer zone temperature before its discharge from the dryer as exhaust air (or flue gas). Makeup air is required in a drying system to allow for moisture within product to be absorbed into the air stream.

The process of heating makeup air in a dryer can consume a large percentage of the total heat used for drying. It is advisable to control the makeup air and keep it to as minimum value as possible without adversely affecting the product drying rate. Too little air can raise humidity and moisture level in the dryer and adversely affect the drying rate while too much air uses extra but unnecessary energy. This tool allows the user to calculate energy saving associated with reducing extra ventilation air, make up air or dilution air, over and above the required level.

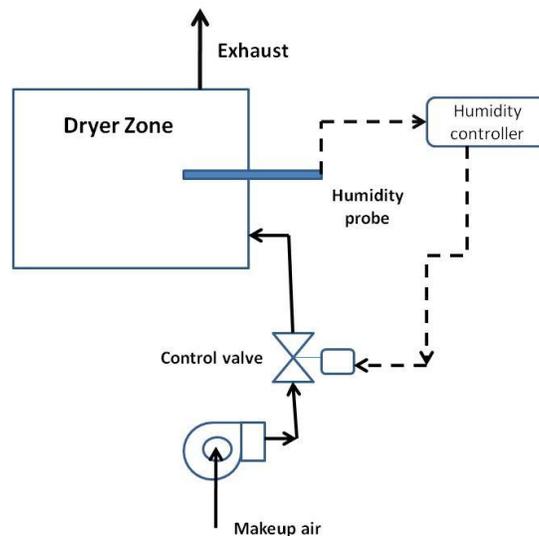


Exhibit 1: A typical humidity control system setup

This calculator estimates the annual expected energy savings in terms of million (MM) Btu/year. It also estimates energy cost reduction using a given cost of energy used for the application and number of operating hours per year. This calculator also calculates the reduction in CO<sub>2</sub> emissions resulting from reduced natural gas consumption. Primary objective of this calculator is to promote energy savings in industrial heating operations and allow a user to calculate potential savings that can be used to make a go/no go decision on additional detailed engineering and economics analysis. The user is required to give data or values for several operating parameters that can be measured or estimated during the average operating conditions using available records or actual measurements. The data should be collected at typical or average operating conditions. Accuracy of the results is expected to be within plus or minus 5 percent.

#### **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.



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## **1. Description of the subject area**

This technical guide describes a calculator tool that will allow a user estimate annual energy (fuel) savings, reductions in CO<sub>2</sub> emissions, and energy cost savings (\$/year) by installing and operating relative humidity (RH) monitoring and control technology on a dryer where moisture or other vapors are present. Such systems are used in many industries such as paper drying, food drying, ceramic parts drying and curing, powder drying, grain drying etc.

The mass transfer process occurring during the drying operation requires that concentration of vapors present in drying ovens or kilns be maintained below a certain level of RH. The exact value of the recommended or required RH value depends on the product, process, and drying equipment used. In most cases, the RH set point is based on the experience of company personnel. The RH value can be controlled by insuring proper amount of makeup air that is introduced into the drying process. Often, air enters the oven due to negative pressure and the amount of air is often uncontrolled. In some cases, a separate ventilation or make up air blower is used to supply set amount of makeup air. The air has to be heated to the exhaust air temperature and the amount of heat required for raising air temperature could be very large percentage (in some cases as high as 75%) of the total heat requirement for the drying equipment. If RH monitoring equipment is used to ensure proper moisture or water vapor concentration, it may be possible to reduce the mass flow or volume of exhaust air resulting in reduction in the energy use and CO<sub>2</sub> emissions.

This humidity control calculator tool can be used to estimate annual energy savings and the associated cost (US dollars) savings, and reductions in CO<sub>2</sub> emissions through monitoring and/or control of RH value in a dryer. The user is required to measure the current value of RH and use it as current value in this tool. Savings resulting from using higher, but allowable, RH value can be calculated by entering the allowable RH limit for a specific product and its process specifications.

The calculator estimates the annual expected energy savings in terms of millions of British thermal units (MMBtu/year). It also estimates the energy cost reduction by using the given cost of fuel and the number of operating hours per year. This calculator also calculates the reduction of CO<sub>2</sub> emissions that result from the reduced consumption of natural gas.

A brief summary of the important parameters follows:

**RH reading for the exhaust air** – This value is measured inside the dryer or in the exhaust air. A RH probe should be used to obtain this reading. If the probe is not available, it is necessary to go through calculations of RH based on water evaporation rate and the amount of ventilation air, and flue gases from the burner. Note that the burner fuel combustion products contain significant amount of water vapor and should be accounted for the RH calculations. Value of RH is required before and after implementation of the efficiency measure.

**Exhaust air temperature** – The temperature of the exhaust air exiting the dryer before and after implementation of the efficiency measure. This is referred to as dry bulb temperature of flue gas or exhaust gas (air).

**Oxygen content of exhaust air from the dryer** – The percentage of oxygen in the exhaust air measured on a dry basis before and after implementation of the energy saving measures.

**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.

**Excess air used for the burners.** – This is the amount of excess air (above the amount required for complete combustion of the fuel) used for the burners. Note that this air is separate or different from the make up air used in the oven or dryer.

**Fuel consumption (average) or current firing rate per hour (MM Btu/hour)** – is the average estimated hourly consumption of natural gas (or other type of fuel) used by the baseline combustion system. This value should be based on a recent 12-month period (MM Btu/year) and number of hours for the heating system.

**Number of operating hours (hours/year)** – The number of hours for which the equipment is operated. This should be based on a recent 12-month period.

**Cost of fuel** - The average fuel cost (\$/MMBtu) based on the history and, if possible, future projected cost based on contacts with the energy supplier.

The focus of this tool is on the reduction of natural gas consumption by controlling RH levels by controlling amount of ventilation air used in dryers. The following measures can be used to accomplish this goal:

**Use a RH probe to monitor RH in the dryer or dryer exhaust air** – This measure allows the monitoring of RH level within a dryer and/or the exhaust air exiting the dryer. The probe can be obtained from several suppliers. Most probe designs have indicators for RH and an output signal that can be used for a remote display and control purposes. The user is advised to discuss their specific application with the supplier before making final decision on the type of the probe to be used.

**Control or reduction of makeup air** – This measure involves controlling the makeup air entering the dryer to meet the required RH requirements. The degree to which control over the makeup air is possible depends on the heating process itself. The dryer supplier should be contacted to determine the best course of action that would allow control of the air to meet the drying process requirements. Some of the possible methods include:

- Control of speed of the induced draft (ID) fan located at the exhaust of the dryer
- Dryer pressure control to reduce air leakage into the dryer
- Control of the dryer inlet and outlet openings
- Other methods specific to the dryer design

**Control of Ventilation or Make Up Air** – This measure involves use of controlled and necessary amount of makeup air to meet the process RH requirements.

## **2. Impact of RH control on energy savings and CO<sub>2</sub> emissions**

This calculator allows a user to estimate energy (fuel) savings that can be achieved by controlling RH or increasing the RH value in a dryer where water vapors are present in the exhaust air. These fuel savings result in reduction of CO<sub>2</sub> emissions. All commonly used fossil fuels such as natural gas results in the formation of CO<sub>2</sub>. The reduction in CO<sub>2</sub> emissions is directly proportional to the reduction in natural gas usage.

The calculator is designed to give results assuming that the dryer uses natural gas as fuel. The actual savings in fuel consumption and the associated energy costs depend on several operating parameters. These include:

- Amount of water vaporized from the product (or other sources in addition to the water vapor) from combustion of fuel. This determines quantity of ventilation air required for the dryer to maintain desired value of RH.
- Current and future (modified conditions) values of RH as measured in the exhaust air for the dryer
- Average firing rate (fuel used per hour)
- Temperature of exhaust air leaving the dryer (generally referred to as dry bulb temperature)
- Amount of excess air used for the burners
- Number of operating hours per year
- Average temperature of the combustion and excess air entering the heating system.
- Cost of fuel in terms of \$/MMBtu

The energy savings can vary from 10% for well run drying processes to as high as 40% in case where the dryers are poorly operated. The exact value of savings can be estimated by using this calculator.

The CO<sub>2</sub> 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<sub>2</sub> per MMBtu heat input. For convenience, most calculations use 117 lbs. CO<sub>2</sub> emission per MMBtu of heat input from natural gas. If the natural gas composition is available, it is advisable to carry out detailed combustion calculations to estimate value that is more accurate for the CO<sub>2</sub> produced by the combustion of natural gas. The reduction in CO<sub>2</sub> emissions is calculated by using the value of reduction in energy (fuel) used for the furnace.

Annual energy cost savings depend on the cost of energy, expressed as US dollars per MMBtu, and the energy savings estimated using the calculator.

### **3. Discussion on the technical approach and the calculations**

Control of RH in drying ovens will result in energy savings while maintaining the desired process conditions and productivity of the dryer. The annual energy savings (MMBtu/year) is the difference between the annual energy use by the baseline system and the annual energy use after the implementation of the efficiency measure. In all cases involving RH level control, an essential step is to measure value of RH before and after implementation of the measure. The RH value in the exhaust air can be measured by a RH probe or through detailed calculations that require knowledge of several parameters. In most cases, the detail calculations are difficult and unreliable.

The ability of an amount of air, inert gas, or combustion products (all referred to as air in the following discussion) to maintain a certain level of RH value depends on the amount of water in the dryer environment or exhaust air from the dryer at a given temperature. In the following discussion it is assumed that dry combustion products have the same density as air, and both are referred to as air.

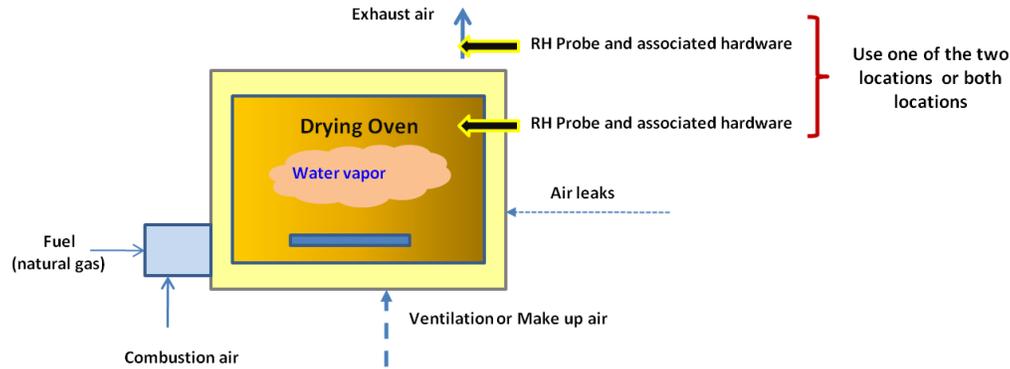


Exhibit 2: Typical dryer or drying oven schematic

Energy savings resulting from proper use of RH monitoring and control is due to reduction in mass flow (volume of air) used to maintain the required operating conditions in the dryer. The total mass flow of exhaust air includes the mass of combustion products from the burners and water vapors (present in the makeup air) that come from various sources. This energy saving calculation requires knowledge of reduction in mass flow of air since it is assumed that mass flow of water vapor will remain constant at a constant production and process conditions. The mass flow of combustion products may change since the heat requirement of the dryer would be reduced. Using the available heat concept, explained later, is used to allow for reduction in burner heat input. It is only necessary to calculate reduction in ventilation airflow that is directly related to the RH value. With use of RH control it is possible to reduce airflow and hence the heat requirement of the oven. The method used in this calculator requires:

- Measurement or estimate of current RH value and projection of expected or desired RH value. This should be for a given amount of water evaporated in the dryer.
- Measured value of exhaust air (dry bulb) temperature
- Calculations for reduction in air flow corresponding to the change in RH value
- Measured value ventilation- combustion air temperature as it enters the dryer
- Oxygen (O<sub>2</sub>) content of exhaust air at current operating conditions
- Burner operating information such as the current fuel use and excess air used for the burners

This information is used to calculate total volume or mass flow of exhaust air and corresponding volume or mass flow rate for the ventilation air at current operating conditions. User input for the expected RH and dry bulb (exhaust air) temperature is used to calculate reduction in ventilation airflow and reduction in the amount of heat required for this airflow reduction. In the following calculations the reduction in air or exhaust air flow is given as  
or .

or

Where

= Change in heat content of exhaust air (Btu/hr)

= Change in mass flow rate (lbs/hr) of air calculated based on change in RH value.

= Specific heat of exhaust air in terms of Btu/(lb. °F)

= Change in volume flow rate [Standard cubic feet (SCF)/hr.] of air calculated based on change in RH value.

= Specific heat of exhaust air in terms of Btu/scoff. °F)

= Increase or change in temperature of exhaust air (°F)

The reduction in heat requirement ( ) for the air heating is used to calculate actual reduction in burner heat input for the oven. This calculation requires knowledge of available heat (often known as combustion efficiency) of the burners used in the oven. This term and its use are explained in a following section.

The energy savings and associated CO<sub>2</sub> emission reduction are calculated for most commonly used hydrocarbon fuels such as natural gas.

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

The following symbols are used in the equations below:

= Oven or furnace heat demand (Btu/hr)

= Available heat (Btu/hr)

= Heat input in the oven (Btu/hr)

= Heat content of exhaust air leaving the heating system or oven (Btu/hr)

(%) = Percent available heat

The total heat input is defined as

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

The dryer heat demand includes heat required to raise temperature of the makeup air as reflected in the change in heat contained in the exhaust air and can be used to calculate the reduction in the burner heat input or heat required for the oven.

The energy savings ( ) would be equal to the change in exhaust air heat content divided by the available heat for the burner combustion products.

, the available heat expressed as a percentage, depends on the following variables:

- Fuel composition
- Exhaust gas temperature
- Combustion air temperature
- Percent oxygen (dry) in the combustion products for the burners.

Available heat can be calculated by using combustion calculations for a given fuel. For this 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 add up 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.

For this calculator, the “higher heating value” or “gross heating value” for the fuel is used. The higher (gross) heating value for commonly used natural gas with the composition shown in **Exhibit 3** is 1,020 Btu per standard cubic foot (scf). Natural gas heating value varies between 970 Btu/scf and 1,200 Btu/scf. In many situations 1,000 Btu/scf is considered a good approximation. 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 very small effect on the available heat as a percentage of the heating value. Available heat changes are within a narrow range and the error for this value is relatively small and is within  $\pm 5\%$ . Thus, we advise users of this calculator that the accuracy of its estimates will be in the same order of magnitude (i.e.  $\pm 5\%$ ). 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 from that stated in Exhibit 3.

Further discussion on available heat and the effect of fuel composition is discussed in References 1 and 2.

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%
<b>Total of fuel components</b>	<b>99.85%</b>	<b>100.000%</b>
<b>Difference</b>	<b>0.15%</b>	<b>0.00%</b>
<p>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.</p>		

Exhibit 3: Composition of natural gas used for calculations

We define \_\_\_\_\_ as the annual energy savings in Btu/year. Then

\_\_\_\_\_

Annual savings can be expressed in terms of Btu/year, Therms/year or million Btu/year (MMBtu/year) by using the appropriate equations given below.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

The CO<sub>2</sub> savings can be calculated by using the fuel combustion calculations or by using the EPA guidelines for CO<sub>2</sub> generation calculations. Reference 2 gives details of US EPA guidelines.

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#### **4. 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.

The following input data is required from the user.

- Dry bulb temperature for exhaust air or exhaust gas(°F)
- Relative humidity – current reading or value (%)
- O<sub>2</sub> content of exhaust air (dry %)
- Burner combustion air temperature (°F).
- Excess air used for the burners (%)
- Average or current firing rate (MMBtu/hr)
- Number of operating hours per year
- Cost of fuel (energy) cost (\$/MMBtu)

The calculator gives following results.

- Absolute humidity (lbs. of H<sub>2</sub>O/lb. of dry air)
- Heat content (Btu/lb of wet air mixture)
- Total mass flow of gases (Lbs/hr)

- Mass flow of dry gases (Lbs/hr)
- Heat content of exhaust air (Btu/hr)
- Available heat for the heating system (%)
- Reduction in heat demand for the dryer (Btu/hr)
- Annual fuel cost saving (\$/year)
- Reduction in CO<sub>2</sub> emissions (tons/year)

Note that the CO<sub>2</sub> 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 humidity control calculator requires the following input parameters describing the heating process in order to estimate the savings. **Exhibit 4** shows the user information screen and **Exhibit 5** shows the calculator screen.

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

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 individual is main contact and is responsible for collecting and providing the required information.

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: <a href="mailto:b.smith@abccorp.com">b.smith@abccorp.com</a>
7	Date (format mm/date/year)	May 12, 2010		
<b>Heating equipment description (where the energy saving measure is applied)</b>				
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		

Exhibit 4: Required information for the calculator user

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 can be an oven, furnace, boiler, heater, etc. 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 that can be useful in application of the results

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

**Exhibit 4** shows the required data for the calculator. The calculator cells are color coded. The white color cells are used for data input by the user while the colored (yellow and light blue or green) color cells are protected and give results of the calculations. The user is not allowed change numbers shown in the colored cells.

Line 11 – Dry bulb (exhaust gas) temperature for exhaust air – 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 – Relative Humidity (RH) value - measured (%) – Give measured or calculated value of RH in percentages. The most accurate value can be obtained by using the RH measuring instrument if the instrument is capable of operating at the exhaust air temperature. This value and dry bulb temperature is used to obtain value of water content as discussed in a later section (Line 14 description).

Line 13 – O<sub>2</sub> content of in exhaust gas or exhaust air – 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 14 – Absolute humidity of exhaust gasses (lb of water/lb of dry air) – This is a value calculated using standard tables and equations and it gives amount of water vapor content of the exhaust air per lb of dry air. In case where it is not possible to measure RH value by using an instrument it is necessary to use a calculated value of absolute humidity based on amount of water vaporized in the dryer, current firing rate for the dryer, and O<sub>2</sub> content of the dryer exhaust air. An alternate method is to use measured value of mass or volume flow rate of exhaust gases, amount of water vaporized in the

dryer and calculated value of water vapor in combustion products. It may be necessary to contact experienced engineering personnel for these calculations.

Line 15 – Heat content of exhaust gasses (Btu/lb of wet air mixture) – This is a value calculated using standard formula (Reference 1) based on exhaust air temperature and water content (humidity) of the exhaust air. Simplified equation used is given below.

- $t$  = exhaust air temperature
- $x$  = amount of water vapor per lb. of dry air
- 0.240 is specific heat of air (Btu/lb°F)
- 0.444 is specific heat of water vapor (Btu/lb°F)
- 970 Btu/lb. is latent heat of vaporization for water.

Line 16 – Burner combustion air temperature (°F) – If possible, give measured value of temperature of combustion air entering the burners. In many cases, it is not possible to get the exact air temperature at the burner, and it is common to use the temperature of air entering the combustion air blower or the ambient temperature around the air blower. For a case where preheated combustion air is used it is necessary to use combustion air temperature at the burner or at the exit of the air preheating equipment such as a recuperator, regenerator, or regenerative burners.

Line 17 – Excess air used for burners (%) – This is obtained by measuring air and fuel (natural gas) flow for the burners. *Note that in this scenario  $O_2$  reading for the exhaust air is NOT a good indication of the burner excess air.* If it is not possible to get flow readings use a value suggested by the oven supplier or by the burner supplier, if no further information is available, use 10% excess air as a default number.

Line 18 – Average firing rate (MM Btu/hr) from burners – This is the value of average fuel consumption or burner heat input expressed in MMBtu/hour. This should be an average value based on measurements of fuel use over a period of time or at “average” operating conditions. It is possible to get this value if the fuel consumption data is available over a period of time (monthly, annually etc.) for the furnace being considered. Note that the meter data, if used to calculate the fuel use, must be corrected for the pressure and temperature at the meter and the heat input should be calculated using the heating value of the fuel. For the most commonly used or average-quality natural gas in California, a heating value of 1,020 per standard cubic foot (scf) will be a good approximation.

Line 19 – Total mass flow of exhaust gasses (lb/hr) – This is calculated value based on the data given above. Total mass includes water evaporated during the drying process, mass flow of combustion products from the dryer, and make up air entering into the oven. This is calculated based on measured value of  $O_2$  in exhaust air, burner heat input, excess air used for the burner and properties of natural gas (particularly stoichiometric air requirement). The calculations are carried out in a separate calculation sheet that

uses data from the available heat calculator and data given in this calculator.

Line 20 – Number of operating hours (hours/year) – This represents annual operating hours at the average firing conditions given above.

Line 21 – Heating value (Btu/scf or Btu per standard cubic feet) of natural gas – This is an average heating value. It is in the range of 950 to 1050 for most commonly used natural gas in California. An average value 1020 Btu/scf is used as default value. The user can change it if necessary.

Line 22 – Mass flow dry gases (lb/hr) – This is a calculated value based the values and calculations provided in previous cells. It represents difference between total mass flow of wet gases and the amount of water vapor present in the exhaust air. Note that the total water content includes water from the product or process carried out in the dryer plus water vapor from combustion of natural gas.

Line 23 – Heat content of exhaust air (Btu/hr) – This is calculated value which represents heat content (sensible and latent heat) of exhaust air. It uses values of heat content of exhaust air based on its temperature and moisture content.

Humidity Control in Dryers and Ovens				
		Units	Current	New
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 <sub>2</sub> ) 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
26	Energy saved for heating equipment (dryer/oven/furnace)	MM Btu/year	3,763	
27	Cost of energy (natural gas)	\$/MM Btu	\$6.00	
28	Energy cost savings	\$/year	<b>\$22,575.31</b>	
29	CO <sub>2</sub> emission reduction	Tons/year	<b>220.11</b>	

Exhibit 5: Example of calculator inputs and results

Line 24 – Available heat for the heating system or burners (%) – This is a 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 5** above.

Line 25 – Reduction in heat demand in the dryer (Btu/hr) – This is a calculated value based on a reduction in heat content of exhaust air and available heat for the dryer combustion system. It accounts for a reduction in the exhaust air volume and its heat content including the sensible heat and latent heat of water vapor in exhaust air. It is total “gross” heat savings at the burner tip.

Line 26 – Energy saved for heating equipment (MM Btu/year) – This is a calculated value based on reduction in heat demand, value of available heat and number of annual operating hours.

Line 27 – Cost of energy or fuel (\$/MMBtu) – The user gives cost of fuel expressed in terms of \$/MMBtu. The cost should include all charges related to use of fuel at “the burner tip”. This value can be obtained directly from monthly or annual gas bills. It is often stated as a line item on the bill. If the bill does not specifically mention the gas cost then it is necessary to calculate average cost of fuel by using values of total fuel cost and annual fuel used.

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

Line 28 – Energy (fuel) cost savings (\$/year) – This is the difference between cost of energy (heat input) used per year at the current operating conditions and cost of energy after implementation RH monitoring and control system for the dryer.

Line 29 – CO<sub>2</sub> emission reduction (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.

*Note that this calculator does not include any input or result related to water savings. In most cases, reduction in excess air has no direct effect on water savings..*

## 5. References and Resources

1. “Enthalpy of moist air” from [http://www.engineeringtoolbox.com/enthalpy-moist-air-d\\_683](http://www.engineeringtoolbox.com/enthalpy-moist-air-d_683).
2. *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>
3. *North American Combustion Handbook*, Third Edition, 1986. Published by North American Mfg. Company, Cleveland, OH.
4. *Combustion Technology Manual*, Fifth Edition, 1994. Published by Industrial Heating Equipment Association, Cincinnati, OH.
5. *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](http://www1.eere.energy.gov/industry/bestpractices/pdfs/process_heating_sourcebook2.pdf)
6. *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](http://www1.eere.energy.gov/industry/utilities/steam_tools.html)

7. Training opportunities for process heating technology
  - The U. S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE) Office of Industrial Technologies (ITP) web site.  
<http://www1.eere.energy.gov/industry/>
  - Sempra Energy – Southern California Gas Company web site. [www.socalgas.com](http://www.socalgas.com)
  - California Energy Commission web site  
[www.energy.ca.gov](http://www.energy.ca.gov)