FOOD SERVICE

AUTOMATED CONVEYOR BROILER, COMMERCIAL

SWFS017-02

CONTENTS

MEASURE NAME

Automatic Conveyor Broiler, Commercial

STATEWIDE MEASURE ID

SWFS017-02

TECHNOLOGY SUMMARY DESCRIPTION

A conveyor broiler cooks food by direct and indirect contact with gas-fired flames, giving the product a signature flame-broiled flavor and texture. These types of broilers are mostly used for cooking burgers but can also cook a variety of other foods including grilled chicken and vegetables. Food is placed on a conveyor belt which runs through a cooking cavity. Gas burners reside above and below the belt carrying the food product.

There are two types of automatic conveyor broiler configurations: 1) in a through broiler, the food product is fed into one side of the unit and exits on the opposite end; 2) in a return broiler food product is discharged on the same side as the feed.

Technical Description:

- Their high-energy usage and long operating hours make the conveyor broiler one of the most energy intensive appliances in the kitchen.
- Energy efficient automatic conveyor broilers have potential to save large amounts of energy while providing similar production capacities and reducing the heat load in the kitchen.
- Some units have two conveyors with independently adjustable speeds.
- Another type of automated broiler cooks food in batches instead of continuously.
- Typical conveyor broilers operate at a constant input rate maintaining average cavity temperatures between 600 °F and 700 °F. The temperature is regulated by a gas manifold pressure adjustment.
- Constant input rate broilers do not differentiate between cooking and idle operation – the broiler operates at the same rate throughout the day.
- Typical ¼-lb frozen burger patty cook times range between two and three minutes.

Control Strategies

- Technology advancements in broiler technology have introduced controls that adjust the input rate of the broiler based on cooking conditions or that turn the gas heating elements ON and OFF to maintain a desired temperature.
- Advanced automatic batch broilers cycle gas burners ON and OFF to maintain cooking cavity temperature.
- Advanced automatic conveyor broilers utilize a dual-stage gas valve that reduces the input rate during cooking conditions to prevent flare ups.
- Broilers utilizing a catalyst on top of their cooking cavity reduce emissions and further insulate the cavity, resulting in lower input rates needed to maintain cooking temperatures.
- Advanced automatic conveyor broilers also use active airflow management techniques to recirculate hot air inside the cavity, resulting in lower gas input rates needed to maintain cooking temperatures.
- Broiler lane width should not be confused with individually speed controlled lanes that can hold several lanes of product.

Target Market

- Energy efficiency automated conveyor broilers are ideal for national restaurant chains and independent foodservice facilities requiring high production capacity and consistent results.

Industry Standard Test Method

Conveyor broiler performance is determined by applying the American Society for Testing and Materials (ASTM) Standard Performance of Conveyor Broilers, ASTM F2239-10, the industry standard method for quantifying the efficiency and performance of a commercial conveyor broiler. ASTM F2239-10 characterizes the broiler preheat, idle, and cooking energy in terms of gas and electric energy consumption. These laboratory test values can be then used to populate an energy model by applying operating hours. Broiler operating hours can be determined by restaurant hours of operation schedule, operation surveys stating how many minutes before opening the broiler gets turned ON and OFF, and/or sub metered field data.

Summaries of Key Studies

Automatic conveyor broiler energy consumption has been measured through laboratory testing as well as field verification. Field gas and electric sub-metering data provides broiler hours of operation and broiler operating mode. Automatic conveyor broilers are primarily installed in quick service restaurants where the units are usually turned ON one hour prior to restaurant opening and turned OFF at the restaurant close time.

50% Energy Savings for Quick-Service Restaurants (Pacific Northwest National Laboratory, PNNL, 2010).[1] The objective of this research was to develop strategies for quick-service restaurants in all eight U.S. climate zones to achieve whole-building energy savings of at least 50%. The results indicate that 60% of quick-service restaurant hours of operation range between 85 and 167 with an average 128 hours per week or 18.3 hours per day (see Figure 2.7). Based on this finding, this workpaper conservatively uses 18 hours per day as part of the unit energy consumption calculation. This is illustrated in the UEC Inputs tables on page 11.

Energy Efficient Underfired Broilers (Fisher-Nickel, 2017).[2] This study, funded through the PG&E's emerging technologies program, measured broiler energy use at food service facilities to determine energy efficient broiler replacements. Notable results are:

- Hours of Operation. A small restaurant chain that does not serve breakfast had measured conveyor broiler operating hours of 14.9 hours per day and a catering facility had conveyor broiler operating hours of 20.4 hours per day. The average between the two sites was 17.7 hours per day.
- Energy usage of a 2-lane conveyor broiler at the catering facility was 15.7 therms per day. The study was conducted for 91 days in Los Angeles starting January 2016 using a gas meter with 1/8-ft^3 resolution.

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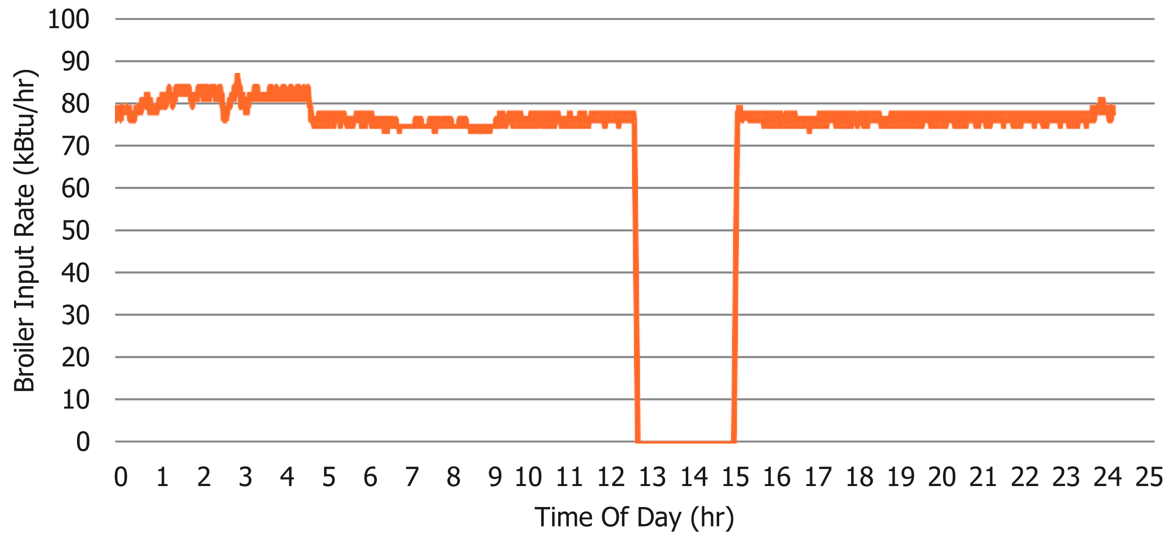
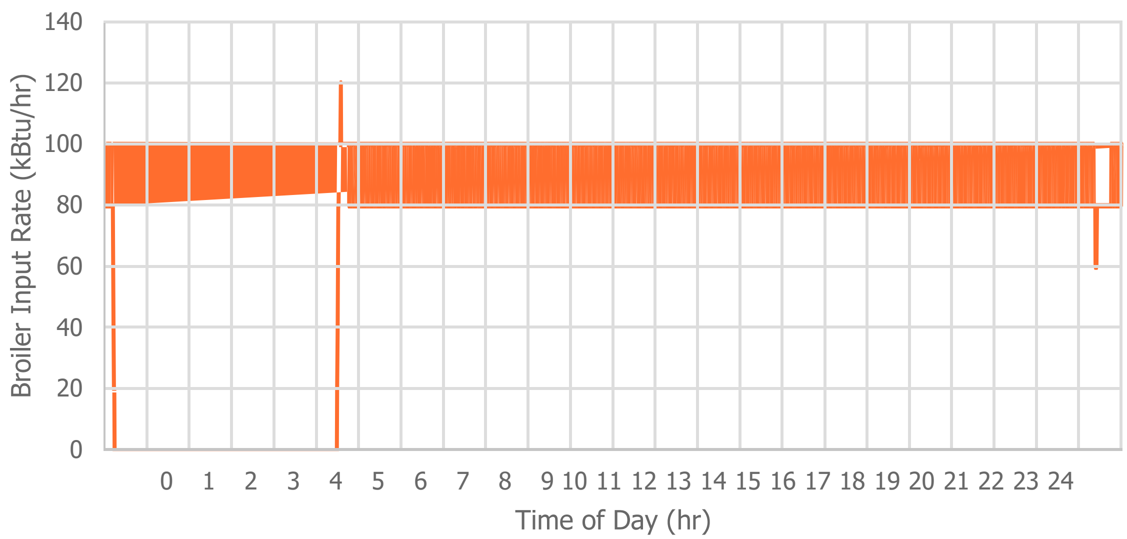
[1] Pacific Northwest National Laboratory (PNNL). 2010. *Technical Support Document: 50% Energy Savings for Quick-Service Restaurants.* Prepared for the U.S. Department of Energy (DOE). PNNL-198809. September. Figure 2.7

[2] Livchak, D. (Fisher-Nickel, Inc.). 2017. *Energy Efficient Underfired Broilers.* Prepared for Pacific Gas and Electric Company (PG&E). ET Project Number ET16PGE1941. March 24.



Conveyor Broiler Energy Profile Catering

Custom rebate incentives were calculated for automatic conveyor broilers in PG&E territory based on field measured data for a minimum of two weeks. Both sites were large quick service restaurants serving breakfast, lunch, and dinner. One site had a baseline broiler that operated 18.2 hours per day and consumed 16.3 therms and 77.4 kWh per day. The other site had an energy efficient automatic batch broiler that operated 18.2 hours per day and consumed 9.8 therms and 0.6 kWh per day. The study was conducted in June 2017 by PG&E in Fairfield and Suisun City in California using 1-ft^3 resolution gas meters.



Conveyor Broiler Energy Profile QSR

Unpublished Field Monitoring Data (PG&E and SCG, 2017)[3]. Broiler hours of operation and energy usage was analyzed at four quick service restaurant chains. This information was collected via direct gas monitoring (chain A and B) and operator surveying for hours of operation (chain D and E). The hours of operation were supplemented with laboratory data to extrapolate daily energy use. Each chain had a specific baseline and energy efficient broiler. Electric energy usage results varied greatly based on the holding needs of each chain. The results are shown in the table below.

Automatic Conveyor Broiler Restaurant Energy Use

	Restaurant Chain			
	A	B	D	E
Operation Hours	17.1	20.3	13.0	12.0
Daily Energy Use (Therms/day)	16.2	16.4	18.2	6.5
Daily Energy Use (kWh/day)	77.4	27.4	0.1	22.0

Energy data gathered by SCG for custom rebates for large restaurant chain "B" for four different locations in Southern California showed that two sites operated 24 hours on weekends and 18 hours on weekdays. One site operated 24 hours daily and another site operated 18 hours daily. The average operating hours were found to be 20.3 for that chain.

Chain operators were surveyed for the pounds of food cooked per day which mostly consisted of ¼-lb frozen burgers. Food cooked for restaurant chain A, B, and D ranged between 90 and 150 lbs per day but did not have a great effect on the broiler energy due to similar cooking and idle energy rates. Restaurant chain E is open only for lunch and dinner resulting in shorter hours of operation and lower gas energy usage due to a narrower conveyor belt than the other surveyed chains restaurants.

Additionally, restaurant chain D utilized a broiler that did not have an electric bun grill, as opposed to the other chains, and the electric energy consumption was solely a result of the conveyor motor, resulting in smaller consumption.

MEASURE CASE DESCRIPTION

The measure case is defined as an energy efficient automatic conveyor broiler (EEACB) with three measure offerings based upon belt width, as specified below. The broiler belt widths are based on number of burgers that can be fed into the cooking cavity simultaneously. Automatic conveyor broilers available on the market were divided into 2, 3 and 4 burger wide categories based on their conveyor belt width shown in the table below. If the conveyor broiler has multiple belts on the same level, the entire cavity width shall be used for measurement.

Additionally, EEACB must have a catalyst and an input rate less than 80 kBtu/hr or a dual stage or modulating gas valve with a capability of throttling the input rate below 80 kBtu/hr.

[3] Compton, La Palma, Moorpark and Ontario sites

Measures Offerings

Statewide Measure Offering ID	Measure Offering Description
A	Automatic Conveyor Broilers Belt Width < 20”
B	Automatic Conveyor Broilers Belt Width 20” to 26”
C	Automatic Conveyor Broilers Belt Width > 26”

BASE CASE DESCRIPTION

The base case is defined as an existing conveyor broiler. ASTM F2239 conveyor broiler test data generated by Fisher Nickel for PG&E was used to determine the threshold between low energy usage broilers with a modulating gas valve utilizing catalysts and ingle input rate forced air circulation and natural convection broilers with no catalyst. The existing (base case) broiler must be an automatic conveyor broiler than can maintain a temperature above 600 °F with a tested idle rate greater than based on available lab test data on natural convection broilers.

CODE REQUIREMENTS

This measure is not governed by state or federal regulations. The California Appliance Efficiency Regulations (Title 20) includes a category for cooking appliances but does not address broilers specifically.

There are 35[4] Air quality management districts (AQMDs)/pollution control districts in California and many of which regulate particulate matter emissions from restaurant operations. For example, the South Coast Air Quality Management District Rule 1138 stipulates that devices that cook more than 1,250 pounds of beef per week shall be operated with pollution control equipment that reduces PM2.5 emissions.[5,6] This particulate matter reduction can be achieved through ventilation systems including HEPA filters, wet scrubbers, electrostatic precipitators, or ultraviolet filtration. PM reduction in an enclosed cavity broiler, such as automatic conveyor broiler, can be achieved with a catalyst.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	None.	n/a
CA Building Energy Efficiency Standards – Title 24	None.	n/a
Federal Standards	None.	n/a
South Coast Air Quality Management District	Rule 1138	July 1, 2013

[4] https://ww2.arb.ca.gov/air-pollution-control-districts

[5] South Coast Air Quality Management District. (n.d.) *South Coast AQMD Rule Book.* “Rule 1138. Control of Emissions from Restaurant Operations.”

[6] PM2.5 is the category of particulate matter with aerodynamic diameters less than or equal to 2.5 µm.

NORMALIZING UNIT

Each.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Normal Replacement	DnDeemed	Commercial
New Construction	DnDeemed	Commercial
Normal Replacement	UpDeemed	Commercial
New Construction	UpDeemed	Commercial
Normal Replacement	DnDeemDI	Commercial
New Construction	DnDeemDI	Commercial
Normal Replacement	DnDeemed	Agriculture
New Construction	DnDeemed	Agriculture
Normal Replacement	UpDeemed	Agriculture
New Construction	UpDeemed	Agriculture
Normal Replacement	DnDeemDI	Agriculture
New Construction	DnDeemDI	Agriculture
Normal Replacement	DnDeemed	Industrial
New Construction	DnDeemed	Industrial
Normal Replacement	UpDeemed	Industrial
New Construction	UpDeemed	Industrial
Normal Replacement	DnDeemDI	Industrial
New Construction	DnDeemDI	Industrial

The automatic conveyor broiler market is relatively small, with few restaurant chains that specify conveyor broilers as standard specification. However, the restaurant chains that use conveyor broilers are large and have several franchisees. Broiler manufacturers usually have internal salespeople that work directly with the restaurant chains and franchisees. As such, multi-store franchisees are the best candidates for the downstream incentives. As conveyor broilers gain popularity, smaller individual operators may be interested in broiler savings, midstream Incentives will encourage conveyor broiler sales personnel to seek out these operators for an energy efficient replacement.

Eligible Products

Eligibility Requirements (Measure). The replacement automatic conveyor broiler must have a catalyst and an input rate less than 80 kBtu/hr or a dual stage or modulating gas valve with a capability of throttling the input rate below 80 kBtu/hr.

Eligibility Requirements (Baseline). The existing (base case) broiler must be an automatic conveyor broiler than can maintain a temperature above 600 °F with a tested idle rate greater than:

40 kBtu/hr for a belt narrower than 20”

60 kBtu/hr for a belt between 20 and 26”

70 kBtu/hr for a belt wider than 26”

The conveyor broiler must be replaced by a conveyor broiler similar in size or smaller.

Implementation and Installation Requirements. Installation shall comply with all policies, codes and regulations within the installation territory.

Eligible Building Types and Vintages

This measure is applicable in all building types and vintages.

Eligible Climate Zones

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

Used or rebuilt equipment is not eligible.

DATA COLLECTION REQUIREMENT

Data collection requirements are to be determined.

USE CATEGORY

Food service (FoodServ)

ELECTRIC SAVINGS (kWh)

The annual electric unit energy saving (UES) is calculated as the difference between the baseline and measure case unit energy consumption (UEC).

Annual Electric Unit Energy Consumption

Broiler annual energy consumption is a function of preheat, cooking, and idle energy requirements. The daily electric UEC (baseline or measure case) is equal to the sum of the energy required for cooking, preheat, and idle modes of broiler operation.[7] These calculations and the inputs are provided below.

$$UEC\_DAY = cooking\ energy + idle\ energy + preheat\ energy$$

Cooking energy is a function of the estimated pounds of food cooked per day (lbs/day), multiplied by the cooking energy rate (Btu/hr), and divided by the production capacity (lbs/hr).

$$cooking\ energy = \left[\frac{LBFOOD \times CER}{PCAP}\right]$$

LBFOOD =	*Estimated pounds of food cooked per day (lbs/day)*
CER =	*Cooking Energy rate(Btu/hr)*
PCAP =	*Production Capacity (lbs/hr)*

Preheat energy is calculated as the product of the assumed number of preheats per day and the energy required per preheat mode.

$$preheat\ energy = (nP \times EP)$$

nP =	*Estimated number of preheats per day (#)*
EP =	*Measured preheat energy (kWh)*

Idle energy is a function of the idle energy rate, operating hours per day, and production capacity; idle energy does not include preheat time

$$idle\ energy = [IDLERATE \times (EHOUR - \frac{LBFOOD}{PC} - (nP \times TP/MinHr))]$$

IDLE RATE =	*Measured idle energy rate (kW)*
EHOUR=	*Estimated operating hours per day (hrs)*
LBFOOD =	*Estimated pounds of food cooked per day (lbs)*
PC =	*Measured production capacity (lbs/hr)*
nP =	*Estimated number of preheats per day (#)*
TP =	*Estimated preheat time (min)*
MinHr =	*Constant, 60 minutes per hour (min)*

The annual UEC is calculated as the daily UEC multiplied by the number of operating days per year.

$$UEC\_YEAR = UEC\_DAY \times EDAYS$$

UEC_DAY =	*Daily unit energy consumption (kWh)*
EDAYS=	*Estimated operating days per year (days)*

[7] American Society for Testing and Materials (ASTM). 2016. *ASTM F2239-10, Standard Test Method for the Performance of Conveyor Broilers.* West Conshohocken (PA): ASTM International.

Annual Electric Unit Energy Savings

The annual UES is calculated as the difference between the baseline and measure case annual UEC.

$$UES_{YEAR} = [UEC\_YEAR_{Base} - UEC\_YEAR_{Measure}]$$

$UEC\_YEAR =$ *Annual UEC, baseline or measure (kWh/year)*
$UES\_YEAR =$ *Annual UES (kWh/year)*

Inputs and Assumptions

The inputs for the calculation of the electric UEC and UES of an automated conveyor broiler for each measure offering (width) are specified below. Base Case and Measure Case assumptions are described in the tables on page 10-11.

UEC Inputs - Automated Conveyor Broiler, 2-lane width (< 20”)

Parameters	Base Case Model	Measure Case Model
Preheat Time (min)	10	29
Electric Cooking and Idle Energy Rate (kW)	1.84	0.20
Production Capacity (lb./hr)	29	21
Operating Hours/Day	12	12
Operating Days/Year	363	363
Pounds of Food Cooked per Day	75	75

UEC Inputs - Automated Conveyor Broiler, 3-lane width (20”-26”)

Parameters	Base Case Model	Measure Case Model
Preheat Time (min)	8.42	16.25
Electric Cooking and Idle Energy Rate (kW)	1.35	0.37
Production Capacity (lb./hr.)	47.6	41.7
Operating Hours/Day	18	18
Operating Days/Year	363	363
Pounds of Food Cooked per Day	150	150

UEC Inputs - Automated Conveyor Broiler, 4-lane width (> 26”)

Parameters	Base Case Model	Measure Case Model
Preheat Time (min)	22	12
Electric Cooking and Idle Energy Rate (kW)	4.8	1.15
Production Capacity (lb./hr.)	90	86
Operating Hours/Day	18	18
Operating Days/Year	363	363
Pounds of Food Cooked per Day	110	110

Most conveyor broilers operate at a constant input rate that is close to the idle rate. Some broilers utilize a two-stage gas valve that reduces the input rate slightly during cooking so that the burger grease does not burn uncontrollably. It is estimated that the broiler is cooking under heavy load conditions for two hours per day. With average hours of operation ranging between 12 and 18 hours per day, most of the energy usage is driven by idle energy. Flame broiling is usually done between 700˚F and 900˚F, though American Society for Testing and Materials (ASTM) Standard Performance of Conveyor Broilers, ASTM F2239-10, does not specify a broiling temperature. Idle energy usage for the calculations shall be reported with broiler cavity temperatures exceeding 600 °F.

Conveyor broilers can be of different sizes depending on the required production capacity and cooking product variety. Energy usage depends on the cooking cavity dimensions which are characterized by width and depth, cavity height shall not be taken into consideration (usually 1” opening for product). Cooking cavity depth often ranges between 25 and 30 inches.

With a small difference in height and depth between conveyor broilers, the biggest energy driver is the width of the broiler, which is characterized by the belt. Conveyor broiler belt width can accommodate between one and four ¼-lb 5” diameter burger patties (called lanes) depending on broiler model and should be categorized accordingly. Smaller belt width corresponds to a lower idle rate but a lower production capacity. Large quick service restaurant chains will use a 3-lane or a 4-lane wide conveyor broiler.

ASTM F2239 conveyor broiler test data generated by Fisher Nickel for PG&E was used for baseline and measure case assumptions. Low energy usage broilers with a modulating gas valve utilizing catalysts and ingle input rate forced air circulation were used for the measure case and natural convection broilers with no catalyst were used for base case. Field test data from four sites provided by SoCalGas on a large quick service restaurant chain in 2017 was used to supplement baseline and measure average broiler input rates.

Automatic Conveyor Broiler – Baseline Size and Energy Usage

Model Number	Conveyor Width Category (in)	Burger Lane Width	Lab Tested Idle Rate kW)
F	<20	2	1.84
G	20-26	3	2.19
H	20-26	3	1.35
J	>26	4	4.8

Automatic Conveyor Broiler – Measure Case Size and Energy Usage

Model Number	Conveyor Width Category (in)	Burger Lane Width	Lab Tested Idle Rate (kW)
A	<20	2	0.20
B	20-26	3	0.06
C	20-26	3	0.37
D	>26	4	1.15
E	>26	6x2 (12 burgers per batch, equivalent to 4 lanes)	0.04

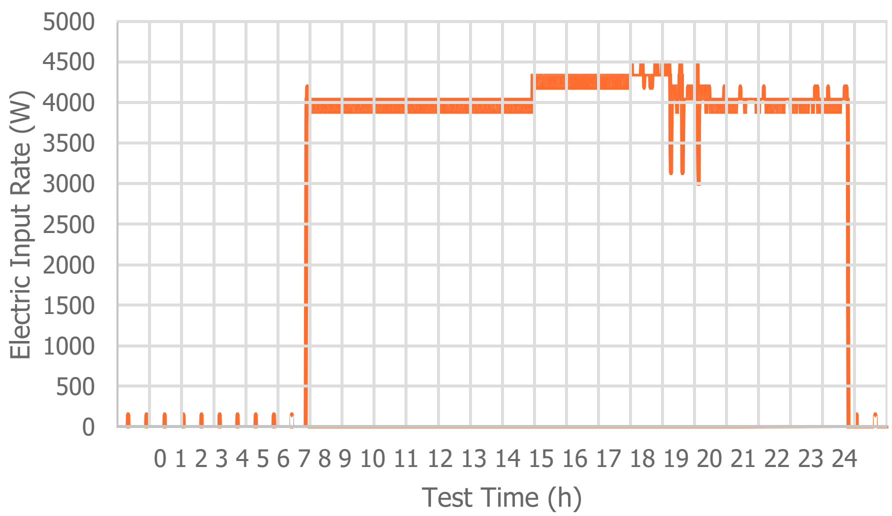
Hours of Operation. The hours of operation for this measure are well documented in the referenced studies. It is possible to estimate broiler hours of operation accurately knowing the facility hours of operation and if the facility serves breakfast, lunch, and dinner.

Field test data from 7 sites representing two biggest conveyor broiler using quick service restaurant chains monitored in 2017 by SoCalGas and PG&E was used for this dataset. This data was supplemented by hours of operation of 3 other quick restaurant chains using conveyor broilers. Quick-service restaurants that serve lunch and dinner used conveyor broilers an average of 12 hours per day, while restaurants that served breakfast averaged 18 hours of operation per day. Certain restaurants were open 24 hours with an average of 23 hours of operation per day, which included downtime for broiler cleaning. Of the 1,135 restaurants in California that use automatic conveyor broilers, the weighted average hours of operation are 18.1 hours per day. Quick-service restaurants examined are open seven days per week except for Christmas and Thanksgiving with 363 days per year operation.

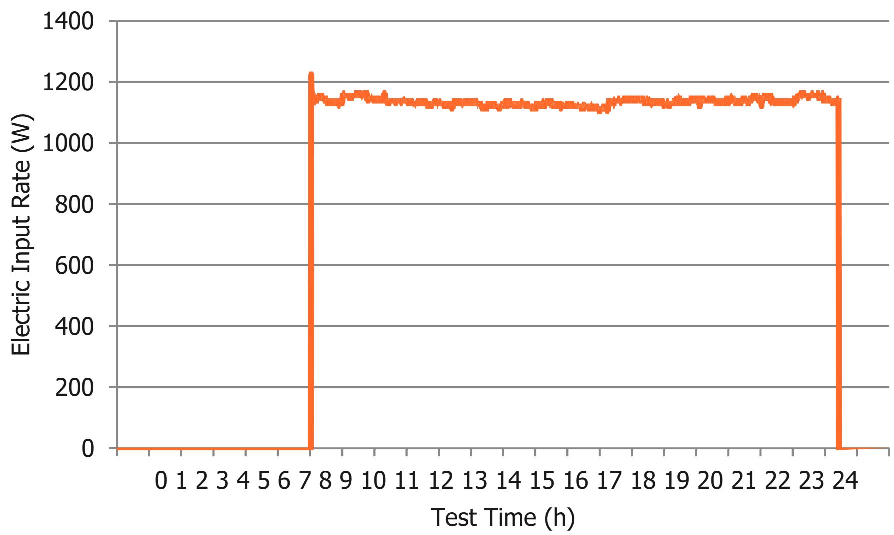
Automated Conveyor Broiler - Hours of Operation

	Restaurant Chain					Total
	A	B	C	D	E	
Number of Stores in California	268	497	213	71	86	1,135
Operation Hours per Day	18	18	23	12	12	18.1
Total Hours of Operation per Day (all stores)	4,824	8,946	4,899	852	1,032	20,553

Some gas conveyor broilers are equipped with heating and warming elements. These resistance heating elements are on at a constant rate to keep the product warm as it exits the conveyor belt. The profile below shows 18-hour broiler electrical profile.



Base Case Broiler: Hourly Electric Profile



Measure Case Broiler: Hourly Electric Profile

The profile shown is for the largest 4-lane conveyor broiler with warming elements, with the baseline broiler operating at 4 kW constant rate, the energy efficient broiler consumed 1.2 kW, which resulted in a 3.8 kW demand reduction. Not all broilers are equipped with warming elements and the input rate of the conveyor belt motors and controls is less than 100W. In all monitored applications, the broiler was on and using electricity during a demand window between noon and 6 p.m.

Sample Calculation

A sample calculation of the annual electric UEC of the base case model of a 2-lane width broiler is provided below.

*Annual Energy Consumption - Base Case (AECB) = [EIER * OHY * ODY]*

EIER =	*Electrical Idle Energy rate (kW) = 1.84 kW*
OHY =	*Operating Hours/Day= 12 hrs/day*
ODY =	*Operating Days/Year= 363 Days/Year*
AECB =	*1.84 kW*12 hrs/day*363 days/year= 8,015 kWh*

PEAK ELECTRIC DEMAND REDUCTION (KW)

The actual contribution of a commercial conveyor broiler to building peak demand may vary significantly depending on its usage pattern in relation to that of other electric equipment in the facility (operating schedule, appliance ON time, etc.). The probability of an appliance drawing its average rate during the period that the building peak is set is significantly higher than for any other input rate for that appliance.

It is assumed that this measure operates within the Database of Energy Efficient Resources (DEER) peak period of 4 p.m. to 9 p.m. on weekdays[8] at a constant load throughout the day. The average and peak demand reduction calculations utilize the measured data of base case and measure case broilers specified for Electric Savings. The average demand (baseline or measure case) is equal to the annual unit energy consumption (UEC) divided by the assumed annual hours of operation.

$$Demand_{avg} = \frac{UEC\_YEAR_{kWh}}{EDAYS \ x \ EHOUR}$$

$UEC\_YEAR =$	*Annual UEC, baseline or measure (kWh/year)*
$EDAYS =$	*Estimated operating days per year (days)*
$EHOUR =$	*Estimated operating hours per day (hrs)*

The average demand reduction is the difference between the baseline and measure case average demand. As an example, the base case and measure case peak demand for a 2-lane conveyor broiler are 1.84 kW and 0.20 kW, respectively. The average demand reduction is 1.64 kW.

The estimated peak demand reduction is calculated as the average demand reduction multiplied by the coincident demand factor (CDF).

$$PeakDemandReduction = [(Demand_{avg,base} - Demand_{avg,measure}) \ x \ CDF] = 1.64 \text{ kW} * 0.9 = 1.48 \text{ kW}$$

$Demand_{avg} =$	*Average demand, base or measure case (kW) = 1.64 kW*
$CDF =$	*Coincident demand factor = 0.90*

The demand reduction estimation is based on measured data for standard efficiency conveyor broilers and for high-efficiency conveyor broilers. The measured data are derived from tests conducted under American Society for Testing and Materials (ASTM) Standard Performance of Conveyor Broilers, ASTM F2239-10. A conveyor broiler consumes energy for both gas and electric constantly at the maximum input rate. As such, the energy is not averaged during different modes of operation and the power demand is used to estimate demand reduction.

The CDF is specified below. See Electric Savings for inputs to derive the annual UEC and average demand.

Demand Reduction Inputs

Parameter	Value	Source
Coincident Demand Factor	0.90	Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report.* Prepared for Southern California Edison. Pages 3-15 to 3-17, Table 3-14.

GAS SAVINGS (THERMS)

The annual gas unit energy saving (UES) is calculated as the difference between the baseline and measure case unit energy consumption (UEC).

Annual Gas Unit Energy Consumption

Broiler annual UEC is a function of preheat, cooking, and idle energy requirements. The daily gas UEC (baseline or measure case) is equal to the sum of the energy required for cooking, preheat, and idle modes of broiler operation.[9] These calculations and the inputs are provided below.

$$UEC\_DAY = cooking \ energy + idle \ energy + preheat \ energy$$

[8] California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. Op 1.

[9] American Society for Testing and Materials (ASTM). 2016. *ASTM F2239-10, Standard Test Method for the Performance of Conveyor Broilers.* West Conshohocken (PA): ASTM International.

Cooking energy is a function of the estimated pounds of food cooked per day (lbs/day), multiplied by the cooking energy rate (Btu/hr), and divided by the production capacity (lbs/hr).

$$cooking\ energy = \frac{(LBFOOD\ x\ CER)}{PCAP}$$

LBFOOD = Estimated pounds of food cooked per day (lbs)
CER = Cooking Energy rate(Btu/hr)
PCAP = Production Capacity (lbs/hr)

Preheat energy is calculated as the product of the assumed number of preheats per day and the energy required per preheat mode.

$$preheat\ energy = (nP\ x\ EP)$$

nP = Estimated number of preheats per day (#)
EP = Measured preheat energy (Btu)

Idle energy is a function of the idle energy rate, operating hours per day, and production capacity; idle energy does not include preheat time

$$idle\ energy = [1DLERATE\ x\ (EHOUR - \frac{LBFOOD}{PC} - (nP\ x\ TP/MinHr))]$$

IDLE RATE = Measured idle energy rate (Btu/hr)
EHOUR= Estimated operating hours per day (hrs)
LBFOOD = Estimated pounds of food cooked per day (lbs)
PC = Measured production capacity (lbs/hr)
nP = Estimated number of preheats per day (#)
TP = Estimated preheat time (min)
MinHr = Constant, 60 minutes per hour (min)

The annual UEC is calculated as the daily UEC multiplied by the number of operating days per year.

$$UEC\_YEAR = (\frac{UEC\_DAY\ x\ EDAYS}{Btu\_Therm})$$

UEC_DAY = Daily unit energy consumption (Btu)
EDAYS = Estimated operating days per year (days)
Btu_Therm = Btu to therm conversion factor

Annual Gas Unit Energy Savings

The annual UES is calculated as the difference between the baseline and measure case annual UEC.

$$UES_{YEAR} = [UEC\_YEAR_{Base} - UEC\_YEAR_{Measure}]$$

UEC_YEAR = Annual UEC, baseline or measure (Therms/year)
UES_YEAR= Annual UES (Therms/year)

Inputs and Assumptions

The inputs for the calculation of the gas UES of an automated conveyor broiler are specified below. See Electric Savings for a discussion of the derivation of these inputs.

ASTM F2239 conveyor broiler test data generated by Fisher Nickel for PG&E was used for baseline and measure case assumptions. Low energy usage broilers with a modulating gas valve utilizing catalysts and ingle input rate forced air circulation were used for the measure case and natural convection broilers with no catalyst were used for base case. Field test data from four sites provided by SoCalGas on a large quick service restaurant chain in 2017 was used to supplement baseline and measure average broiler input rates.

Automated Conveyor Broiler – Baseline Size and Energy Usage

Model Number	Conveyor Width Category (in)	Burger Lane Width	Lab Tested Idle Rate (kBtu/hr)
F	<20	2	55
G	20-26	3	87
H	20-26	3	78
J	>26	4	104

Automated Conveyor Broiler – Measure Case Size and Energy Usage

Model Number	Conveyor Width Category (in)	Burger Lane Width	Lab Tested Idle Rate (kBtu/hr)
A	<20	2	28
B	20-26	3	56
C	20-26	3	48
D	>26	4	57
E	>26	6x2 (12 burgers per batch, equivalent to 4 lanes)	67

UEC Inputs - Automated Conveyor Broiler, 2-lane width (< 20”)

Performance	Base Model	Measure Case Model
Preheat Time (min)	10	29
Idle Energy Rate (Btu/hr.)	54,500	28,000
Cooking Energy Rate (Btu/hr.)	55,000	28,500
Production Capacity (lb./hr)	29	21
Operating Hours/Day	12	12
Operating Days/Year	363	363
Pounds of Food Cooked per Day	75	75

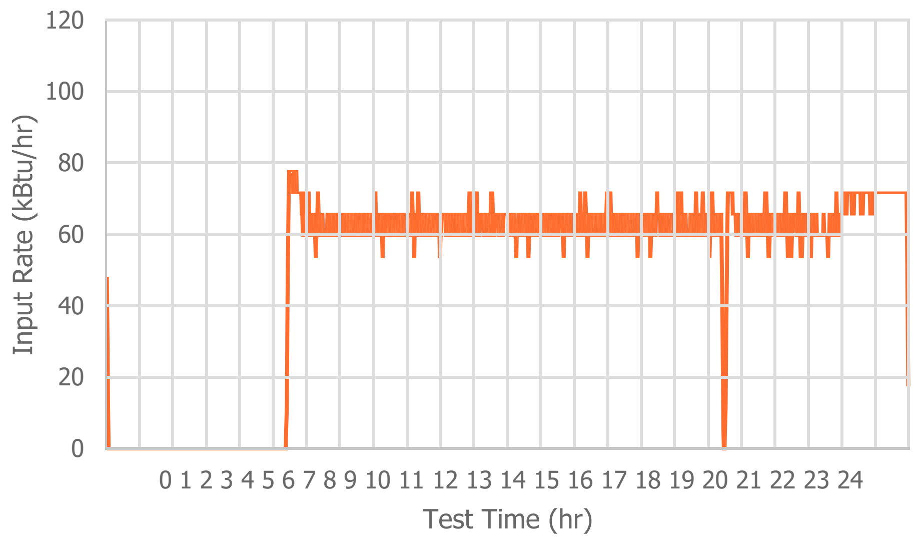
UEC Inputs - Automated Conveyor Broiler, 3-lane width (20”-26”)

Performance	Base Model	Measure Case Model
Preheat Time (min)	8.42	16.25
Idle Energy Rate (Btu/hr.)	78,120	47,960
Cooking Energy Rate (Btu/hr.)	78,240	50,938
Production Capacity (lb./hr.)	47.6	41.7
Operating Hours/Day	18	18
Operating Days/Year	363	363
Pounds of Food Cooked per Day	150	150

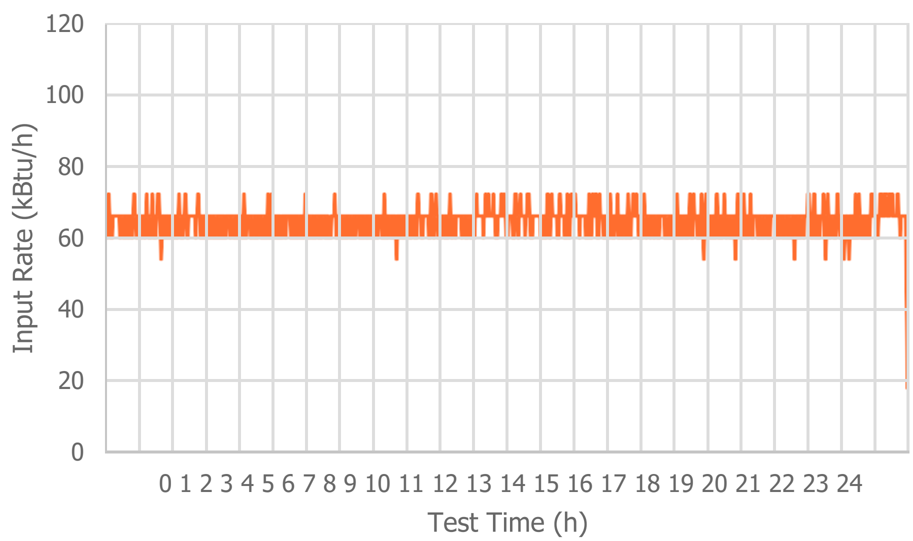
UEC Inputs - Automated Conveyor Broiler, 4-lane width (> 26”) Cost Effectiveness Example

Performance	Base Model	Measure Case Model
Preheat Time (min)	22	12
Idle Energy Rate (Btu/hr.)	104,000	57,000
Cooking Energy Rate (Btu/hr.)	111,210	67,117
Production Capacity (lb./hr.)	90	86
Operating Hours/Day	18	18
Operating Days/Year	363	363
Pounds of Food Cooked per Day	110	110

Hours of Operation. Quick service restaurants utilizing conveyor broilers may be 24 hours per day operation every day or 24 hours operation per day on weekends only. The following gas load shapes show the differences in operation profile for baseline broilers.

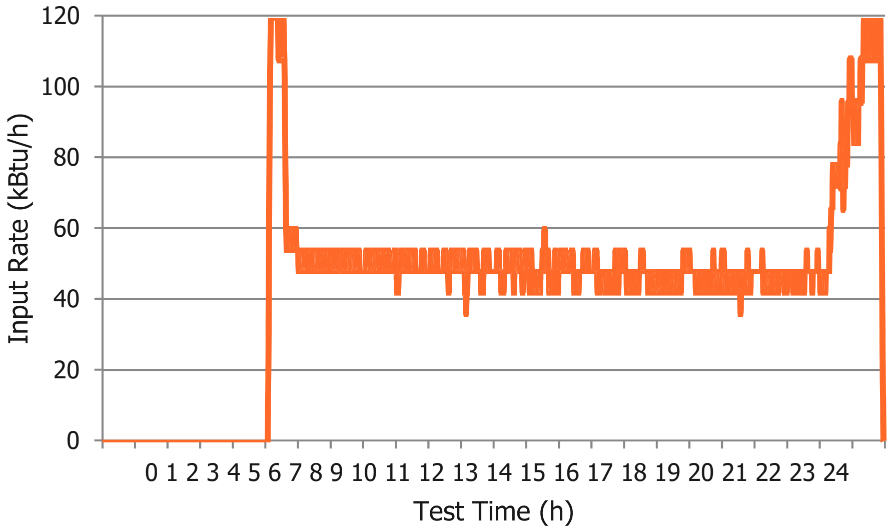


Base Case Broiler: 18 Hours per day, Weekday Operation

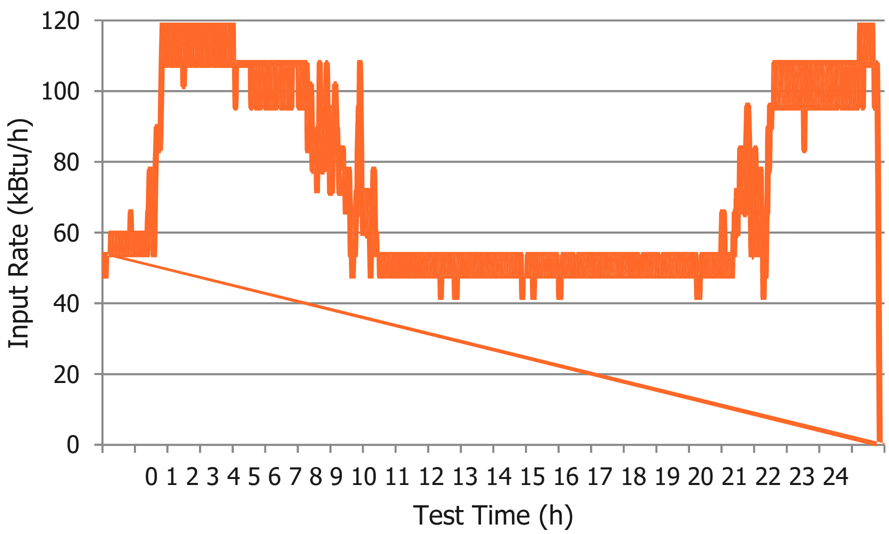


Base Case Broiler: 24 hours per day, Weekend Operation

Energy efficient replacement broilers have a lower average input; however, they have a dual stage valve that allows the unit to have a higher input rate during preheat and shutdown.



Measure Case Broiler: 18 Hours per day, Weekday Operation



Measure Case Broiler: 24 hours per day, Weekend Operation

Sample Calculation

A sample calculation of the annual gas UEC of the base case model of a 2-lane width broiler is provided below.

Daily cooking energy *= Pounds of Food Cooked per Day/ Production Capacity (lbs/hr)* Cooking Energy Rate (Btu/hr) = [75(lbs/Day)/29(lbs/hr)*55000(Btu/hr)]= 142,241 Btu*

Daily idle energy *= [Operating Hours/Day – (Pounds of Food Cooked per Day/Production Capacity (lbs/hr))* Idle Energy Rate (Btu/Hr)] = [12 hrs/Day – (75 lbs/day/29 lbs/hr)*54500 Btu/hr] = 513,052 Btu*

Daily preheat energy *= 11,500 Btu (See calculations spreadsheet)*

UEC_DAY = Daily Cook Energy +Daily Idle Energy + Daily preheat Energy = 142,241 Btu + 513,052 Btu + 11,500 Btu = 666,793 Btu

UEC_YEAR = UEC_Day* Operating Days per year/100,000 Btu/Therm = 666,793 Btu/Day * 363 Days/year / 100,000 Btu/Therm = 2,420 therms/year

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology, or piece of equipment replaced or altered, by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration. The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends "one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values."[10] This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.[11] Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on measures so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component." [12]

The EUL and RUL for Commercial Conveyor Broilers are specified below. Note that RUL is only applicable for add-on and accelerated replacement measures and not applicable for this measure.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs.)	12	Robert Mowris & Associates. 2005. *Ninth Year Retention Study of the 1995 Southern California Gas Company Commercial New Construction Program*. Prepared for Southern California Gas Company. Study ID Number 718A. California Public Utilities Commission (CPUC), Energy Division. 2003. *Energy Efficiency Policy Manual v 2.0.* Page 18 Table 4.1.
RUL (yrs.)	n/a	n/a

[10] California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

[11] KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

[12] California Public Utilities Commission (CPUC). 2016. Resolution E-4807. December 16. Page 13.

BASE CASE MATERIAL COST ($/UNIT)

Cost data was obtained from broiler manufacturers for the most popular energy efficient models. Models vary in size dictated by the conveyor width and accessories including burger holding warming elements and individually controlled conveyor belt speeds for multiple products. Pricing depends on the size of the order, with larger chain restaurants purchasing in bulk receiving lower pricing. Pricing was compared in each size category between baseline and measure models to get incremental measure cost. Categories that had multiple models were averaged for each baseline and measure category separately.

The base case material cost was derived from average pricing of Conveyor Broiler Manufacturer, obtained in 12/2017. Cost data was available for the 4-burger wide broiler for both measure case and base configurations. However, baseline costs were not available for other broiler sizes. Therefore, the cost premium over the energy efficient broiler for the 4-burger wide model was assumed for the smaller 2-burger and 3-burger width models.[13]

MEASURE CASE MATERIAL COST ($/UNIT)

Measure case cost data was gathered for energy efficient broilers from equipment manufacturers. Each model was assigned to one of the three belt width categories. Models that fell in the same category were averaged together. With not all model size options available with both single and dual belt controls, the cost for both models were extrapolated based on the cost premium of the dual belt model over the single belt option. Then the pricing was averaged for both models to achieve the measure costs.

BASE CASE LABOR COST ($/UNIT)

The installation costs are the same for the baseline and energy efficient automatic conveyor broilers. The cost of purchasing an automatic conveyor broiler usually includes delivery, installation, and setup costs if purchased directly from the factory or an authorized retailer. In other cases, broiler delivery and installation costs can be up to $1000 (Based on 8 hours of labor at $125/hr including travel time for two installation technicians), this cost will be used for both the measure labor and base labor cost.

MEASURE CASE LABOR COST ($/UNIT)

Measure labor costs are the costs to install the automatic conveyor broiler and are the same for both the baseline and the energy efficient automatic conveyor broilers. See Base Case Labor Cost.

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. These NTG values are based upon the average of all NTG ratios for all evaluated 2006 – 2008 commercial, industrial, and agriculture programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. These sector average NTGs (“default NTGs”) are applicable to all energy efficiency measures that have been offered through commercial, industrial, and agriculture sector programs for more than two years and for which impact evaluation results are not available.

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[13] Pricing and IMC spreadsheet

Net-to-Gross Ratios

Parameter	Value	Source
Agric-Default>2yrs	0.6	Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.
Com-Default>2yrs	0.6	
Ind-Default>2yrs	0.6	

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current "default" rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment

Parameter	GSIA	Source
GSIA - Default	1.00	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of inputs and methods based upon the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	No
DEER Operating Hours	No
DEER eQUEST Prototypes	No
DEER Version	DEER 2021, READI v2.5.1
Reason for Deviation from DEER	DEER does not contain Energy Efficient Automatic Conveyor Broilers.
DEER Measure IDs Used	None
NTG	Source: DEER. The NTG of 0.60 is associated with NTG ID: *Agric-Default>2yrs, Com-Default>2yrs, Ind-Default>2yrs*

DEER Item	Comment
GSIA	The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER. The value of 12 years is associated with EUL ID: *Cook-ConvBroiler*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	10/28/2019	Jaime Lopez – SCG RMS Energy Consulting, LLC	This statewide COMMERCIAL CONVEYOR BROILERS workpaper consolidates the following workpapers: • WPSCGNRCC171226A • PGECOFST129
	12/16/2019	Tai Voong PG&E	Added delivery types UpDeemed and DnDeemDI to PG&E.
02	4/14/2021	Andres Marquez, SoCalGas	Update Net-to-Gross (NTG) from *All-Default<=2yrs* to *Com-Default>2yrs* as the measures have been offered in the marketplace for 2 years Added missing delivery types to Implementation Eligibility table and EAD implementation tab Added missing calculations to data spec file
	06/28/2021	Harpreet Singh, PG&E	Adopted all remaining measures for PG&E