DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Product: Heating Efficiency

Description:

Prescriptive rebates will be offered for Hot Water Boilers (Condensing and non-condensing), Commercial Water Heaters and various heating system improvements, high efficiency furnaces,high efficiency unit heaters that are either: power vented (83% efficiency), condensing (>= 90% efficiency), or low-intensity tube radiant heaters. Electric rebates will be offered for furnaces with ECM fans, both for new furnaces and for retrofitting existing furnaces.

Gas Savings Algorithms:

New High Efficiency Boiler Savings (Gross Dth)	= Input Capacity x Alt x ((Effh - Adj) / Effb) - 1) x EFLH
Boiler Tune Up savings (Gross Dth)	= Input Capacity x Alt x ((Effh / Effb - 1)) x EFLH
Outdoor Air Reset savings (Gross Dth)	= Input Capacity x Alt x (1 - (Effb / Effh)) x EFLH
Stack Dampers savings (Gross Dth)	= Input Capacity x Alt x (1 - (Effb / Effh)) x EFLH
Modulating Burner Controls savings (Gross Dth)	= Input Capacity x Alt x (1 - (Effb / Effh)) x EFLH
O2 Trim Control savings (Gross Dth)	= Input Capacity x Alt x (1 - (Effb / Effh)) x EFLH
New High Efficiency Furnace Savings (Gross Dth)	= Input Capacity x Alt x ((Effh / Effb) - 1) x EFLH / 1,000,000
Steam Traps savings (Gross Dth)	= Leak_Rate x Leak_Hours x BTU_per_Pound / EFFb/1,000,000
New Water Heater Savings (Dth)	=(Input Capacity x Alt x (Effh / Effb -1) x EFLH + (SLb/Effb -SLe / Effh) x SLHrs) / 1,000,000
Pipe Insulation Savings (Dth)	= LF x Hrs x (BTU_per_foot_U - BTU_per_foot_I) x Existing / EFFb
BTU_per_Foot_U	= Heat loss per foot of uninsulated pipe '= [Coef0 + (Coef1 x DeltaT) + (Coef2 x DeltaT^2) + (Coef3 x DeltaT^3)] 'where the coefficients are selected based on the pipe size and an insulation thickness (both provided by customer). 'Coefficient values are listed in Table 7.
BTU_per_Foot_I	= Heat loss per foot of insulated pipe '= [Coef0 + (Coef1 x DeltaT) + (Coef2 x DeltaT^2) + (Coef3 x DeltaT^3)] 'where the coefficients are selected based on the pipe size (provided by customer) and an insulation thickness of zero. 'Coefficient values are listed in Table 7.
DeltaT	= (Tfluid - Tambient)
Unit Heater Savings (Dth)	= Input Capacity x Alt x ((Effh / Effb) - 1) x EFLH-UH x (Oversize Factor_heat) / 1,000,000
Infrared Heater Savings (Dth)	= Dth_Base_Radiant - Dth_eff_radiant
Dth_Base_Radiant	= ((Rad Input Capacity x Alt) / Radiation Size Factor) x (Oversize Factor_heat) x EFLH-UH x (1 Dth / 1000000 BTU) - Dth_fan

Dth_eff_radiant	= Rad Input Capacity x Alt x Oversize Factor_heat x EFLH-UH
EFLH-UH	= HDD x (24 Hrs/Day) x [1/ (T_indoor - T_design)]
HDD	= %Conditioned x Sum $(T\_indoor - T\_avg)^{+}_{365\ days}$ = (HDD_a x T_indoor ^2 - HDD_b x T_indoor + HDD_c) x %conditioned
HDD/day	= $(T\_indoor - T\_avg)^{+}_{365\ days}$
HDD/day_max	= Max(HDD/day) of all 365 days = T_indoor + T-Offset
FLH	= Sum $[(HDD/day / HDD/day\_max)]_{365\ days}$ x 24 x %conditioned = (HDD_a x T_indoor ^2 - HDD_b x T_indoor + HDD_c) / (T_indoor + T-Offset) x 24 x %conditioned.
Dth_fan	= Fan_kW x 3412 x FLH / 1,000,000 For Radiant Unit Heater Measure only
Custom Boiler savings (Dth)	Gas energy savings and any associated savings or increase in electrical energy will be calculated based on the project specific details. Each project will undergo an engineering review in accordance with standard engineering practices. The review will be in accordance with the calculation methodologies detailed in the prescriptive products where applicable.

Electric Savings Algorithms:

EC Fan Savings Customer kWh	=(Heating_kW_PSC - Heating_kW x Heat_EFLH + (Cooling_KW_PSC -Cooling_kW) x Cool_EFLH + (Ventilation_kW_PSC - Ventilation_kW) x Ventilation_Only_Hours+Cooling_kWh_Savings				
	Area	Cooling	Without Cooling	with Cooling	without Cooling
	Denver / Front Range	1474	1464	1134	1150
	Alamosa / Mountain	1616	1636	1131	1175
	Grand Junction / Western Slope	1469	1643	1155	1360
EC Fan Savings Customer kW	= Customer kWh / Op_Hrs				
	Area	New Units With Cooling	New Units Without Cooling	Retrofit Units with Cooling	Retrofit Units without Cooling
	Denver / Front Range	0.412	0.455	0.317	0.358
	Alamosa / Mountain	0.430	0.453	0.301	0.325
	Grand Junction / Western Slope	0.395	0.524	0.311	0.433
Cooling_kWh_Savings	= Cooling_kW_Savings x Cool_EFLH = New_Motor_Hp x 172 for Denver / Front Range = New_Motor_HP x 104 for Alamosa / Mountain = New_Motor_HP x 244 for Grand Junction / Western Slope				
Cooling_kW_Savings	= kW/ton x (Cooling_kW_PSC - Cooling_kW) x 3.413 / 12 = New_Motor_HP x 0.225				

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Peak Coincident KW	= Customer kW X Coincidence Factor
Heating Penalty	= -(Heating_kW_PSC -Heating_kW) x 3413 x Heat_EFLH / 1,000,000 / EFFb, = New_Motor_HP x $-8.04 for Denver / Front Range = New_Motor_HP x $-11.82 for Alamosa / Mountain = New_Motor_HP x $-7.25 for Grand Junction / Western Slope, for new fans, taken as a non-energy benefit. = New_Motor_HP x $-2.47 for Denver / Front Range = New_Motor_HP x $-3.64 for Alamosa / Mountain = New_Motor_HP x $-2.23 for Grand Junction / Western Slope, for retrofit fans,
Fan_kWh (Customer Gross kWh)	= Fan_kW x FLH For Radiant Unit Heater Measure Only
Fan_kW (Customer gross kW)	= Fan_HP x 0.746 x LF / Mtr_eff For Radiant Unit Heater Measure Only
Fan_HP	= kBtu/hr_heat x Alt / Radiation Size Factor x Oversize Factor_heat x HP/BTUh x 1000

Variables:

Input Capacity	Boilers = Rated input million BTUH nameplate data for the new boiler, Provided by the customer. Furnace, Unit Heater, or Water Heater. = Rated input BTUH nameplate data, Provided by the customer.	
Alt	= Altitude Adjustment factor to adjust the sea level manufacturer's rated input for altitude effects ~~= 0.891~~	
	0.823	Denver / Front Range is climate zone CO1 with an altitude of 5,285 ft ASL
	0.756	Alamosa / Mountain is climate zone CO3 with an altitude of 7,536 ft ASL
	0.837	Grand Junction / Western Slope is climate zone CO2 with an altitude of 4,839 ft ASL
EFFb	= Efficiency of Baseline equipment. Refer Table 1 below	
EFFh	= Minimum Qualifying Efficiency for higher efficiency equipment. Refer Table 1 below. Actual efficiency provided by the customer.	
Adj	= Adjustment for operation at less than nominal efficiency =5% for condensing boilers (Ref 29) =0% for all other equipment	
EFLH	=The equivalent full load heating hours for the boiler, furnace, or unit heater. Refer to Table 2 below.	

1,000,000	= Conversion from BTU to Dth
Leak_Rate	=Leakage rate, pounds of steam per hour. High Pressure = 11, Low Pressure = 5 (Reference 24)
Leak_Hours	= Annual hours boiler lines are pressurized = 6000 hours (Based on estimate of 30% installed on systems operate year round, and 70% installed on heating only systems.)
BTU_Per_Pound	Low Pressure Applications: = 1164 BTU per pound for lost to atmosphere, 964 BTU per pound lost to condensate. Assume 50/50 mix = 1064 BTU per pound. (Reference 24) High Pressure Applications: = 1181 BTU per pound for lost to atmosphere, 981 BTU per pound lost to condensate. Assume 50/50 mix = 1081 BTU per pound. (Reference 24)
Input Capacity	= Rated input capacity of the hot water heater (provided by customer)
Effh	= The rated efficiency of the new water heater, provided by the customer
Effb	= The minimum water heater thermal efficiency allowed by the federal standard = 80%
SLb	= Standby Losses for baseline storage water heater = 13.21 BTUH per gallon of storage (Ref 23)
Sle	= Standby Losses for efficient water heater = 8.90 BTUH per gallon of storage (ref 23)
SLHrs	= Standby loss hours for commercial water heaters = 8,760 hrs/yr
LF	= Linear feet of insulation installed, provided by the customer.
Hrs	=The operating hours for the boiler system. Refer to Table 3 below.
T_{fluid}	= Average temperature of the fluid in the pipe receiving insulation in degrees F, provided by the customer.
$T_{ambient}$	= Average temperature of the space surrounding the pipe. We will ask the customer if the pipe is in a conditioned space or outside. We will use 70 degrees for conditioned spaces and 51 degrees for outside domestic hot water (full year average) and 44 degrees for outside space heating (average excluding June-September) which are the average TMY3 temperatures for Colorado. (Ref 10)

Existing	= Pipe insulation savings multiplier to determine credit if existing deteriorated insulation is being replaced. We will use 1 if no existing insulation is present and 0.25 if existing insulation is being replaced.	
kBtu/hr_heat	= Rated output kBTU/h of the new radiant unit heater = Rad Input Capacity / 1000 x 80%	
Rad Input Capacity	= Rated capacity/input of the new radiant heater, in BTU/h, provided by customer	
%conditioned	= Percentage of the time during heating season the space is heated, provided by customer	
T_indoor	= Space temperature set point of space being heated, provided by customer	
T_avg	= Average daily outdoor dry bulb temperature for the given location for each day of the year, calculated from TMY3 weather data	
HP/BTUh	=Average fan power (rated) per BTU/h of heating output. Taken from manufacturer data for 38 unit heaters from Trane and Sterling. =1.8990E-6 for axial/propeller fans, 4.0377E-6 for centrifugal/blower fans.	
Oversize Factor_heat	= Factor to account for design oversize commonly found on unit heater installations. = 0.9 (Ref 1)	
T_design	= Winter Design temperature for the given location, (Ref 2) - See Table 4	
LF	= Design load factor of fan motor, deemed at 0.8 based on typical engineering assumption	
Heat_base	= Thermal efficiency of the baseline, non-power-vented, code-compliant unit heater. = 0.8 (Ref 3)	
Heat_eff	= Thermal efficiency of the new, efficient unit heater. Refer to Table 1 below.	
Heat_eff_radiant	= Thermal efficiency of the new, radiant heater. = 0.80, same as baseline because the radiant heaters do not have specific combustion efficiency improvements over the baseline unit heater, their savings are all from radiation heat transfer versus convection. Also, Ref 5 uses this value.	
Radiation Size Factor	= Factor to account for the fact that radiant heaters should be designed smaller than an equivalent standard unit heater due to radiation heat transfer being more effective at producing thermal comfort. This also accounts for the lower room temperature afforded by radiant heaters. = 0.85 (Ref 4)	
HDD_a	See Table 4	Polynomial Constants used in calculating HDD based on TMY3 weather data and design indoor temperature. HDD is proportional to the indoor temperature based on the formula HDD = a * Tin^2 + b * Tin + c

HDD_b	See Table 4	Polynomial Constants used in calculating HDD based on TMY3 weather data and design indoor temperature. HDD is proportional to the indoor temperature based on the formula HDD = a * Tin^2 + b * Tin + c
HDD_c	See Table 4	Polynomial Constants used in calculating HDD based on TMY3 weather data and design indoor temperature. HDD is proportional to the indoor temperature based on the formula HDD = a * Tin^2 + b * Tin + c
T-Offset	= the difference between the maximum heating degree day and the indoor design temperature. See Table 4 for values in each climate zone.	
Mtr_eff	= Average efficiency of 6 unit heater fans, calculated by taking the manufacturer-provided (Reznor, Sterling, and Trane) current draw to calculate power consumption and working backwards with the rated motor power and an assumed load factor of 0.8 to compute the efficiency for each fan and then taking the average of all of the fans. = 0.296 and includes both axial and centrifugal fans.	
0.746	= Conversion factor from HP to kW	
1,000	= Conversion factor from kBTU/h to BTU/h	
3,412	= Conversion factor from kW to BTU/h	
heat EFLH	= Annual Equivalent Full Load Hours (EFLH) of the furnace for heating = 950 (same as efficient furnace measure) for Denver/Front Range, 1396 for Alamosa/Mountain, and 856 for Grand Junction/Western Slope.	
Occ Hours	= Annual operating hours of the space served by the furnace, assumed to be equal to the operating hours of a typical office, as used in the Lighting Efficiency program (2567 hours)	
Op_Hrs	= Combined heating and cooling full load hours occuring during unoccupied hours plus Occ Hours. Calculated using bin hours and the assumed balance point of 57F. This value is location specific. For projects without cooling, this value does not include any cooling full load hours. For projects with cooling, in Denver/Front Range: 3579 hours, in Alamosa/Mountain: 3755, in Grand Junction/Western Slope: 3717. For projects without cooling, in Denver/Front Range: 3215 hours, in Alamosa/Mountain: 3611 hours, in Grand Junction/Western Slope: 3139 hours.	
Heating_kW_PSC	0.707	
Cooling_kW_PSC	0.880	
Ventilation_kW_PSC	0.747	

Cool EFLH	= Annual Equivalent Full Load Hours of the furnace in cooling mode, calculated by estimating building loads based on outdoor conditions and building balance point (balance point set by heating EFLH analysis at 57F) = 765 Hours for Denver/Front Range, 460 hours for Alamosa/Mountain, and 1083 hours for Grand Junction/Western Slope.
Ventilation Only Hours	= Annual Hours of the furnace in ventilation mode, calculated by subtracting the cooling and heating EFLH occuring during occupied hours from Op Hrs, = 1865 hours in Denver/Front Range, 1900 hours in Alamosa/Mountain, and 1779 hours in Grand Junction/Western Slope with cooling and 2265 hours with no cooling in Denver/Front Range, 2215 hours with no cooling in Alamosa/Mountain, and 2567 hours with no cooling in Grand Junction/Western Slope.
kW/ton	= Efficiency of air conditioning system, calculated by taking new baseline SEER of 13, dividing by 1.1 to get EER and then taking 12/EER to get kW/ton (1.015)
Cooling_kW	0.709
Heating_kW	0.271
Ventilation_kW	0.285
condeff	= Assumed efficiency of condensing furnace that EC fan will be installed in. Deemed at 90%, a typical value for thermal efficiency of a condensing furnace.
3.413	= Conversion from Watts of power to BTU/h of heat
12,000	= Conversion from BTU/h to tons of cooling
ECM Coincidence Factor	= Ratio of average kW to peak kW (including cooling interactive effects) = 79.7% for Denver with Cooling, 100% for Denver without cooling, 47.9% for Mountain Areas with Cooling, 100% for Mountain Areas without Cooling, and 100% for the Western Slope with our Without Cooling.
Measure Life	= Length of time the boiler (or furnace) equipment will be operational = See table 10.
Incremental Cost	= Refer to Tables 3 to 8.
NTG	Net-to-gross = 86% Per 2011 Cadmus Program Evaluation and Michaels Energy Review.

Needed from Customer/Vendor/Administrator for Calculations:

For boilers:

Boiler size rated at sea level (BTUH)

New boiler type (Non-Condensing or Condensing)

Boiler Use (Space heating and/or water heating)

For steam traps:

High or low pressure
Incremental cost

For all but boilers, steam traps, and pipe insulation:

Boiler size (BTUH)

Implemented measure
Incremental cost

For Insulation:

Linear feet of insulation added
Nominal diameter of pipe
Thickness of insulation
Insulation R-Value or thermal conductivity (k)
Average fluid temperature
Pipe location (conditioned space or not)
Pipe use (Space heating and/or water heating)

Was existing insulation replaced
Incremental cost

For Water Heaters:

Building type
Square footage served by water heater
Storage capacity (gallons); 0 if tankless
BTUH input
Other Water Heater BTUH Input
Thermal efficiency rating

For Furnaces:

New furnace size (BTUH)
New furnace efficiency

For Furnace fans:

New furnace fan size (hp)

For non-radiant unit heaters:

Space temperature set point
% of the time the space is heated
Output capacity of the unit heater in kBTU/h
Fan type (blower/propeller)

For radiant heaters:

Space temperature set point
% of the time the space is heated
Input capacity of the heater in kBTU/h

Assumptions:

- Each boiler or furnace is replaced with the same size on a 1 for 1 basis.
- Only boilers used for space and/or domestic water heating can receive prescriptive rebates; other boilers must go through Custom Efficiency.
- Assumed savings for boiler tune-up = 2% for non condensing boiler. This is an average value of the two years, 4% initial to no savings at the end of the two years. Life of product is 2 years. DOE states up to 5%.
- Assumed savings for outdoor air reset on non condensing boilers = 3%. Life of product is 20 years. The Natural Gas consortium states up to 5% savings
- Assumed savings for installing Stack dampers on non condensing boilers = 1%. Life of product is 20 years. Canada energy council, up to 4%
- Assumed savings for modulating burner controls on non condensing boilers = 3%. Life of product is 20 years. The Natural Gas consortium states up to 4% savings
- Assumed savings for O2 trim controls on non condensing boilers = 2%. Life of product is 20 years. The Natural Gas consortium states of 2 to 4% savings
- The baseline efficiency for the furnace is based on 2015 IECC, minimum of 80%.
- Thermal Efficiency as defined in ASHRAE 90.1-2007 indicates the total efficiency of the boiler equal to 100% fuel energy minus all losses.
- Prescriptive rebates are only given for furnaces put into service, rebates are not given for backup furnaces.
- Furnaces must have a minimum efficiency of 92% AFUE for a rebate, and 94% AFUE or higher efficiency will receive a larger rebate.

Infrared heater is vented (has exhaust to exterior)

"% Conditioned" is the percentage of the time that the space temperature set point is maintained
The infrared heater has no fan energy consumption (it may have a very small (<100W) fan to distribute hot exhaust, but that is ignored)
The fan full load hours equal the heating full load hours
Fan power per BTU/h is constant, regardless of fan size for each fan type
Heat produced by the fan is beneficial to heating the space
Fan motor efficiency is constant
Radiant heaters are low-intensity tube type

- Furnace fan will operate for ventilation during all business hours, assumed to be equal to the "office" lighting hours for the business lighting program technical assumpt
- For furnace fan measure, cooling is assumed to be 13 SEER and heating 90% efficient
- The baseline PSC furnace fan motor is 2/3 the size of the new motor, based on Ref 20 and 21
- Furnace fan measure: there is no ventilation during unoccupied hours
- Climate zone assumed to be Denver, unless otherwise specified

Table 1: Heating Equipment Efficiencies

	Baseline Efficiency (EFFb)	Efficient Efficiency (EFFh)	Unit	Reference
New Boilers (Non-Condensing) <300,000 BTU/h	80.0%	85.0%*	AFUE	Ref. 11
New Boilers (Non-Condensing) >= 300,000 BTU/h and <=2,500,000 BTU/h	80.0%	85.0%*	Et (Thermal Eff)	Ref. 11
New Boilers (Non-Condensing) >2,500,000 BTU/h	82.0%	85.0%*	Ec (Combustion Eff)	Ref. 11
New Boilers (Condensing) <300,000 BTU/h	80.0%	92.0%*	AFUE	Ref. 11
<=2,500,000 BTU/h	80.0%	92.0%*	Et (Thermal Eff)	Ref. 11
New Boilers (Condensing) >2,500,000 BTU/h	82.0%	92.0%*	Ec (Combustion Eff)	Ref. 11
Boiler Tune Up (Non-Condensing)	78.0%	80.0%		Ref. 12
Boiler Tune Up (Condensing)	87.2%	88.0%		Ref. 29
Outdoor Air Reset	80.0%	83.0%		Ref. 13
Stack Dampers	80.0%	81.0%		Ref. 14
Modulating Burner Controls	80.0%	83.0%		Ref. 15
O2 Trim Control	80.0%	82.0%		Ref. 16
Steam Traps	80.0%	N/A		Ref. 17
Commercial Furnaces < 225,000 BTUH input	78.0%	92.0%*	AFUE	Ref. 3
Commercial Furnaces >= 225,000 BTUH input	80.0%	92.0%*	Et (Thermal Eff)	Ref. 3
Water Heaters	80.0%	92.0%*		Ref. 18
Unit Heater (Non-condensing)	80.0%	83.0%*		Ref. 3
Unit Heater (Condensing)	80.0%	90.0%*		Ref. 3

Pipe Insulation	80.0%	N/A		Ref 17

*High efficiency boiler and furnace efficiencies are per customer. Listed efficiencies are minimum qualifying efficiencies.

Table 2: Effective Full Load Heating Hours

Equipment	Use	Hours	Explanation
Boiler	Space Heating Only	769	Based on Bin Analysis assuming 30% oversizing for boiler plant. See "Forecast Boiler Op Hours " tab.
	Domestic Hot Water Only	674	
	Space Heating and Domestic Hot Water	1,443	Based on Bin Analysis assuming 30% oversizing for boiler plant. See "Forecast Boiler Op Hours " tab.
Furnace	All	950	
Commercial Water Heaters	All	1,092	Based on historical custom rebate projects from MN

Table 3: Hours for Pipe Insulation

Use of Pipe	Location	Pipe Insulation Hours	Explanation
Domestic Hot Water	Inside	5,558	Hours when outside temp is above building balance point. Heat loss from pipe is wasted.
Domestic Hot Water	Outside	8,760	Domestic hot water available year round, outside temp is always less than 120 F.
Space Heating	Inside	1,648	Hours when boiler is running but outdoor temp is above building balance point
Space Heating	Outside	4,791	Hours that boiler is running