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.

Algorithms:

BTUH_upgraded	= Input BTUH for the upgraded boiler or water heater to generate the same output as existing boiler or water heater that is being retrofitted = BTUH_existing x EFFb/EFFh
BTUH_base	= Input BTUH for the baseline boiler or water heater to generate the same output as the new high efficient boiler or water heater = BTUH_new x EFFh/EFFb
New Boiler Savings (Dth)	= (BTUH_base - BTUH_new) x Hrs / 1,000,000
Furnace Savings (Gross Dth)	= Alt x ((BTUH_new x EFFh/EFFb) - BTUH_new) x Hrs / 1,000,000
Boiler Tune Up savings (Gross Dth)	= ((BTUH x EFFh/EFFb) - BTUH) x Hrs / 1,000,000
Outdoor Air Reset savings (Gross Dth)	= (BTUH - (BTUH x EFFb/EFFh)) x Hrs / 1,000,000
Stack Dampers savings (Gross Dth)	= (BTUH - (BTUH x EFFb/EFFh)) x Hrs / 1,000,000
Modulating Burner Controls savings (Gross Dth)	= (BTUH - (BTUH x EFFb/EFFh)) x Hrs / 1,000,000
O2 Trim Control savings (Gross Dth)	= (BTUH - (BTUH x EFFb/EFFh)) x Hrs / 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)	= BTUH_New x Eff_Rating_High)/(BTUH Input x Eff_Rating_High + Other_Water_Heater_BTUH_Input x Eff_Rating_Standard) x {density x C_p x Volume_Daily_SqFt_Usage x Days_Year x SqFt_Served x (T_setpoint - T_supply) x (1/ Eff_Rating_Standard - 1 / Eff_Rating_High) + [(SL_base - SL_new) x 8760 hours]} x (1 MMBTU / 1,000,000 BTU)
Pipe Insulation Savings (Dth)	= LF x Hrs x (BTU_per_foot_U - BTU_per_foot_I) x Existing / EFFb
DeltaT	= (Tfluid - Tambient)
BTU_per_Foot	= [Coef0 + (Coef1 x DeltaT) + (Coef2 x DeltaT^2) + (Coef3 x DeltaT^3)] / EFFb The U or I designation after the name indicates Uninsulated or Insulated.
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.
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 = New_Motor_HP x kWh factor (below)

Area	New Units With Cooling	New Units Without Cooling	Retrofit Units with Cooling	Retrofit Units without Cooling
Denver / Front Range	2507	2019	2026	1436
Alamosa / Mountain	2424	2183	1934	1613
Grand Junction / Western Slope	2724	2190	2266	1529

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

<table>
<tr><td rowspan="5">EC Fan Savings Customer kW</td><td colspan="5">= Customer kWh / Op_Hrs

= New_Motor_HP x kW factor (below)</td></tr>
<tr><td>Area</td><td>New Units With Cooling</td><td>New Units Without Cooling</td><td>Retrofit Units with Cooling</td><td>Retrofit Units without Cooling</td></tr>
<tr><td>Denver / Front Range</td><td>0.700</td><td>0.628</td><td>0.566</td><td>0.447</td></tr>
<tr><td>Alamosa / Mountain</td><td>0.646</td><td>0.605</td><td>0.515</td><td>0.447</td></tr>
<tr><td>Grand Junction / Western Slope</td><td>0.733</td><td>0.698</td><td>0.610</td><td>0.487</td></tr>
<tr><td>Cooling_kWh_Savings</td><td colspan="5">= 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</td></tr>
<tr><td>Cooling_kW_Savings</td><td colspan="5">= kW/ton x (Cooling_kW_PSC - Cooling_kW) x 3.413 / 12 = New_Motor_HP x 0.225</td></tr>
<tr><td>Peak Coincident KW</td><td colspan="5">= Customer kW X Coincidence Factor</td></tr>
<tr><td>Heating Penalty</td><td colspan="5">= -(Heating_kW_PSC -Heating_kW) x 3413 x Heat_EFLH / 1,000,000 / EFFb,
= New_Motor_HP x $-10.41 for Denver / Front Range
= New_Motor_HP x $-15.30 for Alamosa / Mountain
= New_Motor_HP x $-9.38 for Grand Junction / Western Slope,
taken as a non-energy benefit</td></tr>
</table>

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Variables:

BTUH_new	= Rated boiler or water heater Input BTUH nameplate data for the new boiler or water heater.
BTUH_existing	= Rated boiler or water heater Input BTUH nameplate data for the existing boiler or water heater that is being replaced or retrofitted with OA Reset dampers, Modulating Burner Controls, Tabulators or O2 Trim Controls.
Eff_Rating_High	= The rated efficiency of the new water heater, provided by the customer
Eff_Rating_Standard	= The minimum water heater thermal efficiency allowed by the federal standard = 80%
Volume_Daily_SqFt_Usage	=The daily usage of hot water by market segment per sq. ft. (Table 9)
Days_Year	= Days per year of hot water usage by market segment (Table 9)
T_setpoint	= Water heater setpoint = 140 deg F (Reference 11)
T_supply	= Cold water temperature = 58 deg F (Reference 11)
Other_Water_Heater_BTUH_Input	=The total input in btu/hr of all existing water heater that will remain in service
Hrs	= 659 hrs/yr for space heating only boilers = 2,190 hrs/yr for domestic hot water only boilers = 1,443 hrs/yr for space heating & domestic hot water boilers Pipe insulation hours are given in Table 2. = 950 hrs/yr for commercial furnaces
Alt	= Altitude Adjustment factor to adjust the sea level manufacturer's rated input for altitude effects = 0.891
SL_Hrs	= Standby loss hours for commercial water heaters = 8,760 hrs/yr
EFFb	= Efficiency of Baseline equipment. Refer Table 1 below
EFFh	= Efficiency for higher efficiency equipment. Refer Table 1 below.

SL_base	= Standby Losses for baseline storage water heater = 13.21 BTUH per gallon of storage (Ref 13)
SL_new	= Standby Losses for efficient water heater = 8.90 BTUH per gallon of storage (ref 13)
Leak_Hours	= Annual hours boiler lines are pressurized = 6000 hours
Leak_Rate	=Leakage rate, pounds of steam per hour. High Pressure = 11, Low Pressure = 5 (Reference 5)
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 5) 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 5)
LF	= Linear feet of insulation installed, provided by the customer.
Coef	= Heat loss polynomial equation coefficient. The number represents the power to which DeltaT is raised. Values for insulation/pipe combinations allowed in the product are listed in Table 7. Coefficients will be selected based on the pipe diameter, R (or k) value and insulation thickness provided by the customer.
k	= Thermal conductivity, btu-in/hr-ft^2-F
R-Value	= Thermal Resistance, (1/k)*thickness(inches)
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.
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.
Heating_Speed	= Speed of furnace fan in the heating mode = 80%
Cooling_Speed	= Speed of furnace fan in the cooling mode = 100%
Ventilation_Speed	= Speed of the furnace fan in fan only mode = 80% for the baseline and 80% for furnaces retrofitted with ECMs, and 60% for new furnaces equipped with ECMs.

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.
Full_Load_kW	= New_Motor_HP / New_Motor_Eff x 0.746 kW/HP = New_Motor_HP x 0.878
Heating_kW	= Full_Load_kW x Heating_Speed $^{Fan\_Law\_Exp}$ = New_Motor_HP x 0.502
Cooling_kW	= Full_Load_kW = New_Motor_HP x 0.878
Ventilation_kW	= Heating_kW for furnaces retrofitted with ECMs, and Full_Load_kW x Ventilation_Speed $^{2.5}$ = New_Motor_HP x 0.245 for new furnaces with ECMs
Fan_Law_Exp	= 2.5
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
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)

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Cooling_kW_PSC	= Cooling_kW x New_Motor_Eff / PSC_Motor_Eff = New_Motor_HP x 1.658
Heating_kW_PSC	= Heating_kW x New_Motor_Eff / PSC_Motor_Eff = New_Motor_HP x 0.948
Ventilation_kW_PSC	= Heating_kW_PSC = New_Motor_HP x 0.948
New Motor hp	= Rated power of EC fan motor installed by customer, in HP, taken from application
New_Motor_Eff	= Efficiency of the EC motor = 85%
PSC_Motor_Eff	= Efficiency of the PSC Motor = 45%
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	= Probability that the kW savings will occur during the Xcel system peak = 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.
1,000,000	= Conversion from BTU to Dth
Measure Life	= Length of time
Incremental Cost	= Refer to Tables 3 to 7
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)

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Assumptions:

- Each boiler 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.
- Climate zone assumed to be Denver for all boilers and water heaters
- Thermal Efficiency as defined in ASHRAE 90.1-2007 indicates the total efficiency of the boiler equal to 100% fuel energy minus all losses.
-The full load efficiency of condensing boiler is assumed to be 92%. For savings calculations, part load efficiency of 96.2% was used.
- Standby losses are from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) database based on a 100 gallon tank.
- Standby losses are equal for the baseline and efficient storage type water heaters and cancel out.
- Each furnace is replaced with the same size on a 1 for 1 basis.
- Prescriptive rebates are only given for furnaces put into service, rebates are not given for backup furnaces.
- Service life of typical furnace is 20 years (per FEMP), 15 years used in the calculations. Reference 10
- Furnaces must have a minimum efficiency of 92% AFUE for a rebate, and 94% AFUE or higher efficiency will receive a larger rebate.
- The baseline efficiency for the furnace is based on 2009 IECC, minimum of 78%.
- Efficiency of all furnaces is Annual Fuel Utilization Efficiency ("AFUE")
- For 175,000 Btu/h hot water boilers: 100% of capacity used for space heating. For 500,000-4,000,000 Btu/h boilers: 50% of capacity used for space heating, 50% of capacity used for hot water.

*Condensing boiler efficiencies at part loads were taken from AERCO International Inc Thermal Efficiency curve for condensing boilers.

- Prescriptive rebates are only given for boilers put into service, rebates are not given for backup boilers. Even though we do not rebate backup boilers, our assumed hours have been conservatively reduced to 65% of the predicted hours to account for boiler redundancy.
- Steam boiler has condensate return.
- 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
- For boilers: Though the BTU input and output are affected by altitude, the efficiency stays the same, so the elevation effect is not considered.
- 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 assumptio
- 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 14 and 17
- Furnace fan measure: there is no ventilation during unoccupied hours

Table 1: Heating Equipment Efficiencies		
	Baseline Efficiency (EFFb)	**Efficient Efficiency (EFFh)**
New Boilers (Non-Condensing)	80.00%	85.00%
New Boilers (Condensing)	80.00%	96.20%
Boiler Tune Up	78.00%	80.00%
Outdoor Air Reset	80.00%	83.00%
Stack Dampers	80.00%	81.00%
Modulating Burner Controls	80.00%	83.00%
O2 Trim Control	80.00%	82.00%
Steam Traps	80.00%	N/A
Commercial Furnaces	78.00%	92.00%
Water Heaters	80.00%	96.00%
Pipe Insulation	80.00%	N/A

Table 2: Hours for Pipe Insulation

Use of Pipe	Location	Pipe Insulation Hours	Explanation
Domestic Hot Water	Inside	5,584	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	2,622	Hours when boiler is running but outdoor temp is above building balance point
Space Heating	Outside	6,000	Hours that boiler is running

Table 3: Hot water boiler costs, Vendor supplied, Engineered Products					
	Non-condensing		Condensing	Incremental	Incremental
Boiler Nameplate Capacity	Baseline	High Efficient - Non Condensing	High Efficient - Condensing	Baseline to High Efficient - Non Condensing	Baseline to High Efficient - Condensing
175,000 Btuh	$3,000	$3,500	$4,600	$500	$1,600
500,000 Btuh	$5,000	$9,000	$11,200	$4,000	$6,200
1,000,000 Btuh	$7,300	$11,700	$15,000	$4,400	$7,700
2,000,000 Btuh	$12,000	$17,000	$26,500	$5,000	$14,500
4,000,000 Btuh	$24,000	$34,000	$53,000	$10,000	$29,000
6,000,000 Btuh	$36,000	$51,000	$79,500	$15,000	$43,500
8,000,000 Btuh	$48,000	$68,000	$106,000	$20,000	$58,000

Table 4	
Baseline Equipment Sizing compared to New Construction Tankless	
Customer Segment	Sizing multiplier for equivalent Storage System with 100 gallons of storage
Fast Food Restaurant	48%
Sit-Down Restaurant	54%
Elementary School	52%
Junior High School	88%
Motel	98%
Apartment Building	51%
Fitness Center	65%
Other	65%
Incremental Cost per Nameplate Input BTUH for Storage Water Heater per 100 gallons of storage	
Customer Segment	$/BTUH
Fast Food Restaurant	0.0326
Sit-Down Restaurant	0.0056
Elementary School	0.0056
Junior High School	0.0085
Motel	0.0056
Apartment Building	0.0340
Fitness Center	0.0085
Other	0.0144

Incremental Cost per Nameplate Input BTUH for Tankless Water Heater	
Customer Segment	**$/BTUH**
Fast Food Restaurant	0.0105
Sit-Down Restaurant	0.0044
Elementary School	0.0044
Junior High School	-0.0049
Motel	-0.0080
Apartment Building	0.0105
Fitness Center	0.0037
Other	0.0029

Table 5: Other Heating System Improvements	
Boiler Tune Up	Actual costs will be provided by customer
Outdoor Air Reset	Actual costs will be provided by customer
Stack Dampers > 750 Mbtuh	Actual costs will be provided by customer
Stack Dampers > 750 Mbtuh	Actual costs will be provided by customer
Modulating Burner Controls < 750 Mbtuh	Actual costs will be provided by customer
Modulating Burner Controls > 750 Mbtuh	Actual costs will be provided by customer
O2 Trim Control	Actual costs will be provided by customer
Steam Traps	Actual costs will be provided by customer
Pipe Insulation	Actual costs will be provided by customer

Table 6: Commercial Furnaces (Reference 3)	
Btu Input	**Incremental Cost**
60,000	$804.95
70,000	$782.26
80,000	$775.83
90,000	$785.68
100,000	$811.80
115,000	$893.02
120,000	$912.86
125,000	$948.29
140,000	$1,079.00

Table 7: Commercial Furnaces (References 15 & 16)	
	Cost
Baseline Fan	$236.00
EC Fan	$448.00
Incremental	$212.00