DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Product: Heating Efficiency

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_base - BTUH_new) x Hrs / 1,000,000) + ((SL_base - SL_new) X SL_Hrs / 1,000,000)
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.

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.
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. = 1,092 hrs/yr for commercial water heaters = 950 hrs/yr for commercial furnaces
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 = 1,200 BTUH (Reference 4)
SL_new	= Standby Losses for efficient water heater = 1,200 BTUH for storage models and 0 BTUH for tankless models (Reference 4)
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.

1,000,000	= Conversion from BTU to Dth
Measure Life	= Length of time the boiler equipment will be operational = See table 8.
Incremental Cost	= Refer to Tables 3 to 6
NTG	Net-to-gross = 86% for all measures. Reference 6

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)

Additional Information for Plan B boilers:

Efficiency of boiler being replaced

Current State of Colorado Inspection certificate indicating the age and active status of the boiler

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

For Water Heaters:

Water heater type (Non-condensing or Condensing)

Water heater storage capacity (Gallons) i.e. 0 if tankless

Water Heater size rated at sea level (BTUH)

Incremental cost

For Furnaces:

New furnace size (BTUH)

New furnace efficiency

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 94% was used.
-The full load efficiency of the baseline Plan B boiler is assumed to be 78%. For savings calculations, the actual nameplate efficiency provided by the customer will be
- 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 2006 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 Tetra Tech's final report "Comprehensive Process and Impact Evaluation of the Business Heating Efficiency Program - Colorado" to Xcel Energy dated December 14, 2011
- 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 12 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.

Table 1: Heating Equipment Efficiencies		
	Baseline Efficiency (EFFb)	Efficient Efficiency (EFFh)
New Boilers (Non-Condensing)	80.00%	85.00%
New Boilers (Condensing)	80.00%	94.00%
Replacement Boilers (Condensing)	78.00%	94.00%
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	Incremental
Boiler Nameplate Capacity	Baseline	High Efficient - Non Condensing	High Efficient Condensing	Baseline to High Efficient - Non Condensing	Baseline to High Efficient - Condensing	Plan B Replacement High Efficient - Condensing
175,000 Btuh	$3,000	$3,500	$4,600	$500	$1,600	$6,613
500,000 Btuh	$5,000	$9,000	$11,200	$4,000	$6,200	$16,951
1,000,000 Btuh	$7,300	$11,700	$15,000	$4,400	$7,700	$26,502
2,000,000 Btuh	$12,000	$17,000	$26,500	$5,000	$14,500	$49,504
4,000,000 Btuh	$24,000	$34,000	$53,000	$10,000	$29,000	$99,008
6,000,000 Btuh	$36,000	$51,000	$79,500	$15,000	$43,500	$148,512
8,000,000 Btuh	$48,000	$68,000	$106,000	$20,000	$58,000	$198,016

Table 4: Commercial Water Heater Costs, Vendor supplied			
Water Heater Nameplate Capacity	Baseline	High Efficient	Incremental
Commercial Water Heater - Condensing; 125 MBTUH	$3,105	$4,006	$901
Commercial Water Heater - Condensing; 160 MBTUH	$3,512	$4,530	$1,018
Commercial Water Heater - Condensing; 199 MBTUH	$3,450	$4,450	$1,000
Commercial Water Heater - Condensing; 300 MBTUH	$5,959	$7,687	$1,728
Commercial Tankless Water Heater - Condensing; 150 MBTUH	$4,284	$5,526	$1,242
Commercial Tankless Water Heater - Condensing; 199.9 MBTUH	$3,450	$4,450	$1,000

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: Pipe Insulation polynomial equation coefficients and incremental cost

Pipe Nominal Diameter (inches)	Insulation Thickness (Inches)	Polynomial Coefficients, Uninsulated				Polynomial Coefficients, Insulated			
		Coef0	Coef1	Coef2	Coef3	Coef0	Coef1	Coef2	Coef3
0.50	1.0	-3.0374E+00	4.5690E-01	8.6645E-04	4.0333E-07	-1.4187E-01	9.4515E-02	9.5675E-05	2.0500E-07
0.50	1.5	-3.0374E+00	4.5690E-01	8.6645E-04	4.0333E-07	-9.3332E-02	7.8916E-02	7.4175E-05	1.7167E-07
0.75	1.0	-3.6084E+00	5.5068E-01	1.0738E-03	4.9833E-07	-1.8348E-01	1.1210E-01	1.1840E-04	2.4000E-07
0.75	1.5	-3.6084E+00	5.5068E-01	1.0738E-03	4.9833E-07	-1.1155E-01	9.0618E-02	8.7550E-05	1.9667E-07
1.00	1.0	-4.4355E+00	6.6986E-01	1.3218E-03	6.3167E-07	-1.9200E-01	1.1754E-01	1.2070E-04	2.5333E-07
1.00	1.5	-4.4355E+00	6.6986E-01	1.3218E-03	6.3167E-07	-1.1202E-01	9.8294E-02	9.6075E-05	2.1167E-07
1.25	1.0	-5.7434E+00	8.3004E-01	1.5980E-03	8.8500E-07	-2.9272E-01	1.4849E-01	1.5975E-04	3.1667E-07
1.25	1.5	-5.7434E+00	8.3004E-01	1.5980E-03	8.8500E-07	-1.3118E-01	1.0982E-01	1.0618E-04	2.3833E-07
1.50	1.0	-6.3813E+00	9.3332E-01	1.8326E-03	9.9000E-07	-2.7700E-01	1.5147E-01	1.5938E-04	3.2500E-07
1.50	1.5	-6.3813E+00	9.3332E-01	1.8326E-03	9.9000E-07	-1.6005E-01	1.2339E-01	1.2200E-04	2.6667E-07
2.00	1.0	-7.7082E+00	1.1384E+00	2.2752E-03	1.2350E-06	-3.3948E-01	1.7646E-01	1.8525E-04	3.8333E-07
2.00	1.5	-7.7082E+00	1.1384E+00	2.2752E-03	1.2350E-06	-2.0389E-01	1.4083E-01	1.3790E-04	3.0667E-07
2.50	1.5	-9.3690E+00	1.3590E+00	2.6993E-03	1.5500E-06	-1.7869E-01	1.4528E-01	1.4075E-04	3.1667E-07
2.50	2.0	-9.3690E+00	1.3590E+00	2.6993E-03	1.5500E-06	-1.3498E-01	1.2739E-01	1.1985E-04	2.7667E-07
3.00	1.5	-1.1275E+01	1.6288E+00	3.2514E-03	1.9067E-06	-2.6414E-01	1.8400E-01	1.8783E-04	3.9500E-07
3.00	2.0	-1.1275E+01	1.6288E+00	3.2514E-03	1.9067E-06	-1.7765E-01	1.5601E-01	1.5245E-04	3.3667E-07
4.00	1.5	-1.4044E+01	2.0490E+00	4.1818E-03	2.3833E-06	-3.3314E-01	2.2060E-01	2.2868E-04	4.7167E-07
4.00	2.0	-1.4044E+01	2.0490E+00	4.1818E-03	2.3833E-06	-2.3785E-01	1.8565E-01	1.8200E-04	4.0000E-07
5.00	1.5	-1.6652E+01	2.4856E+00	5.2152E-03	2.8167E-06	-4.5046E-01	2.6745E-01	2.7580E-04	5.8000E-07
5.00	2.0	-1.6652E+01	2.4856E+00	5.2152E-03	2.8167E-06	-2.9805E-01	2.2138E-01	2.1908E-04	4.7833E-07
6.00	1.5	-2.0439E+01	2.9514E+00	6.0177E-03	3.6500E-06	-6.1558E-01	3.1278E-01	3.1310E-04	6.9333E-07
6.00	2.0	-2.0439E+01	2.9514E+00	6.0177E-03	3.6500E-06	-3.4456E-01	2.4953E-01	2.4818E-04	5.3833E-07
8.00	1.5	-2.6767E+01	3.8025E+00	7.6705E-03	4.9667E-06	-6.9016E-01	3.7481E-01	3.9035E-04	8.1000E-07
8.00	2.0	-2.6767E+01	3.8025E+00	7.6705E-03	4.9667E-06	-1.4066E+00	3.3454E-01	9.9850E-05	1.1100E-06
10.00	1.5	-3.1882E+01	4.6589E+00	9.7102E-03	5.8167E-06	-8.7637E-01	4.4116E-01	4.4313E-04	9.7500E-07
10.00	2.0	-3.1882E+01	4.6589E+00	9.7102E-03	5.8167E-06	-5.2419E-01	3.5989E-01	3.6058E-04	7.7833E-07
12.00	1.5	-3.8751E+01	5.5187E+00	1.1240E-02	7.3333E-06	-1.0195E+00	5.1188E-01	5.2188E-04	1.1250E-06
12.00	2.0	-3.8751E+01	5.5187E+00	1.1240E-02	7.3333E-06	-5.6113E-01	4.1443E-01	4.3003E-04	8.8167E-07

Note:
The updated coefficients were developed using the NAIMA 3E Plus 4.0 Software.
The following assumptions were used:

Base metal - Steel
Insulation - 650F min.Fiber Pipe and Tank, Type II, C1393-00a
Jacket Material – 0.13 Stainless Steel, new, cleaned
Ambient Temperature -45F
Wind Speed - 0mph
Max Surface Temp - 140F
System Application - Pipe Horizontal
System Units - ASTM C585

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

Measure	Product Life (yrs)	Source of Information
Hot Water Boilers (Non-condensing)		
Hot Water Boiler - Non-condensing 175 MBTUH	20	Federal Energy Management Program
Hot Water Boiler - Non-condensing 500 MBTUH	20	Federal Energy Management Program
Hot Water Boiler - Non-condensing 1MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Non-condensing 2 MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Non-condensing 4 MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Non-condensing 6 MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Non-condensing 8, MMBTUH	20	Federal Energy Management Program
Hot Water Boilers (Condensing)		
Hot Water Boiler - Condensing 175 MBTUH	20	Federal Energy Management Program
Hot Water Boiler - Condensing 500 MBTUH	20	Federal Energy Management Program
Hot Water Boiler - Condensing 1 MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Condensing 2 MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Condensing 4 MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Condensing 6 MMBTUH	20	Federal Energy Management Program
Hot Water Boiler - Condensing 8 MMBTUH	20	Federal Energy Management Program
Commercial Furnaces	15	Federal Energy Management Program
Commercial Water Heaters		
Commercial Hot Water Heater - Condensing; 125 MBTUH	15	Federal Energy Management Program
Commercial Hot Water Heater - Condensing; 160 MBTUH	15	Federal Energy Management Program
Commercial Hot Water Heater - Condensing; 199 MBTUH	15	Federal Energy Management Program
Commercial Hot Water Heater - Condensing; 300 MBTUH	15	Federal Energy Management Program
Commercial Tankless Hot Water Heater - Non-condensing; 150 MBTUH	15	Federal Energy Management Program
Commercial Tankless Hot Water Heater - Non-condensing; 199 MBTUH	15	Federal Energy Management Program
Commercial Tankless Hot Water Heater - Non-condensing; 399 MBTUH	15	Federal Energy Management Program
Commercial Tankless Hot Water Heater - Non-condensing; 500 MBTUH	15	Federal Energy Management Program
Steam Traps		
Gas Boiler - Steam Traps - Low Pressure - average of 10 and 15 PSI	5	Internet
Gas Boiler - Steam Traps - High Pressure - average of 50 PSI and 65 PSI	5	Internet
Boiler Tune Ups	2	Federal Energy Management Program
Pipe Insulation		
Insulation - Hot Water System	15	Reference Tetra Tech Final Report to X
Insulation - Steam System	15	Reference Tetra Tech Final Report to X

DEEMED SAVINGS TECHNICAL ASSUMPTIONS

References:

1. The baseline efficiency for new boilers is based on 2006 IECC, ASHRAE 90.1, and Federal Rule10 CFR Part 431 [Docket No. EERE–2008–BT–STD–0013] RIN 1904–AB83 "Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards and Test Procedures for Commercial Heating, Air-Conditioning, and Water-Heating Equipment"

2. The baseline efficiency for replacement hot water boilers is based on the baseline efficiency used in the DOE document "TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR COMMERCIAL AND INDUSTRIAL EQUIPMENT: EFFICIENCY STANDARDS FOR COMMERCIAL HEATING, AIRCONDITIONING, AND WATERHEATING EQUIPMENT" dated July 9, 2008

3. The baseline efficiency for baseline furnace (AFUE), as defined in the 2006 IECC. It is 78%.

4. Water heater efficiencies and standby losses are from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) database.

5. Leakage data from Energy Management Handbook, by Wayne Turner

6. Net-to-Gross factor is calculated using the California self report approach for previous program participaiton with a 1% upward adjustment to account for increasing influence for a maturing program. Reference Tetra Tech Final Report "Comprehensive Process and Impact Evaluation of the Business Heating Efficiency Program - Colorado" to Xcel Energy dated December 14, 2011

7. not used

8. not used

9. The average baseline and high efficiency costs are based on the California DEER database.

10. Measure life from the Federal Energy Management Program (FEMP).

11. Tetra Tech final report "Comprehensive Process and Impact Evaluation of the Business Heating Efficiency Program - Colorado" to Xcel Energy dated December 14, 2011