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Witness:	Laureen M. Welikson
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File No.:	GR-2019-0077
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MISSOURI PUBLIC SERVICE COMMISSION

FILE NO. GR-2019-0077

DIRECT TESTIMONY

OF

LAUREEN M. WELIKSON

ON

BEHALF OF

UNION ELECTRIC COMPANY

d/b/a AMEREN MISSOURI

St. Louis, Missouri
December, 2018

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DIRECT TESTIMONY

OF

LAUREEN M. WELIKSON

FILE NO. GR-2019-0077

I. INTRODUCTION

Q. Please state your name and business address.

A. My name is Laureen M. Welikson and my business address is Union Electric Company d/b/a Ameren Missouri ("Ameren Missouri" or "Company"), One Ameren Plaza, 1901 Chouteau Avenue, St. Louis, Missouri 63103.

Q. What is your position with Ameren Missouri?

A. I am a Senior Consultant in Energy Efficiency Evaluation & Strategy.

Q. Please describe your educational background and employment experience.

A. I received a Bachelor of Science degree in Electrical Engineering from the University of Illinois in 1986. I subsequently received a Master of Business Administration Degree from Colorado State University in 2001. During my college career, I completed an internship at Sargent & Lundy, LLC., a large firm that provides consulting, engineering, design, analysis, and project management services for power and generation projects worldwide. Upon completion of my bachelor's degree, I began working full time for Illinois Power Company as an engineer in the System Planning Department. I later worked in the Marketing Department at Illinois Power Company as a Competitive Development Engineer developing contracts to retain customers from competition such as cogeneration opportunities and other electric suppliers as Illinois deregulated.

I joined Ameren Services as a Business Development Executive in 2000, developing competitive contracts as the Company pursued opportunities to obtain customers in other utilities' service territories following deregulation. In 2004, I moved to a role in the regulatory group, primarily working on line extension policy and standards of conduct. In 2009, I was promoted to my current role as Senior Consultant in Energy Efficiency Evaluation & Strategy. In that role, I coordinate the evaluation of Ameren Missouri's energy efficiency programs, assist in the planning of those programs, and run cost effectiveness analyses of programs and measures. In 2015 I obtained certification as a Project Management Professional.

II. PURPOSE OF TESTIMONY

Q. What is the purpose of your direct testimony in this proceeding?

A. My direct testimony in this proceeding concerns proposed changes to Ameren Missouri's natural gas energy efficiency programs, including the addition of a low-income natural gas energy efficiency program, the use of a natural gas Technical Resource Manual, and a new red tag repair program. I also provide details for calculating conservation under Ameren Missouri's proposed Weather & Conservation Adjustment Rider ("WCAR").

Q. What will the impact of these recommendations be on the revenue requirement?

A. All these energy efficiency programs create a net zero impact on the Company's revenue requirement compared to the revenue requirement used to set rates in Ameren Missouri's last rate case. Funding for all of the proposed energy efficiency programs will not increase above the amount included in rates for similar programs in the last rate case, plus the remaining regulatory liability amount associated with unspent energy efficiency dollars since that case.

III. PROPOSED ENERGY EFFICIENCY PLAN

Q. Does Ameren Missouri currently run natural gas energy efficiency programs?

A. Yes, Ameren Missouri currently has energy efficiency programs for customers that take service in either the Company's Residential or General Service natural gas rate classes. Under current energy efficiency programs, rebates are provided to Residential customers who replace equipment such as boilers, furnaces, water heaters, insulation, thermostats, and hot water measures such as faucet aerators and showerheads. Rebates are provided to General Service customers for many of the same measures as Residential customers; however, rebates to General Service customers also include steam traps and cooking measures.

Q. Have conservation programs for gas customers been operated similar to the energy efficiency programs Ameren Missouri makes available to its retail electric customers?

A. No, there is currently no plan for natural gas customers similar to the plan available to Ameren Missouri's electric customers because the Missouri Energy Efficiency Investment Act ("MEEIA") does not apply to natural gas utilities. Instead, funding for natural gas energy efficiency has been approved as part of a natural gas rate case. As authorized by the Commission in the Company's last natural gas rate case (File No. GR-2010-0363), each year Ameren Missouri collects $700,000 from its customers. Of this total, $437,000 has been set aside for natural gas energy efficiency programs and $263,000 has been provided to the Missouri Division of Energy ("DE") for low-income weatherization programs.

Q. What is included in the Natural Gas Energy Efficiency Plan Ameren Missouri is proposing in this case?

A. The Natural Gas Energy Efficiency Plan Ameren Missouri is proposing in this case includes: (1) new energy efficiency programs for low-income customers, (2) the addition of a "custom" measure for Business[1] customers to allow gas transportation customers to participate, (3) use of a Natural Gas Technical Resource Manual for natural gas measures,[2] which is based upon the Missouri Statewide Technical Reference Manual, (4) a set-aside that would be used to fund a red tag program, (5) a portion of a new rider that would allow Ameren Missouri to recover the throughput disincentive associated with natural gas energy efficiency programs, and (6) the continued funding of the low-income weatherization programs. Each of these proposals is discussed in greater detail later in my direct testimony. Funding for the proposed low-income weatherization program would come from unspent funds set aside in prior years for energy efficiency.

Q. What is the total budget of the Natural Gas Energy Efficiency Plan Ameren Missouri is proposing in this case?

A. First, the Company proposes to keep the $700,000 included in base rates in its last gas rate case at the same level going forward. Second, the Company proposes to earmark the same portion of that total approved in the last rate case for low-income weatherization programs -- $263,000 -- except $25,000 of that amount would be further

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[1] The term "Business" refers to customers taking service under the Company's General Service or Transportation Service.

[2] This also includes measures that save both electricity and natural gas.

earmarked for a red tag repair program.[3] Lastly, the Company proposes to fund new low-income programs with its unspent regulatory liability from previously approved energy efficiency programs. Typically, regulatory liabilities are refunded to customers over a reasonable period (e.g., three years); therefore, the Company expects to use the unspent regulatory liability to fund low-income programs over a three-year period. Based on the Company's proposal, and the three-year amortization of the regulatory liability, program funding would be as follows:

Table 1 Estimated Three Year Budget

	2020	2021	2022	Total
Residential	$ 349,600	$ 349,600	$ 349,600	$ 1,048,800
Business	$ 87,400	$ 87,400	$ 87,400	$ 262,200
New Low-Income	$ 266,531	$ 266,531	$ 266,531	$ 799,594
Weatherization	$ 238,000	$ 238,000	$ 238,000	$ 714,000
Red Tag	$ 25,000	$ 25,000	$ 25,000	$ 75,000
Total	$ 966,531	$ 966,531	$ 966,531	$ 2,899,594

Q. What is the anticipated energy savings from these programs?

A. The anticipated savings, in therms, for these programs is as follows:

Table 2 Estimated Energy Savings

	2020	2021	2022	Total
Residential	229,559	229,559	229,559	688,678
Business	23,497	23,497	23,497	70,492
New Low-Income	27,922	27,922	27,922	83,767
Total	280,979	280,979	280,979	842,937

[3] The proposed weatherization budget is $238,000 and the tariff for weatherization has been updated accordingly and attached as Schedule LMW-D1.

Q. What is the anticipated cost-effectiveness of the programs?

A. Based on the Total Resource Cost Test ("TRC") and the Utility Cost Test ("UCT"), as defined in the Commission's MEEIA rules, anticipated cost-effectiveness for the programs is as follows:

Table 3 Estimated Cost Effectiveness Results

TRC	2020	2021	2022	Total 3 Year
Residential	3.45	3.36	3.28	3.36
Business	1.20	1.17	1.15	1.17
New Low-Income	1.12	1.09	1.06	1.09
Combined	2.55	2.48	2.42	2.48

UCT	2020	2021	2022	Total 3 Year
Residential	6.84	6.67	6.50	6.67
Business	2.49	2.43	2.37	2.43
New Low Income	1.12	1.09	1.06	1.09
Combined	4.13	4.03	3.93	3.76

Q. What will happen in the event the Company spends more or less than the Commission approved program budget?

A. Following the current procedures, the Company will track the difference of actual program costs compared to the approved budget using a regulatory asset or liability.

IV. NEW LOW-INCOME ENERGY EFFICIENCY PROGRAM

Q. Why is Ameren Missouri proposing a low-income natural gas energy efficiency program?

A. We believe this market is underserved by current natural gas energy efficiency programs. The low-income weatherization program run by the DE has a cap on the amount they are allowed to spend per home. Consequently, DE is prevented from providing all of the energy efficiency measures that these homes may need, such as insulation, windows, a new water heater, and a new furnace. In addition, a home can only be weatherized once no matter the level of project completed for that property unless the prior weatherization occurred prior to September 30, 1994. The Company's existing natural gas energy efficiency programs only provide a moderate incentive based on the incremental cost difference between an efficient measure and a standard baseline unit for that measure. That incentive level is not enough for low-income customers to overcome the high total cost of the measure they need to install. The proposed low-income program would provide higher incentives to help overcome the upfront cost. In order to limit the amount that must be provided, the program would work with other funding sources, including government grants and electric energy efficiency programs, to share the funding of energy efficient measures.

Q. How did Ameren Missouri arrive at the proposed budget for this program?

A. Over the past few years, Ameren Missouri has not spent the entire budget allocated to its natural gas energy efficiency programs ($437,000). During each of those years, unexpended funds were set aside in a regulatory liability account. The proposed budget for new low-income energy efficiency program allocates the regulatory liability entirely as a one-time budget increase to fund the low-income program. As of the end of the proposed test year in this rate case (June 30, 2018), this amount was $799,594, which is anticipated to be sufficient to fund the program for three years.

Q. Will this program provide incentives for multi-family properties or only single-family properties?

A. Both. It is anticipated that Ameren Missouri's natural gas operations will partner with existing and proposed electric low-income programs that provide incentives to both multifamily and single-family low income customers.

Q. Are customers required to participate in a partnering electric energy efficiency program in order to participate in the proposed gas energy efficiency programs?

A. No. While Ameren Missouri's natural gas operation intends to partner with its electric energy efficiency programs as much as possible in order to better serve customers who receive both natural gas and electric services and to share the costs of measures that save both electricity and natural gas, customers would not be required to participate in an electric program in order to participate in the natural gas energy efficiency program.

Q. How will customers qualify for the low-income program?

A. Customers can qualify in one of two ways. If they are participating in an Ameren Missouri electric low-income energy efficiency program, they will automatically be eligible for the natural gas low-income program. If they are not participating in an electric energy efficiency low-income program, they must meet at least one of the following requirements[4] to participate in the proposed natural gas program:

1. Reside in federal, state, or local subsidized housing and fall within that program's income guidelines.

[4] These are the same requirements as Ameren Missouri's electric low income programs.

2. Reside in non-subsidized housing with proof of income levels at or below 80% of the area median income ("AMI").
3. Fall within a census tract that indicates at least 85% of customers are at or below 80% of AMI.

V. CHANGES TO EXISTING ENERGY EFFICIENCY PROGRAMS

Q. What changes are being proposed to the Company's existing natural gas energy efficiency programs?

A. The two primary changes to the existing natural gas program are related to the business customers. First, I am proposing to open the business program to customers who take natural gas transportation service. Second, I am proposing to add a "custom" measure to the program to open the program to more savings opportunities that are cost effective but are not specifically stated on the prescriptive list. Revised tariffs for the natural gas energy efficiency programs including the addition of a low income program are included in my Schedules LMW-D2 and LMW-D3.

Q. Are these changes expected to result in additional savings?

A. Yes, I believe opening the programs to a larger pool of customers and allowing unique projects to qualify for incentives will result in additional savings.

Q. Is there a relationship between making these program changes and the Company's rate design and WCAR proposal?

A. Yes. Effective mitigation of the throughput disincentive has a direct relationship to these proposed changes; otherwise taking steps to produce additional natural gas savings will systematically weaken the Company's ability to recover its costs.

VI. APPROVAL OF TECHNICAL RESOURCE MANUAL ("TRM")

Q. Is the Company requesting the Commission to approve a Natural Gas TRM?

A. Yes. The Company recognizes that parties have put effort into the development of a draft statewide TRM and believes this case is a good opportunity for the Commission to approve a TRM for natural gas measures.

Q. Has the Company provided a Natural Gas TRM for approval?

A. Yes. The Company started with the draft statewide TRM version, isolated measures that provide natural gas savings, and made limited additions and modifications. The proposed Natural Gas TRM is included in three schedules:

- Schedule LMW-D4 Gas TRM Volume 1 – Overview and User's Guide
- Schedule LMW-D5 Gas TRM Volume 2 – C and I Measures
- Schedule LMW-D6 Gas TRM Volume 3 – Residential Measures

In addition, the calculated results of the algorithms in the Natural Gas TRM with Ameren Missouri inputs are included as Schedule LMW-D7 Ameren Missouri Natural Gas Deemed Savings Table.

Q. Does the Company support the approval of its provided Natural Gas TRM as a Statewide Natural Gas TRM?

A. Yes. Since other natural gas utilities have energy efficiency programs, the Commission may find it useful to have consistency across utilities. The Company is supportive of participating in the appropriate proceeding leading to adoption of a Statewide Natural Gas TRM.

Q. How would a Statewide Natural Gas TRM be updated and administered?

A. I propose the Commission Staff be the ultimate owner of the Statewide Natural Gas TRM, but I expect it to be a shared responsibility from all regulatory stakeholders. I realize Staff is busy and additional responsibilities should not be taken lightly; however, given there are already ongoing collaborative efforts in the natural gas business I believe that we can carve out some time here and there to manage the Statewide Natural Gas TRM as a collaborative effort with Staff helping to coordinate and officiate the efforts. There is no need for an intense and/or rigid update process.

VII. NEW RED TAG REPAIR PROGRAM

Q. Please describe the purpose of the proposed red tag repair program.

A. The proposed red tag repair program is designed to help low-income customers retain natural gas service in the event unexpected repairs are needed. For instance, during the normal course of business (e.g. a gas smell, a meter inspection, etc.) it may be determined there is an unsafe appliance or piping that requires service be disconnected (a.k.a., "red tagged"). The proposed program makes funds available to make repairs to prevent service disconnection. Natural gas service interruption, especially during the heating season, can be very disruptive, so a program like this offers an important opportunity to resolve equipment and piping issues quickly to prevent or minimize service interruptions.

Q. Who qualifies for the proposed red tag repair program?

A. This will be a program for low-income customers; that is, those customers with an income at or below 80% of the AMI.

Q. What specific services and resources are available for qualifying customers?

A. There are two primary components of the red tag repair program: (1) funding to allow a third party to make repairs to equipment and/or piping and (2) permission for an Ameren Missouri utility worker or contractor to use a limited amount of effort and resources to make repairs. For equipment and/or piping repairs, no customer shall receive assistance greater than $1,000, with no more than $700 going toward permanent space heating equipment repairs and no more than $450 going toward each other gas appliance or piping. For minor repairs that would otherwise result in a red tag, an Ameren Missouri utility worker or contractor is allowed no more than 15 minutes using parts that cost $20 or less to perform the repair and prevent service. Details are provided in the proposed tariff, attached to my testimony as Schedule LMW-D8.

Q. What is the proposed budget and source of funding for the proposed red tag repair program?

A. As I explained earlier in my direct testimony, the Company is proposing to repurpose $25,000 from the low-income weatherization funds for the new red tag repair program. Using this source of funding will enable this new service without adding an additional cost to the revenue requirement in this case.

Q. Do other natural gas utilities in Missouri have a similar red tag repair program?

A. While I have not surveyed all of the natural gas providers in Missouri, the proposed program is essentially the same program offered by Spire.

VIII. CALCULATION OF CONSERVATION FOR RATES

Q. Mr. Harding has provided testimony about the Company's proposed WCAR calculation. Please provide a summary of how the Conservation component will be determined.

A. The first input required for the monthly calculation is the Ccf savings[5] by end-use category by rate class. Monthly load shapes by end-use category are used to distribute types of energy savings (which are reported as annualized Ccf savings) across the months in the year to better reflect the seasonality of the savings that were achieved. For example, the heating category has most of its savings during the winter months while the water heating category has savings spread out more evenly. The end-use categories and load shapes are included in the WACR rider. The conversion to monthly savings data allows the Company to determine current month energy savings[6] as well as cumulative monthly energy savings from prior month energy savings activities. As energy savings are incorporated into base rates, the cumulative monthly savings are reduced to avoid double counting. The process of including savings in base rates and rebasing the throughput disincentive is discussed further below. The proposed Natural Gas TRM expresses savings as therms; therefore a conversion to Ccf is necessary to match billing practices. To convert the TRM therm savings to Ccf, the Company will use its existing processes and conversion factors inherent in its ongoing accounting practices.[7] This monthly savings (current month

[5] A net-to-gross ("NTG") of 1.0 will be used for these calculations as the rider mechanism covers all directly quantifiable conservation from energy efficiency not just those savings attributable to Ameren Missouri's programs.
[6] Current month savings are divided by 2 to reflect a "half-month" convention, which reflects the fact that not all measures were installed on day 1 of a month just as all measures were not installed on the last day of the month.
[7] Customers are billed in Ccf, but the Company's accounting system reports therms which inherently relies on the creation of monthly conversion factors that are based on the characteristics of natural gas that were delivered in that month.

plus cumulative savings less savings included in base rates) by rate class is then multiplied by the appropriate margin rate to arrive at the monthly dollar value of throughput disincentive by rate class.

When base rates are adjusted, upon the conclusion of a general rate proceeding or otherwise, the cumulative, annualized, and normalized (at a net-to-gross factor of 1.0) Ccf savings from all active programs will be reflected in the unit sales and retail revenues used in setting the rates through the rate case true-up period. Upon the adjustment for the Ccf savings in the rate case, the throughput disincentive will be rebased to subtract the Ccf savings that are reflected in the billing units used to establish new rates from the cumulative Ccf savings when the rates take effect.

Q. Is this process being used in other approved recovery mechanisms?

A. Yes. The Company is proposing a process identical to the process that has been in operation under MEEIA since 2016 and recently included as part of the Company's MEEIA 2019-21 plan. In fact, the process is so similar that we are using the same spreadsheets to perform the calculations but with inputs relevant to natural gas.

Q. Does this conclude your direct testimony?

A. Yes, it does.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of Union Electric Company d/b/a Ameren Missouri's Tariffs to Increase Its Revenues for Natural Gas Service.	)))	File No. GR-2019-0077

AFFIDAVIT OF LAUREEN M. WELIKSON

STATE OF MISSOURI)
) **ss**
CITY OF ST. LOUIS)

Laureen M. Welikson, being first duly sworn on his oath, states:

1. My name is Laureen M. Welikson. I work in the City of St. Louis, Missouri, and I am employed by Union Electric Company d/b/a Ameren Missouri as Senior Consultant in Energy Efficiency Evaluation & Strategy.

2. Attached hereto and made a part hereof for all purposes is my Direct Testimony on behalf of Union Electric Company d/b/a Ameren Missouri consisting of 14 pages and Schedule(s) LMW-D1 to LMW-D8, all of which have been prepared in written form for introduction into evidence in the above-referenced docket.

3. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded are true and correct.

Laureen M Welikson
Laureen M. Welikson

Subscribed and sworn to before me this 29th day of November, 2018.

Cathleen A Dehne
Notary Public

My commission expires:
March 7, 2021

CATHLEEN A DEHNE
Notary Public – Notary Seal
St. Louis City – State of Missouri
Commission Number 17119727
My Commission Expires Mar 7, 2021

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

WEATHERIZATION PROGRAM

PURPOSE

This voluntary Weatherization Program (Program) is intended to assist qualified residential gas customers in reducing their use of energy through weatherization and conservation.

AVAILABILITY

This voluntary Program is available to customers receiving service under the Company's Residential Service Rate and who meet the customer eligibility requirements.

TERMS AND CONDITIONS

a. Pursuant to the Order issued by the Missouri Public Service Commission (MPSC) in Case No. GR-2019-0077, the Company will provide $238,000 annually (the Program funds) for a residential weatherization grant program, including energy education, for primarily lower income customers. The Program is administered by the Missouri Division of Economic Development (MDED).

b. The Program funds will be forwarded to the State Environmental Improvement and Energy Resources Authority (EIERA) for administration by MDED.

c. The Program offers grants for weatherization services to eligible customers and will be primarily directed to lower income customers.

d. The total amount of grants offered to an individual customer for improvements that can be made to their residence will be determined by using the National Energy Audit Tool (NEAT) software or other MDED approved audit tool. The grants and improvements offered will be consistent with the federal weatherization assistance program administered by MDED.

e. The Company will retain at least two years of post-weatherization usage and payment history for each customer's residence that is weatherized.

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS EQUIPMENT AND BUILDING SHELL MEASURE REBATE PROGRAMS

APPLICATION

The Missouri Energy Efficient Natural Gas Equipment and Building Shell Measure Rebate Programs (Program) is designed to encourage more effective utilization of natural gas by encouraging cost effective energy efficiency improvements through the replacement of less efficient natural gas equipment with high efficient ENERGY STAR® Qualified natural gas equipment and other high efficiency equipment and building shell measures.

Rebates are being offered on a limited basis for a portion of the cost of Measures purchased by Participants.

DEFINITIONS

ACH – Air Changes per Hour: ACH represents how many times per hour the air volume inside the living space is naturally replaced by outside air due to air leaks. ACH measurements vary according to the "air-tightness" of the building shell.

Administrator - Company will administer the Program through a contractor experienced in energy efficiency rebate programs.

AFUE – Annual Fuel Utilization Efficiency: Energy efficiency rating measure determined, under specific testing conditions, by dividing the energy output by the energy input. It is a measure of the heat actually delivered by a furnace to the structure compared to the heat potential in amount of fuel supplied to the furnace. For example, a furnace that has a 92% AFUE rating converts 92% of the fuel supplied as heat to the structure – the other 8% is lost as exhaust. This information is available on every furnace sold in the United States.

CUSTOM REBATE - The rebate program will make available custom rebates to business customers for the installation of any natural gas related energy efficiency improvement that does not qualify for a prescriptive rebate. All custom rebates will be individually determined and analyzed prior to installation to ensure that the Total Resource Cost Test is 1.0 or higher. The maximum allowable rebate per customer is $25,000.

EEAG - Energy Efficiency Advisory Group: Includes representatives from the Company, the Commission Staff, Office of the Public Counsel (OPC), and the Division of Energy. The EEAG will function as an advisory group for this Program.

DATE OF ISSUE December 3, 2018 DATE EFFECTIVE January 2, 2019

ISSUED BY Michael Moehn (Name of Officer) President (Title) St. Louis, Missouri (Address)

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS
EQUIPMENT AND BUILDING SHELL MEASURE REBATE PROGRAMS (cont'd)

DEFINITIONS (cont'd)

ENERGY STAR® - A voluntary labeling program designed to identify and promote energy efficient products to reduce energy expenses and greenhouse gas emissions. ENERGY STAR® is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy.

Measure – The replacement of less efficient natural gas equipment with high efficient ENERGY STAR® Qualified natural gas equipment and other high efficiency equipment and building shell measures.

Participant - A customer who is being served under either the Company's Residential, General, or Transportation Service natural gas rate class, is located in Missouri, and elects to either purchase or agrees to receive energy efficient gas saving equipment as described in the Measures. For purposes of receiving rebates under this Program, a Participant is defined as a person, firm, organization, association, corporation, landlord, contractor or other entity that implements Measure(s) and submits a rebate form(s) and documentation.

Qualified Auditor - A nationally recognized contractor trained in natural gas equipment utilization systems and commercial and/or residential structures as an integrated whole building system. Residential training, certification, and accreditation are provided by the Building Performance Institute (BPI) and Residential Energy Services Network's (RESNET®). Commercial training and certification are provided by nationally-respected energy auditor certification organizations. Approved Energy Auditors are found by calling the Company at 1-800-552-7583 or on the internet at http://www.ded.mo.gov/asp/energy/auditors.htm or http://www.bpi.org/locator-tool/find-a-contractor.

Rebate Range Sheet – The list of Measures to be offered to Participants along with the minimum and maximum rebate level permitted for each Measure.

Retailer - Any retailer which has agreed to sell ENERGY STAR® Qualifying or other high efficient natural gas equipment, or provider of energy efficiency services, associated with the Measures.

AVAILABILITY

The Program is voluntary. A Participant may receive rebates, for the quantities listed for each Measure, each calendar year. Rebates must be redeemed through the Administrator. High Efficiency and ENERGY STAR® Equipment availability may vary by each Participating Retailer throughout the Company's territory.

Residential rebates apply only to Residential customers, or their landlords purchasing Measures listed as Residential in the Rebate Range Sheet.

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS
EQUIPMENT AND BUILDING SHELL MEASURE REBATE PROGRAMS (cont'd)

AVAILABILITY (cont'd)

General Service and Transportation Service rebates apply only to General Service and Transportation Service customers purchasing Measures listed as Business in the Rebate Range Sheet.

Program details regarding the interaction between the Company or Program Administrators and Participants in the Program, such as available Measures, Measure ranges, availability of the Program, eligibility, and application and completion requirements may be adjusted through the change process as presented below. Those details, additional details on each Measure, and other details such as process flows, application instructions, and application forms will be provided on the Company's website AmerenMissouri.com/naturalgas, or by calling toll free 1-800-552-7583

CHANGE PROCESS

The change process is applicable to changes in a Measure detail regarding the interaction between the Company or Program Administrators and Participants in the Measures.

1. Identify need for Measure detail change regarding the interaction between the Company or Program Administrators and Participants in the Measures;
2. Discuss proposed change with implementer;
3. Analyze impact on Program and portfolio (Cost effectiveness, goal achievement, etc.);
4. Inform the Staff, Office of the Public Counsel, and the Missouri Department of Economic Development - Division of Energy (DE) of the proposed change, the time within which it needs to be implemented, provide them the analysis that was done and consider recommendations from them that are received within the implementation timeline (the implementation timeline shall be no less than five business days from the time that the Staff, Office of the Public counsel, and the DE are informed and provided the above-referenced analysis);
5. Take timely received recommendations into account and incorporate them where the Company believes it is appropriate to do so;
6. Notify and train customer contact personnel (Contact Center, Energy Advisors, Business Center, Key Account Executives, Customer Service Advisors) of the changes;
7. Make changes to forms and promotional materials;
8. Update Program website;
9. Provide updated web pages and, if appropriate, updated list of Measures and rebate amounts to Staff; and
10. Inform Participants, Trade Allies, etc. Company will also continue to discuss and provide information on ongoing Program and portfolio progress at quarterly regulatory stakeholder update meetings.

DATE OF ISSUE December 3, 2018 **DATE EFFECTIVE** January 2, 2019

ISSUED BY Michael Moehn (Name of Officer) President (Title) St. Louis, Missouri (Address)

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS
EQUIPMENT AND BUILDING SHELL MEASURE REBATE PROGRAMS (cont'd)

CHANGES IN MEASURES OR REBATES

Company may offer the Measures contained in Company's Rebate Range Sheet. The offering of Measures not contained within Company's Rebate Range Sheet must be approved by the Commission. Not all Measures listed in the Rebate Range Sheet will be offered at all times. The actual Measures being offered, and rebates available to Participants, will be listed on Company's website, AmerenMissouri.com/naturalgas. The Measures and rebates being offered are subject to change – Participants must consult AmerenMissouri.com/naturalgas for the list of currently available Measures. The website will expressly state in conspicuous language that the Measures and rebates are subject to change.

REBATES

Each Participant will receive a rebate check from the Administrator within six (6) to eight (8) weeks after the completed Rebate Form is submitted with proper documentation. Rebate Forms, applications and protocols are available on the Company's Website AmerenMissouri.com/naturalgas or by calling Ameren Missouri at 314-342-1111 or 800-552-7583.

PROGRAM TERM

The Program will conclude on December 31, 2022 or at the time new rates go into effect as a result of a general rate proceeding, whichever occurs first. All installations of Measures must occur before the conclusion date of the Program to qualify for a rebate. All rebate forms for this Program must be submitted and post-marked not later than one month after the conclusion date of the Program.

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS
EQUIPMENT AND BUILDING SHELL MEASURE REBATE PROGRAMS (cont'd)

REBATE RANGE SHEET – RESIDENTIAL & LANDLORD MEASURES

Measure	Max Number of Rebates	Minimum Rebate Level ($/Measure)	Maximum Rebate Level ($/Measure)
Programmable Thermostat	2	$0	$50
Learning Thermostat	2	$25	$125
Natural Gas Furnace (Tier 1) AFUE rated 92% to 95.9%	2 (Note 1)	$100	$300
Natural Gas Furnace (Tier 2) AFUE rated 96% or higher	2 (Note 1)	$200	$450
Natural Gas Boiler (Tier 1) AFUE rated 85% to 89.9%	2 (Note 1)	$50	$300
Natural Gas Boiler (Tier 2) AFUE rated 90% or higher	2 (Note 1)	$200	$450
Natural Gas Tank Storage Water Heater, 20-55 gal, EF rating .67 or higher	2	$100	$300
Natural Gas Tankless water heater EF rating .9 or higher	2	$200	$400
Ceiling Insulation R30 to R49	$200	$.004 per sf x ΔR	$.02 per sf x ΔR
Wall Insulation, minimum rating or R11	$400	$.04 per sf x ΔR	$.07 per sf x ΔR
Hot Water Measure Kit (1-shower head, 2-aerators, 10 ft pipe wrap)	2	$0	$25
Ceiling Insulation R30 to R49 w/Audit	$400	$.004 per sf x ΔR	$.02 per sf x ΔR
Wall Insulation, minimum rating or R11 w/Audit	$800	$.04 per sf x ΔR	$.07 per sf x ΔR
Air Sealing Measure w/Audit	$200	$150	$350
Duct Sealing Measure w/Audit	$200	$150	$350
Low Flow Faucet Aerator	1/faucet	$0	$15
Low Flow Showerhead	1/shower	$0	$15
Pipe Wrap	No Limit	$0	$10
Hot Water Measure Kit w/Audit	2	$0	$40
H.E. Boiler (side-arm tank)	2	$300	$600
Furnace Tune-up	2	25% of Incremental Cost	75% of Incremental Cost
Boiler Tune-up	2	25% of Incremental Cost	75% of Incremental Cost

Note (1): For Landlords a maximum of ten (10) units or 10% of the total units whichever is greater

DATE OF ISSUE December 3, 2018 DATE EFFECTIVE January 2, 2019

ISSUED BY Michael Moehn (Name of Officer) President (Title) St. Louis, Missouri (Address)

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS
EQUIPMENT AND BUILDING SHELL MEASURE REBATE PROGRAMS (cont'd)

REBATE RANGE SHEET - BUSINESS MEASURES

Measure	Max Number of Rebates	Minimum Rebate Level ($/Measure)	Maximum Rebate Level ($/Measure)
Programmable Thermostat	2	$1	$50
Learning Thermostat	2	$25	$125
Natural Gas Furnace (Tier 1) AFUE rated 92% to 95.9%	10	$100	$300
Natural Gas Furnace (Tier 2) AFUE rated 96% or higher	10	$200	$450
Steam Trap Replacement	25	$25	$100
Natural Gas Food Service Steam Cookers - 5 pan	2	$1,500	$1,950
Natural Gas Food Service Steam Cookers - 6 pan	2	$1,500	$1,950
Natural Gas Food Service Double Oven	2	$2,000	$2,750
Natural Gas Tank Storage Water Heater, 20-55 gal, EF rating .67 or higher	10	$100	$300
Natural Gas Tankless Water Heater	10	$200	$400
Hot Water Measure Kit (1-shower head, 2-aerators, 10 ft pipe wrap)	3	$0	$25
Ceiling Insulation R18	$250	$.02 per sf x ΔR	$.04 per sf x ΔR
Wall Insulation, minimum rating or R20	$400	$.035 per sf x ΔR	$.06 per sf x ΔR
Ceiling Insulation R18 to R49 w/Audit	$500	$.02 per sf x ΔR	$.04 per sf x ΔR
Wall Insulation, R20-R49 w/Audit	$800	$.035 per sf x ΔR	$.06 per sf x ΔR
Air Sealing Measure w/Audit	$800	$300 per 0.5 ACH reduction	$500 per 0.5 ACH reduction
Hot Water Measure Kit w/Audit	2	$0	$25
Pre-Rinse Spray Valve (less than 1.5 GPM)	2	$25	$175
Natural Gas Large Vat Fryer	2	$700	$1,200
Natural Gas Boiler AFUE rated 90% or higher	2	$200	$450
Furnace Tune-up	10	25% of Incremental Cost	75% of Incremental Cost
Boiler Tune-up	2	25% of Incremental Cost	75% of Incremental Cost
Custom Rebate	1	$5/MCF	$8/MCF

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS CO-DELIVERY PROGRAM

APPLICATION

The Missouri Energy Efficient Natural Gas Co-Delivery Program is designed to deliver energy savings to customers receiving service under the Residential Service Rate, the General Service Rate, or a Transportation Service Rate that also receive electric service from Ameren Missouri. The program will be co-delivered through electric one or more energy efficiency programs offered by Ameren Missouri.

Incentives are being offered on a limited basis for all or a portion of the cost of Measures provided to Participants.

DEFINITIONS

Administrator - Company will administer the Program through a contractor experienced in energy efficiency programs.

Measure – The replacement of less efficient natural gas equipment with high efficiency natural gas equipment and other high efficiency equipment and building shell measures.

Participant - A customer who is being served under either the Company’s Residential Service, General Service, or Transportation Service natural gas rate class, is located in Missouri, and elects to either purchase or agrees to receive energy efficient gas saving equipment as described in Measures And Incentives. For purposes of receiving incentives under this Program, a Participant is defined as a person, firm, organization, association, corporation, landlord, contractor or other entity that implements Measure(s).

AVAILABILITY

The Program is available to Ameren Missouri gas customers that also receive electric service from Ameren Missouri and may be offered through various channels such as direct install, direct mail, secondary education schools, community based organization, and market-rate and low-income multifamily properties.

PROGRAM DESCRIPTION

The Company will partner with the Ameren Missouri electric utility and a program Administrator to implement this Program. The Administrator will provide the necessary services to effectively implement the Program. The Program incorporates various Program partners, products, incentive mechanisms and Program delivery strategies.

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS CO-DELIVERY PROGRAM (cont'd)

MEASURES AND INCENTIVES

Energy Efficiency Measures are delivered through the Program at no cost to Participants and may include but are not limited to thermostats, low flow faucet aerators, low flow showerheads, pipe wrap, and furnace tune-ups. Eligible measures and incentive ranges can be found on the REBATE RANGE SHEET - RESIDENTIAL & LANDLORD MEASURES list in the Missouri Energy Efficient Natural Gas Equipment and Building Shell Measure Rebate Programs tariff.

PROGRAM TERM

The Program will conclude on December 31, 2022 or at the time new rates go into effect as a result of a general rate proceeding, whichever occurs first. All installations of Measures or delivery of Measures for self-install must occur before the conclusion date of the Program.

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS RESIDENTIAL LOW INCOME PROGRAM

APPLICATION

The Missouri Energy Efficient Natural Gas Residential Single Family Low Income Program is designed to deliver energy savings to customers receiving service under the Residential Service Rate who meet income qualifications specified in the Availability section of this tariff.

Incentives are being offered on a limited basis for all or a portion of the cost of Measures provided to Participants.

DEFINITIONS

Administrator - Company will administer the Program through a contractor experienced in energy efficiency programs.

Measure – The replacement of less efficient natural gas equipment with high efficiency natural gas equipment and other high efficiency equipment and building shell measures.

Participant - A customer who is being served under the Company's Residential Service natural gas rate class, is located in Missouri, and elects to either purchase or agrees to receive energy efficient gas saving equipment as described in Measures And Incentives.

AVAILABILITY

The Program is available to qualifying low-income customers receiving service under the Residential Service Rate residing in single family detached housing, duplexes, mobile homes (wood-frame bolted to steel chassis, designed to be transported) and owners and operators of any multi-family properties of three(3) or more dwelling units with eligibile customers receiving service under the Residential Service Rate.

In order to qualify for participation, low-income Participants must meet one of the following income eligibility requirements:

1. Reside in federal, state, or local subsidized housing and fall within that program's income guidelines.
2. Reside in non-subsidized housing with proof of income levels at or below 80% of area median income (AMI).
3. Fall within a census tract that indicates at least 85% of customers are at or below 80% of AMI.

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

MISSOURI ENERGY EFFICIENT NATURAL GAS RESIDENTIAL LOW INCOME PROGRAM (cont'd)

MEASURES AND INCENTIVES

Measures to be installed in this Program are the same as the list of residential measures in the Missouri Energy Efficient Natural Gas Equipment and Building Shell Measure Rebate Program, however the incentives could be as high as 100% of the installed cost of the measure. No single premise can receive incentives more than $3,500 in a thirty-six month period.

PROGRAM TERM

The Program will conclude on December 31, 2022 or at the time new rates go into effect as a result of a general rate proceeding, whichever occurs first. All installations of Measures or delivery of Measures for self-install must occur before the conclusion date of the Program.

Natural Gas Technical Resource Manual

Volume 1: Overview and User Guide

Natural Gas TRM – Volume 1: Overview and User Guide Revision Log

Revision	Date	Description
1.0	12/01/2018	Initial version filed for Commission approval.

Table of Contents

1. Natural Gas TRM Development

1.1.1 Building upon the foundation of the Missouri Statewide TRM

In 2017, the Missouri Department of Economic Development - Division of Energy ("DE") led the development of a statewide Technical Reference Manual, funded by a US Department of Energy ("DOE") grant, facilitated through contract with Vermont Energy Investment Corporation ("VEIC"), and supported by 14 formal, cost-share partners, including Ameren Missouri, Kansas City Power & Light Company, Spire, Inc., Empire District Electric Company, Summit Natural Gas of Missouri, Inc., Missouri American Water Company, Missouri Public Utilities Alliance, Missouri Energy Initiative, Renew Missouri, Sierra Club, Natural Resources Defense Council, Department of Natural Resources, Office of Public Counsel, and Public Service Commission Staff. Although consensus could not be reached on all issues, the active support of these 14 partners led to significant agreement on many aspects of a statewide Technical Reference Manual. The statewide Technical Reference Manual was developed for use by investor-owned utilities and as an available resource for other independent utilities, program administrators, and evaluators. Due to the regulatory and legal roles of the Public Service Commission and the Office of Public Counsel, those two partners actively monitored the development of - but did not take a position on - the actual content of the statewide Technical Reference Manual, which was the foundation for this Natural Gas Technical Resource Manual ("TRM").

2 Organizational Structure

2.1 Overall Organization

For ease of use and update, the Natural Gas TRM is published in three volumes:

Volume 1: Overview and User Guide (this Volume)

Volume 2: Commercial and Industrial Measures

Volume 3: Residential Measures

Information within Volumes 2 and 3 of the Natural Gas TRM is organized in a way to help facilitate its access and use. The structure within these technical documents follows a two-level format, each of which becomes a major heading in the Table of Contents. These levels are designed to define and clarify what the measure is and where it is applied.

Level 1: End-use Category

- This level of organization represents most of the major end-use categories for which an efficient alternative exists. The following table gives examples of the end-use categories likely to be found in the Natural Gas TRM.

End-Use Categories in the Natural Gas TRM

Commercial and Industrial Market Sector	Residential Market Sector
Appliances	Appliances
Food Service	Hot Water
Hot Water	HVAC
HVAC	Shell
Shell	

Level 2: Measure and Technology

Within a particular market, end use, and measure, the Natural Gas TRM is not further divided by implementation or delivery methodology. For example, the characterization of a showerhead installed through any residential pathway – upstream, direct install, efficiency kits, hard-to-reach populations, etc. – is provided in one residential measure document, with lookup tables for the appropriate distinctions in program delivery.

Intended to help answer the question “What technology defines the measure?” this organizational approach seeks to captures the common information about a measure regardless of implementation or delivery mechanism, and then provides within the measure those additional assumptions relevant to such program options. In addition, characterizations are also designed to be agnostic on which fuel the measure is designed to save – electricity or natural gas. By organizing the Natural Gas TRM this way, measures that save on both fuels are captured in one place and defined with formulas and variables that allow visibility into the various fuel savings values. As a result the intent is to create a categorization process for the Natural Gas TRM that is easier to use and to maintain.

Further, information presented for each measure is standardized and may reflect either default/deemed or customer-specific values. Many of the measures may require the user to select the appropriate input value from a list of inputs for a given parameter in the savings algorithm. Where the Natural Gas TRM asks the user to select the input, look-up tables of allowable values are provided. For example, a set of input parameters may depend on building type; while a range of values may be given for each parameter, only one value is appropriate for any specific building type. If no table of alternative inputs is provided for a particular parameter, then the single deemed value will be used, unless the measure has a custom allowable input. Section 2.3 below provides further information on measure characterization content.

2.2 Components of Natural Gas TRM Measure Characterizations

Each measure characterization uses a standardized format that includes at least the following components.

DESCRIPTION

Brief description of measure stating how it saves energy, the markets it serves and any limitations to its applicability.

DEFINITION OF EFFICIENT EQUIPMENT

Clear definition of the criteria for the efficient equipment used to determine delta savings. Including any standards or ratings (if appropriate).

DEFINITION OF BASELINE EQUIPMENT

Clear definition of the efficiency level of the baseline equipment used to determine delta savings including any standards or ratings if appropriate. If there is more than one definition of baseline equipment required for an individual measure – such as a measure that can be offered through “time of sale” or “early replacement” the measure will clearly identify this and state the criteria to be used to determine the delta savings in each case.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected duration in years (or hours) of the savings. If an early replacement measure, the assumed life of the existing unit is also provided.

DEEMED MEASURE COST

For time of sale measures, incremental cost from baseline to efficient is provided. Installation costs should only be included if there is a difference between each efficiency level. For Early Replacement the full equipment and install cost of the efficient installation is provided in addition to the full deferred hypothetical baseline replacement cost.

LOADSHAPE

The appropriate loadshape to apply to electric and/or gas savings is provided.

COINCIDENCE FACTOR

Coincidence factors represent the fraction of connected load expected to be coincident with a particular system peak period, on a diversified basis, and is based on the ratio of the system coincident peak to annual energy by end use. Coincidence factors are provided for summer peak periods. These are also referred to as "kW factors" in the deemed savings tables.

CALCULATION OF ENERGY SAVINGS

Algorithms are provided followed by list of assumptions with their definition.

If there are no input variables, there will be a finite number of output values. These will be identified and listed in a table. Algorithms may be included in any or all of the following:

- **Electric Energy Savings**

  Electric energy savings characterizations are different depending on the measure.

- **Summer Coincident Peak Demand Savings**

  Summer Coincident Peak Demand characterizations are different depending on the end-use category.

- **Natural Gas Savings**

  Natural gas energy savings characterizations are different depending on the measure.

- **Water Impact Descriptions and Calculation**

  Water Impact characterizations are different depending on the measure.

DEEMED O&M COST ADJUSTMENT CALCULATION

Only required if the operation and maintenance ("O&M") cost for the efficient case is different to the baseline.

2.3 Program Delivery

The measure characterizations in the Natural Gas TRM are not grouped by program delivery type. As a result, the measure characterizations provided include information and assumptions to support savings calculations for the range of program delivery options commonly used for the measure. The organizational significance of this approach is that multiple baselines, incremental costs, O&M costs, measure lives, and in-service rates are included in the characterizations for measures that are delivered under two or more different program designs. Values appropriate for each given program delivery type are clearly specified in the algorithms or in look-up tables within the characterization.

Care has been taken to clearly define in the measure's description the types of program delivery that the measure characterization is designed to support. However, there are no universally accepted definitions for a particular program type, and the description of the program type(s) may differ by measure. Nevertheless, program delivery types can be generally defined according to the following table. These are the abbreviations and definitions used in the measure descriptions in the Natural Gas TRM Volumes 2 and 3. When necessary, individual measure descriptions may further refine and clarify these definitions of program delivery type.

2.3.1 Program Delivery Types

Program	Attributes
TOS Time of Sale	**Definition:** A program in which the customer is incented to purchase or install higher efficiency equipment than if the program had not existed. This may include retail rebate (coupon) programs, upstream buy-down programs, online store programs, or contractor based programs as examples **Baseline** = Federal Standard, code or other (explained) baseline equipment **Efficient Case** = New, premium efficiency equipment above federal and state codes and standard industry practice **Example:** LED lamp rebate
NC New Construction	**Definition:** A program that intervenes during building design to support the use of more-efficient equipment and construction practices **Baseline** = Building code, Federal Standard or Baseline Study **Efficient Case** = The program's level of building specification **Example:** Building shell and mechanical measures
RF Retrofit	**Definition:** A program that upgrades existing equipment before the end of its useful life **Baseline** = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life **Efficient Case** = New, premium efficiency equipment above federal and state codes and standard industry practice **Example:** Air sealing and insulation
EREP Early Replacement	**Definition:** A program that replaces existing equipment before the end of its expected life **Baseline** = Dual; it begins as the existing equipment and shifts to new baseline equipment after the expected life of the existing equipment is over **Efficient Case** = New, premium efficiency equipment above federal and state codes and standard industry practice **Example:** Refrigerators, freezers
ERET Early Retirement	**Definition:** A program that retires duplicative equipment before its expected life is over **Baseline** = The existing equipment, which is retired and not replaced **Efficient Case** = Zero because the unit is retired **Example:** Appliance recycling
DI Direct Install	**Definition:** A program where measures are installed during a site visit **Baseline** = Existing equipment **Efficient Case** = New, premium efficiency equipment above federal and state codes and standard industry practice **Example:** Lighting and low-flow hot water measures
KITS Efficiency Kits	**Definition:** A program where measures are provided free of charge to a customer in an Efficiency Kit **Baseline** = Existing equipment **Efficient Case** = New, premium efficiency equipment above federal and state codes and standard industry practice **Example:** Lighting and low-flow hot water measures

3 General Assumptions

Sources that are cited within the Natural Gas TRM have been chosen based on two priorities, geography and age. Whenever possible, it has incorporated Missouri-specific information into each measure characterization.

When Missouri or region-specific evaluations or data were not available, best practice research and data from other jurisdictions was used. In every case, the most recent, well-designed, and best-supported studies have been used to support the Natural Gas TRM, and only if appropriate have conclusions been generalized for practical application to the Missouri programs.

The purpose of this TRM is generally to provide savings assumptions and algorithms for measures which save natural gas, although electricity savings assumptions and algorithms are also included for measures which also save electricity. A benefit of including electric savings is that it provides an opportunity to perform holistic cost effectiveness analysis for those measures that save both natural gas and electricity. In the event that the assumptions and algorithms for electric energy and demand savings are different in the current utility Missouri Energy Efficiency Investment Act ("MEEIA") TRMs, the assumptions and algorithms in the current MEEIA TRM should be used to calculate electric savings, and not the assumptions and algorithms in this TRM. To the extent possible, efforts will be made to synchronize electric savings with Commission-approved MEEIA TRMs.

General Savings Assumptions

The Natural Gas TRM savings estimates are expected to serve as average, representative values, or ways to calculate savings based on program-specific information. All information is presented on a per-measure basis. In using the measure-specific information in the Natural Gas TRM, it is helpful to keep the following notes in mind.

- All estimates of energy (kWh or therms) and peak (kW) savings are for first-year savings, not lifetime savings.
- Unless otherwise noted, measure life is defined to be the life of an energy consuming measure, including its equipment life and measure persistence.
- Where deemed values for savings are provided, they represent the average energy (kWh or therms) or peak (kW) savings that could be expected from the average of all measures that might be installed in Missouri in the program year.
- In general, the baselines included in the Natural Gas TRM are intended to represent average conditions in Missouri. Some are based on data from the state, such as household consumption characteristics provided by the Energy Information Administration. Some are extrapolated from other areas, when Missouri data are not available.

3.1 Algorithms and Variables

Many of the measures in the Natural Gas TRM require the user to select the appropriate input value from a list of inputs for a given parameter in the savings algorithm. Where the Natural Gas TRM asks the user to select the input, look-up tables of allowable values are provided. For example, a set of input parameters may depend on building type; while a range of values may be given for each parameter, only one value is appropriate for any specific building type. If no table of alternative inputs is provided for a particular parameter, then the single deemed value will be used, unless the measure has a custom allowable input.

3.1.1 Custom Value Use in Measure Implementation

This section defines the requirements for capturing Custom variables that can be used in place of defaults for select assumptions within the prescriptive measures defined in this statewide TRM. This approach is to be used when a variable in a measure formula can be replaced by a verifiable and documented value that is not presented in this TRM. This approach assumes that the algorithms presented in the measure are used as stated and only allows changes to certain variable values and is not a replacement algorithm for the measure. A custom variable is when customer input is provided to define the number or the value is measured at the site. Custom values can also be supplied from product data of the measure installed and historical verifiable program data. In certain cases the custom data can be provided from a documented study or report that is applicable to the measure. Custom variables and potential sources are clearly defined in the specific measures where “Actual” or “Custom” is noted.

3.1 Baseline Assumptions

The concept and definition of the baseline is a key element of every measure characterization and is directly related to the program delivery type. Without a clear definition of the baseline, the savings algorithms cannot be adequately specified and subsequent evaluation efforts would be hampered. As a result, each measure has a detailed description (and in many cases, specification) of the specific baseline that should be used to calculate savings. Baselines in the Natural Gas TRM fall into one of the following categories, and are organized within each measure characterization by the program delivery type to which it applies.

1. Building Code: As defined by the minimum specifications required under applicable local codes or applicable federal standards.
2. Existing Equipment: As determined by the most representative (or average) example of equipment that is in the existing stock. Existing equipment baselines apply over the equipment’s remaining useful life.
3. New Equipment: As determined by the equipment that represents standard practice in the current market environment or what has been specified for individual measure use. New equipment baselines apply over the effective useful life of the measure.

3.2 Summer Peak Period Definition (kW)

Summer peak coincidence factors ("CF") can be found within each measure characterization.

3.3 Weather Data for Weather-sensitive Measures

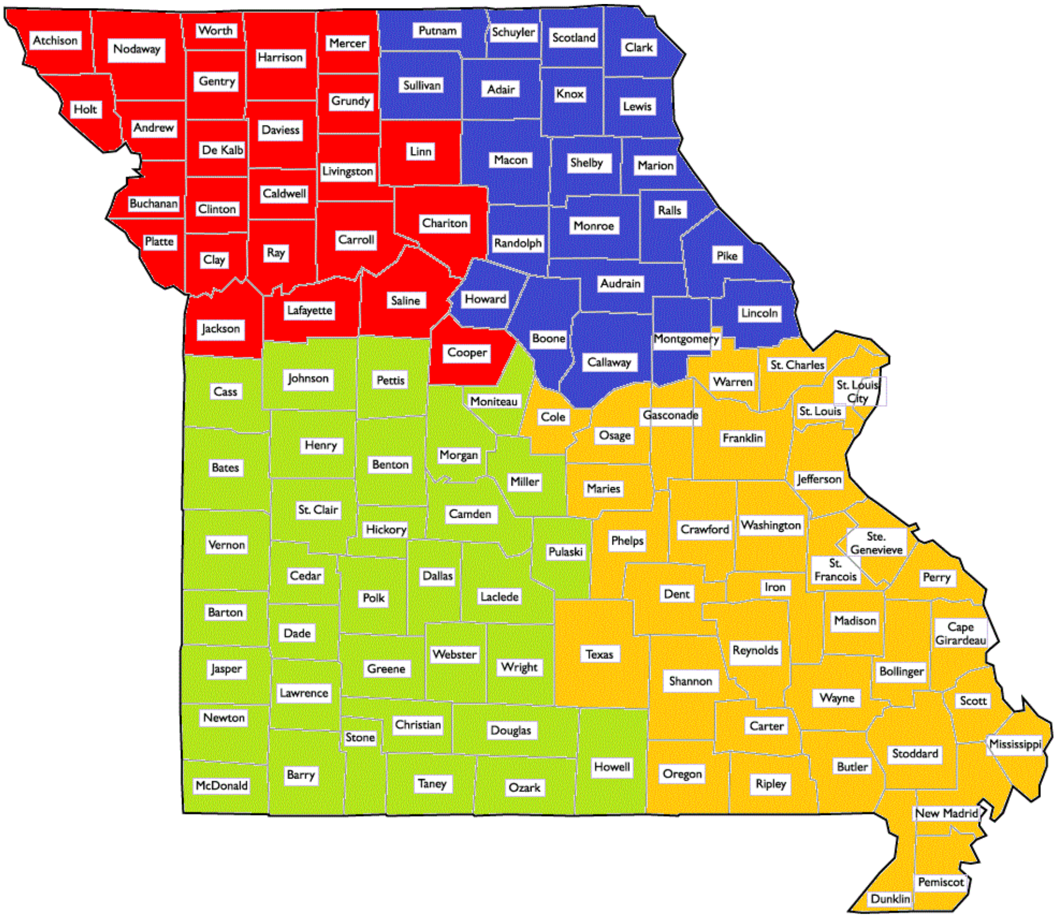
Many measures are weather sensitive. The table below assigns each proxy cities to one of four climate zones and provides a fifth statewide average for when a location is “unknown” as well as two individual categories for the “heat-island affect” of both St. Louis and Kansas City.

Default Weather Sites and Climate Zones:

State	City	Station/Description	Climate Zone
IA	Fort Madison	Fort-Madison	NE
NE	Lincoln	Lincoln-Muni-AP	NW
MO	Cape Girardeau	Cape-Girardeau-Muni-AP	SE
MO	Kaiser	Kaiser-Mem(AWOS)	SW
MO	Knob Noster	Whiteman-AFB	Average/Unknown
MO	St Louis	St-Louis-Lambert-IAP	City
MO	Kansas City	Kansas-City-IAP	City

The following graphic of Missouri State color-codes the counties by the four “climate zones” identified in the table above (NE/NW, SE/SW). Although, the State’s average “unknown” value and individual city zones are not highlighted on this map given each zone has an associated heating and cooling degree-day, the result is that there are a total of 14 climate zones identified for use in the Natural Gas TRM.

Default County Weather Zone Assignment:



3.4 Use of O&M Costs

Some measures specify an operations and maintenance (O&M) parameter that describes the incremental O&M cost savings that can be expected over the measure's lifetime. When estimating the cost effectiveness of these measures, it is necessary to calculate the net present value (NPV) of O&M costs over the life of the measure, which requires an appropriate discount rate. The utility's weighted average cost of capital (WACC) is the most commonly used discount rate that is used in this context.

Each utility has a unique WACC that will vary over time. As a result, the Natural Gas TRM does not specify the NPV of the O&M costs. Instead, the necessary cost and time line information required to calculate the NPV is included. An example is provided below to demonstrate how to calculate the NPV of O&M costs.

EXAMPLE

Baseline Case: O&M costs equal $150 every two years.

Efficient Case: O&M costs equal $50 every five years.

Given this information, the incremental O&M costs can be determined by discounting these cash flows in the Baseline Case and the Efficient Case separately using the applicable WACC. Then the NPV of the incremental O&M costs is calculated by subtracting one NPV from the other. This value is used in each utility's cost-effectiveness screening process.

Effect of O&M costs for those measures that include baseline shifts that result in multiple component costs and lifetimes cannot be calculated by this standard method. In only these cases, the O&M costs are presented as Annual Levelized equivalent cost (i.e., the annual payment that results in an equivalent NPV to the actual stream of O&M costs) and utilities should apply their own real discount rate to determine NPVs.

4 Glossary

Baseline Efficiency: The assumed standard efficiency of equipment, absent an efficiency program.

Building Types: Sixteen C&I building prototypes were modeled using DOE/EnergyPlus for the Natural Gas TRM. The building types are based on the DOE Commercial Reference Buildings developed by DOE, NREL, PNNL, and LBNL. Detailed descriptions and variable calculations for each building prototype can be found on the Missouri Division of Energy TRM's website. Note for C&I modeling efforts, TYM3 weather data is used as it is a designed input of energy modeling.

The following list provides a high level definition for each C&I building type offered in the Natural Gas TRM and follows DOE reference building documentation. For additional information about the prototype models and the associated inputs please refer to https://energy.gov/eere/buildings/commercial-reference-buildings.

Building Type Name	Floor Area (ft2)	Number of Floors	CBECS #	Weighting
Large Office	498,588	12	1,251	0.5%
Medium Office	53,628	3	12,394	5.3%
Small Office	5,500	1	62,691	26.9%
Warehouse	52,045	1	70,785	30.4%
Stand-alone Retail	24,962	1	27,814	11.9%
Strip Mall	22,500	1	2,538	1.1%
Primary School	73,960	1	8,820	3.8%
Secondary School	210,887	2	7,070	3.0%
Supermarket	45,000	1	3,110	1.3%
Quick Service Restaurant	2,500	1	5,385	2.3%
Full Service Restaurant	5,500	1	12,080	5.2%
Hospital	241,351	5	747	0.3%
Outpatient Health Care	40,946	3	9,892	4.2%
Small Hotel	43,200	4	8,051	3.5%
Large Hotel	122,120	6	404	0.2%
Midrise Apartment*	33,740	4		0.0%

Note: To help determine the appropriate building type to use as a reference to a specific project, the user should take into consideration the predominant use type, size of the building/project, and the HVAC systems that serve the project. Where a project is defined by multiple uses or systems it may be appropriate to utilize floor area weighted averages of model outputs (e.g., EFLH) based on the distribution of those use types in the project under consideration. For example, if the user is defining EFLHs for a system or measure that impacts both retail and office spaces within a 75,000 ft^2, 5-story building then they may consider an area-weighted average EFLH from Medium Office and Stand Alone Retail.

Coincidence Factor (CF): Coincidence factors represent the fraction of connected load expected to be coincident with a particular system peak period, on a diversified basis, and is based on the ratio of the system coincident peak to annual energy by end use. CFs are provided for summer peak periods. These are also referred to as "kW factors" in the deemed savings tables.

Commercial & Industrial: The market sector that includes measures that apply to any of the building types defined in the Natural Gas TRM, which includes multifamily common areas and public housing[1].

Connected Load: The maximum wattage of the equipment, under normal operating conditions.

Deemed Value: A value that has been assumed to be representative of the average condition of an input parameter.

Default Value: When a measure indicates that an input to a prescriptive saving algorithm may take on a range of values, an average value is also provided in many cases. This value is considered the default input to the algorithm, and should be used when the other alternatives listed in the measure are not applicable.

End-use Category: A general term used to describe the categories of equipment that provide a service to an individual or building. See Section 2, Level 1: End-use Category Table for a list of the end use categories that are incorporated in the Natural Gas TRM.

Energy Efficiency: "Energy efficiency" means measures that reduce the amount of electricity or natural gas required to achieve a given end use. "Energy efficiency" also includes measures that reduce the total Btus of electricity and natural gas needed to meet the end use or uses.

Equivalent Full Load Hours (EFLH): The equivalent hours that equipment would need to operate at its peak capacity in order to consume its estimated annual kWh consumption (annual kWh/connected kW) or therms.

Evaluation: (synonym EM&V) in the energy efficiency arena, impact evaluation is an investigation process to determine energy or demand impacts achieved through the program activities, including but not limited to savings verification, measure research and program research.

High Efficiency: General term for technologies and processes that require less energy, water, or other inputs to operate.

Incremental Costs: This is a calculated difference in equipment or technology cost between a base equipment model and the more efficient model. Incremental costs can be as little as $0, indicating that there is no expected cost difference between baseline and efficient technologies. Cost of labor or other installation related costs is not considered in incremental costs.

Lifetime: The number of years (or hours) that the new high efficiency equipment is expected to function. These are generally based on engineering lives, but sometimes adjusted based on expectations about frequency of removal, remodeling or demolition. Two important distinctions fall under this definition; Effective Useful Life (EUL) and Remaining Useful Life (RUL).

> **EUL** – EUL is based on the manufacturers rating of the effective useful life; how long the equipment will last. It is an estimate of the median number of years that the measures installed under a program are still in place and operable.
>
> **RUL** – Applies to retrofit or replacement measures. For example, if an existing working refrigerator is replaced with a high efficiency unit, the RUL is an assumption of how many more years the existing unit would have lasted. As a general rule the RUL is usually assumed to be 1/3 of the EUL.

Load Factor (LF): The fraction of full load (wattage) for which the equipment is typically run.

Measure Cost: The incremental (for time of sale measures) or full cost (both capital and labor for retrofit measures) of implementing the High Efficiency equipment.

Measure Description: A detailed description of the technology and the criteria it must meet to be eligible as an energy efficient measure.

[1] Measures that apply to the multifamily and public housing building types describe how to handle tenant versus master metered buildings.

Measure: An efficient technology or procedure that results in energy savings as compared to the baseline efficiency. There are three main measure types:

1) **Prescriptive Measures -** measures or technologies are offered through a standard (in contrast to custom) program, for which partially or fully deemed input values are applicable:
   i. **Fully deemed measures -** measures whose energy savings are expressed on a per unit basis in the Natural Gas TRM and are not subject to change or choice by the program administrator.
   ii. **Partially deemed measures -** measures whose energy savings algorithms are deemed in the Natural Gas TRM, with input values that may be selected to some degree by the program administrator, typically based on a customer-specific input.
2) **Custom Measures –** these are measures or technologies that due to the complexity in the design and configuration of the particular measure in the energy efficiency project, a more comprehensive custom engineering algorithm and financial analysis may be used that more accurately characterize the energy efficiency savings within a project.
3) **Comparison group EM&V measures** – these are measures that determine program savings based on the differences in electricity consumption patterns between a comparison group the program participants, not a deemed savings value. Comparison group approaches include randomized control trials (RCTs) and quasi-experimental methods using nonparticipants, and may involve simple differences or regression methods. Because the effects of implemented measures is reflected in the observed participant-comparison differences, separate verification is not required. These methods are generally used for planning purposes to estimate program-level savings, not facility- or project-level savings, and are therefore considered an evaluation method. *Note: The reference to and inclusion of Residential Peer Comparison Behavior Programs in the Natural Gas TRM is an example of where comparison group EM&V values should be used to support program considerations, rather than deemed, alongside robust reference documentation for the sources of those values and the appropriate use of SEEAction[2] and UMP guidelines[3] as required for program evaluation/savings calculation*.

Measure research: an evaluation process focused on providing better/more granular data to facilitate updating measure-specific Natural Gas TRM input values or algorithms.

Residential: The market sector that includes measures that apply only to detached, residential buildings, duplexes and applicable multifamily units.

Operation and Maintenance (O&M) Cost Adjustments: The dollar impact resulting from differences between baseline and efficient case Operation and Maintenance costs.

Operating Hours (HOURS): The annual hours that equipment is expected to operate.

Program: The mode of delivering a particular measure or set of measures to customers. See Section 2.4.1 for a list of program descriptions that are presently operating in Missouri.

Program research: an evaluation process that takes an alternative look into achieved program level savings across multiple measures. May or may not be specific enough to inform future Natural Gas TRM updates. Ex. Program billing analysis.

Savings verification: an evaluation process that independently verifies program savings achieved through prescriptive measures.

2 Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations; SEEAction (State and Local Energy Efficiency Action Network- EPA/DOE), 2012

3 The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures; Residential Behavior Protocol, NREL/ DOE, 2015.

Appendix A –Loadshapes in Natural Gas TRM

Table 1 – Residential End-Use Category Electric Monthly Shapes and Coincident Peak Factors

End-Use Energy Load Shapes

% Energy by Month

	Residential End-Use Load Shape									
Month	**Building Shell RES**	**Cooling RES**	**Freezer RES**	**Heating RES**	**HVAC RES**	**Lighting RES**	**Miscellaneous RES**	**Pool Spa RES**	**Refrigeration RES**	**Water Heating RES**
January	11.1297%	0.1200%	7.9579%	21.7905%	11.1297%	10.1182%	8.4893%	8.6451%	7.7053%	10.3527%
February	9.3077%	0.1100%	7.2518%	18.2135%	9.3077%	8.8441%	7.7366%	7.1145%	7.2169%	9.0720%
March	7.0042%	0.3130%	8.1080%	13.4833%	7.0042%	9.2879%	8.4863%	8.6052%	8.0272%	9.5543%
April	3.7116%	1.5047%	7.9918%	5.8486%	3.7116%	8.4645%	8.2144%	8.0702%	7.8752%	8.4799%
May	4.0888%	6.5410%	8.4083%	1.7144%	4.0888%	7.9393%	8.4847%	8.6052%	8.5646%	8.3600%
June	10.3973%	21.0823%	8.5730%	0.0510%	10.3973%	6.8508%	8.2122%	8.0702%	8.9112%	7.7065%
July	14.0100%	28.4780%	9.6095%	0.0006%	14.0100%	6.7864%	8.4883%	8.6451%	9.4239%	6.7712%
August	13.3207%	27.0766%	9.6095%	0.0009%	13.3207%	7.0565%	8.4840%	8.5653%	9.4212%	6.3688%
September	6.6759%	12.6605%	8.4277%	0.8809%	6.6759%	7.3792%	8.2136%	8.3032%	8.4971%	6.9373%
October	3.7011%	1.8472%	8.2582%	5.4962%	3.7011%	8.4539%	8.4869%	8.6052%	8.5653%	7.9644%
November	5.9593%	0.1444%	7.8465%	11.5899%	5.9593%	8.9880%	8.2122%	8.1088%	7.8717%	8.4752%
December	10.6937%	0.1222%	7.9579%	20.9301%	10.6937%	9.8312%	8.4915%	8.6619%	7.9204%	9.9577%

End-Use Energy to Coincident Peak Demand Factors

	Building Shell RES	**Cooling RES**	**Freezer RES**	**Heating RES**	**HVAC RES**	**Lighting RES**	**Miscellaneous RES**	**Pool Spa RES**	**Refrigeration RES**	**Water Heating RES**
	0.0004660805	0.0009474181	0.0001685722	0.0000000000	0.0004660805	0.0001492529	0.0001148238	0.0002354459	0.0001285253	0.0000887318

Table 2 – Commercial and Industrial End-Use Category Electric Monthly Shapes and Coincident Peak Factors

End-Use Energy Load Shapes

% Energy by Month

Business End-Use Load Shape												
Air Comp BUS	**Building Shell BUS**	**Cooking BUS**	**Cooling BUS**	**Ext Lighting BUS**	**Heating BUS**	**HVAC BUS**	**Lighting BUS**	**Miscellaneous BUS**	**Motors BUS**	**Process BUS**	**Refrigeration BUS**	**Water Heating BUS**
8.5109%	10.7824%	8.6096%	0.0006%	10.6265%	21.0397%	10.7824%	9.3564%	8.5109%	8.5109%	8.5109%	8.3486%	10.8255%
7.7715%	9.1052%	7.8609%	0.0247%	8.2162%	17.7436%	9.1052%	7.2162%	7.7715%	7.7715%	7.7715%	7.6158%	9.1078%
8.6136%	7.1135%	8.1548%	0.7236%	7.0887%	13.1924%	7.1135%	7.8373%	8.6136%	8.6136%	8.6136%	8.3346%	8.5240%
7.9796%	4.1179%	7.2948%	2.1691%	6.8146%	5.9718%	4.1179%	7.6534%	7.9796%	7.9796%	7.9796%	8.0783%	7.2980%
8.5335%	4.4424%	8.6277%	6.2980%	8.1853%	2.6769%	4.4424%	9.4247%	8.5335%	8.5335%	8.5335%	8.5133%	7.9849%
8.1995%	10.6128%	8.3294%	21.3170%	6.7163%	0.4295%	10.6128%	7.5599%	8.1995%	8.1995%	8.1995%	8.4295%	7.2721%
8.4099%	14.2881%	8.5859%	29.0029%	8.6752%	0.2895%	14.2881%	9.6200%	8.4099%	8.4099%	8.4099%	8.7457%	7.4930%
8.4199%	13.3494%	8.5885%	27.0206%	6.9401%	0.3432%	13.3494%	7.7078%	8.4199%	8.4199%	8.4199%	8.7230%	7.5862%
8.2512%	5.7810%	8.3475%	10.8695%	8.2908%	0.9402%	5.7810%	8.1374%	8.2512%	8.2512%	8.2512%	8.3319%	7.5734%
8.5277%	3.8018%	8.6262%	1.9643%	10.0507%	5.5497%	3.8018%	9.4072%	8.5277%	8.5277%	8.5277%	8.4563%	8.2808%
8.2589%	6.2104%	8.3496%	0.6030%	8.7252%	11.5452%	6.2104%	7.6707%	8.2589%	8.2589%	8.2589%	8.1112%	8.6345%
8.5238%	10.3950%	8.6251%	0.0064%	9.6704%	20.2781%	10.3950%	8.4090%	8.5238%	8.5238%	8.5238%	8.3119%	9.4200%

End-Use Energy to Coincident Peak Demand Factors

Air Comp BUS	**Building Shell BUS**	**Cooking BUS**	**Cooling BUS**	**Ext Lighting BUS**	**Heating BUS**	**HVAC BUS**	**Lighting BUS**	**Miscellaneous BUS**	**Motors BUS**	**Process BUS**	**Refrigeration BUS**	**Water Heating BUS**
0.0001379439	0.0004439830	0.0001998949	0.0009106840	0.0000056160	0.0000000000	0.0004439830	0.0001899635	0.0001379439	0.0001379439	0.0001379439	0.0001357383	0.0001811545

Table 3 – End-Use Category Natural Gas Monthly Shapes

End-Use Category Energy Load Shapes						
	Residential			Business		
Month	Heating	Water Heating	Miscellaneous	Heating	Water Heating	Miscellaneous
January	21.7905%	10.3527%	8.4893%	21.0397%	10.8255%	8.5109%
February	18.2135%	9.0720%	7.7366%	17.7436%	9.1078%	7.7715%
March	13.4833%	9.5543%	8.4863%	13.1924%	8.5240%	8.6136%
April	5.8486%	8.4799%	8.2144%	5.9718%	7.2980%	7.9796%
May	1.7144%	8.3600%	8.4847%	2.6769%	7.9849%	8.5335%
June	0.0510%	7.7065%	8.2122%	0.4295%	7.2721%	8.1995%
July	0.0006%	6.7712%	8.4883%	0.2895%	7.4930%	8.4099%
August	0.0009%	6.3688%	8.4840%	0.3432%	7.5862%	8.4199%
September	0.8809%	6.9373%	8.2136%	0.9402%	7.5734%	8.2512%
October	5.4962%	7.9644%	8.4869%	5.5497%	8.2808%	8.5277%
November	11.5899%	8.4752%	8.2122%	11.5452%	8.6345%	8.2589%
December	20.9301%	9.9577%	8.4915%	20.2781%	9.4200%	8.5238%

Natural Gas Technical Resource Manual

Volume 2: Commercial and Industrial Gas Measures

Natural Gas TRM – Volume 2: C&I Measures Revision Log

Revision	Date	Description
1.0	12/01/2018	Initial version filed for Commission approval.

Volume 2: Commercial and Industrial Measures

2.1 Appliances End Use

2.1.1 Clothes Washer

DESCRIPTION

This measure relates to the installation of a commercial grade clothes washer meeting the ENERGY STAR®® minimum qualifications. Note it is assumed the DHW and dryer fuels of the installations are known.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The Commercial grade Clothes washer must meet the ENERGY STAR®® minimum qualifications (provided in the table below), as required by the program.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a commercial grade clothes washer meeting the minimum federal baseline as of January 2013.[1]

Efficiency Level		Top loading	Front Loading
Baseline	Federal Standard	≥1.6 MEF, ≤8.5 WF	≥2.00 MEF, ≤5.5 WF
Efficient	ENERGY STAR®®	≥2.2 MEF, ≤4.5 WF	

The Modified Energy Factor (MEF) includes unit operation, water heating, and drying energy use, with the higher the value the more efficient the unit; *"The quotient of the capacity of the clothes container, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load."*

The Water Factor (WF) indicates the total water consumption of the unit, with the lower the value the less water required; *"The quotient of the total weighted per-cycle water consumption for cold wash, divided by the capacity of the clothes washer."*[2]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 11 years.[3]

DEEMED MEASURE COST

The incremental cost is assumed to be $200[4]:

[1] See Federal Standard 10 CFR 431.152.
[2] Definitions provided on the ENERGY STAR®® website.
[3] Appliance Magazine, September 2007 as referenced in ENERGY STAR®® Commercial Clothes Washer Calculator.
[4] Based on Industry Data 2007 as referenced in ENERGY STAR®® Commercial Clothes Washer Calculator.

LOADSHAPE

Loadshape – Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left[\left(Capacity * \frac{1}{MEFbase} * Ncycles\right) * \left(\%CWbase + (\%DHWbase * \%Electric_{DHW}) + \left(\%Dryerbase * \%Electric_{Dryer}\right)\right)\right] - \left[\left(Capacity * \frac{1}{IMEFeff} * Ncycles\right) * \left(\%CWeff + (\%DHWeff * \%Electric_{DHW}) + \left(\%Dryereff * \%Electric_{Dryer}\right)\right)\right]$$

Where:

Capacity = Clothes Washer capacity (cubic feet)

= Actual - If capacity is unknown, assume 3.1 cubic feet [5]

MEFbase = Modified Energy Factor of baseline unit

Efficiency Level	MEFbase		
	Top loading	Front Loading	Weighted Average[6]
Federal Standard	1.6	2.0	1.7

MEFeff = Modified Energy Factor of efficient unit

= Actual. If unknown, assume average values provided below.

Efficiency Level	MEFeff		
	Top loading	Front Loading	Weighted Average
ENERGY STAR®	2.2		

Ncycles = Number of Cycles per year

= 2190[7]

[5] Based on the average clothes washer volume of all units that pass the Federal Standard on the CEC database of commercial Clothes Washer products (accessed on 11/26/2015).

[6] Weighted average MEF of Federal Standard rating for Front Loading and Top Loading units. Baseline weighting is based upon the relative top front loading percentage of available non-ENERGY STAR®[®] commercial products in the CEC database (accessed 11/26/2015) and ENERGY STAR®[®] weighting is based on eligible products as of 11/26/2015. The relative weightings are as follows, see more information in "Commercial Clothes Washer Analysis.xlsx":

Efficiency Level	Front	Top
Baseline	37%	63%
ENERGY STAR®[®]	99%	1%

[7] Based on DOE Technical Support Document, 2009; Chapter 8 Life-Cycle Cost and Payback Period Analysis, p 8-15.

%CW = Percentage of total energy consumption for Clothes Washer operation (different for baseline and efficient unit – see table below)

%DHW = Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)

%Dryer = Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)

	Percentage of Total Energy Consumption[8]		
	%CW	%DHW	%Dryer
Federal Standard	6.5%	25.9%	67.6%
ENERGY STAR®	3.5%	14.1%	82.4%

$\%Electric_{DHW}$ = Percentage of DHW savings assumed to be electric

DHW fuel	$\%Electric_{DHW}$
Electric	100%
Natural Gas	0%

$\%Electric_{Dryer}$ = Percentage of dryer savings assumed to be electric

Dryer fuel	$\%Electric_{Dryer}$
Electric	100%
Natural Gas	0%

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below[9]:

	ΔkWH			
Efficiency Level	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®	808.2	229.3	725.3	146.5

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

[8] The percentage of total energy consumption that is used for the machine, heating the hot water, or by the dryer is different depending on the efficiency of the unit. Values are based on a data provided in the ENERGY STAR®® Calculator for Commercial Clothes Washers.

[9] Note that the baseline savings is based on the weighted average baseline MEF (as opposed to assuming Front baseline for Front efficient unit and Top baseline for Top efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.

= 0.0001379439[10]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

Efficiency Level	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®®	0.1115	0.0316	0.1001	0.0202

NATURAL GAS SAVINGS

$$\Delta Therms = \left[\left[\left(Capacity * \frac{1}{IMEFbase} * Ncycles\right) * \left((\%DHWbase * \%Natural\ Gas_{DHW} * R\_eff) + (\%Dryerbase * \%Gas_{Dryer}\%Gas\_Dryer)\right)\right] - \left[\left(Capacity * \frac{1}{IMEFeff} * Ncycles\right) * \left((\%DHWeff * \%Gas_{DHW}\%Natural\ Gas\_DHW * R\_eff) + (\%Dryereff * \%Gas_{Dryer}\%Gas\_Dryer)\right)\right]\right] * Therm\_convert$$

Where:

$\%Gas_{DHW}$ = Percentage of DHW savings assumed to be Natural Gas

DHW fuel	$\%Gas_{DHW}$
Electric	0%
Natural Gas	100%

R_eff = Recovery efficiency factor

= 1.26[11]

$\%Gas_{Dryer}$ = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	$\%Gas_{Dryer}$
Electric	0%
Natural Gas	100%

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

Other factors as defined above.

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

[10] Based on Ameren Missouri 2016 Loadshape for Business Miscellaneous End-Use. Upon inspection and comparison to the Residential clothes washer coincidence factor, this is a reasonable assumption until data becomes available to inform a technology specific coincidence factor. Given that business laundry schedules are likely more variable compared to residential, it follows that less overlap with the system peak hour is possible.

[11] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

Efficiency Level	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®®	0.0	24.9	2.8	27.7

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water\ (gallons) = Capacity * (IWFbase - IWFeff) * Ncycles$$

Where:

WFbase = Water Factor of baseline clothes washer

Efficiency Level	WFbase		
	Top loading	Front Loading	Weighted Average[12]
Federal Standard	8.5	5.5	7.4

WFeff = Water Factor of efficient clothes washer

= Actual - If unknown assume average values provided below

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

	WF			ΔWater (gallons per year)
Efficiency Level	Top Loaders	Front Loaders	Weighted Average	Weighted Average
Federal Standard	8.5	5.5	7.4	n/a
ENERGY STAR®®	4.5			19,874

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[12] Weighted average MEF of Federal Standard rating for Front Loading and Top Loading units. Baseline weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR®® commercial product in the CEC database (accessed 11/26/2015) and ENERGY STAR®® weighting is based on eligible products as of 11/26/2015. The relative weightings are as follows, see more information in "Commercial Clothes Washer Analysis.xlsx":

Efficiency Level	Front	Top
Baseline	37%	63%
ENERGY STAR®®	99%	1%

2.1.2 Clothes Dryer

DESCRIPTION

This measure is for the installation of a residential clothes dryer, utilized in a commercial setting, meeting the ENERGY STAR®® criteria. ENERGY STAR®® qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers[13]. ENERGY STAR®® provides criteria for both gas and electric clothes dryers.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Clothes dryer must meet the ENERGY STAR®® criteria, as required by the program.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years.[14]

DEEMED MEASURE COST

Dryer Size	Incremental Cost[15]
Standard	$75
Compact	$105

LOADSHAPE

Loadshape - Miscellaneous BUS

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13 ENERGY STAR®® Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

14 Based on an average estimated range of 12-16 years. ENERGY STAR®® Market & Industry Scoping Report. Residential Clothes Dryers. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

15 Cost based on ENERGY STAR®® Savings Calculator for ENERGY STAR® Qualified Appliances. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * \%Electric$$

Where:

Load = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.

Dryer Size	Load (lbs)[16]
Standard	8.45
Compact	3

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR® analysis[17]. If product class unknown, assume electric, standard.

Product Class	CEFbase (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft^3)	3.11
Vented Electric, Compact (120V) (< 4.4 ft^3)	3.01
Vented Electric, Compact (240V) (<4.4 ft^3)	2.73
Ventless Electric, Compact (240V) (<4.4 ft^3)	2.13
Vented Gas	2.84[18]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR® unit based on ENERGY STAR® requirements.[19] If product class unknown, assume electric, standard.

Product Class	CEFeff
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	3.93
Vented or Ventless Electric, Compact (120V) (< 4.4	3.80
Vented Electric, Compact (240V) (< 4.4 ft^3)	3.45
Ventless Electric, Compact (240V) (< 4.4 ft^3)	2.68
Vented Gas	3.48[20]

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[16] Based on ENERGY STAR®® test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[17] ENERGY STAR®® Draft 2 Version 1.0 Clothes Dryers Data and Analysis

[18] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

[19] ENERGY STAR®® Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[20] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, refer to the table below.[21]

Application	Cycles per Year
Multi-family	1,074
Laundromat	1,483
On-Premise Laundromat	3,607

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 5% for gas dryers[22]

Using defaults provided above:

Product Class	kWh		
	Multi-family	Laundromat	On-Premise Laundromat
Vented Electric, Standard (≥ 4.4 ft^3)	608.9	840.7	2044.9
Vented Electric, Compact (120V) (< 4.4 ft^3)	222.5	307.3	747.4
Vented Electric, Compact (240V) (<4.4 ft^3)	246.3	340.1	827.2
Ventless Electric, Compact (240V) (<4.4 ft^3)	310.4	428.7	1042.6
Vented Gas	29.4	40.6	98.7

Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

=0.0001379439[23]

Using defaults provided above:

Product Class	kW		
	Multi-family	Laundromat	On-Premise Laundromat
Vented Electric, Standard (≥ 4.4 ft^3)	0.0840	0.1160	0.2821

[21] NOPR analysis for DOE Commercial Clothes Washer standard. Annual use cycles of 1,074 and 1,483 for multi-family and laundromat applications, respectively. https://www.regulations.gov/document?D=EERE-2012-BT-STD-0020-0021. On-premise laundromat cycle average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report.

[22] %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 5% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis. Value reported in 2015 EPA EnergySTAR appliance calculator.

[23] Based on Ameren Missouri 2016 Loadshape for Business Miscellaneous End-Use. Upon inspection and comparison to the Residential clothes washer coincidence factor, this is a reasonable assumption until data becomes available to inform a technology specific coincidence factor. Given that business laundry schedules are likely more variable compared to residential, it follows that less overlap with the system peak hour is possible.

Product Class	kW		
	Multi-family	Laundromat	On-Premise Laundromat
Vented Electric, Compact (120V) (< 4.4 ft^3)	0.0307	0.0424	0.1031
Vented Electric, Compact (240V) (<4.4 ft^3)	0.0340	0.0469	0.1141
Ventless Electric, Compact (240V) (<4.4 ft^3)	0.0428	0.0591	0.1438
Vented Gas	0.0041	0.0056	0.0136

NATURAL GAS ENERGY SAVINGS

Natural gas savings only apply to ENERGY STAR®® vented gas clothes dryers.

$$\Delta Therm = \left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * Therm\_convert * \%Gas$$

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03413

%Gas = Percent of overall savings coming from gas

= 0% for electric units and 84% for gas units[24]

Using defaults provided above:

ΔTherms = (8.45/2.84 – 8.45/3.48) * Ncycles * 0.03413 * 0.84

Product Class	ΔTherms		
	Multi-family	Laundromat	On-Premise Laundromat
Vented Gas	16.8	23.3	56.6

PEAK GAS SAVINGS

Savings for this measure is assumed to be evenly spread across the year. The Peak Gas Savings is therefore assumed to be:

$$\Delta PeakTherms = \frac{\Delta Therms}{365.25}$$

Where:

ΔTherms = Therm impact calculated above

365.25 = Days per year

Using defaults provided above:

[24] %Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

Product Class	ΔPeakTherms		
	Multi-family	Laundromat	On-Premise Laundromat
Vented Gas	0.0461	0.0637	0.1549

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.2 Food Service End Use

2.2.1 Combination Oven

DESCRIPTION

This measure applies to full or half-sized electric ENERGY STAR®® combination ovens with a pan capacity ≥ 5 and ≤ 20 and to full or half-sized natural gas fired ENERGY STAR®® combination ovens with a pan capacity ≥ 6 installed in a commercial kitchen. Combination ovens combines the function of hot air convection (convection mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating, to perform steaming, baking, roasting, re-thermalizing, and proofing of various food products. ENERGY STAR® certified combination ovens are approximately 20% more efficient than standard ovens.

This measure was developed to be applicable to the following program type: TOS.

If applied to other program types, measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified combination oven meeting idle energy rate (kW or Btu/hr)) and cooking efficiency (%) limits, as determined by fuel type, operation mode (steam or convection), and pan capacity.

ENERGY STAR® Requirements (Version 2.2, Effective October 7, 2015)

Fuel Type	Operation	Idle Rate (Btu/hr for Gas, kW for Electric)	Cooking-Energy Efficiency (%)
Natural Gas	Steam Mode Convection Mode	≤ 200P+6,511 ≤ 150P+5,425	≥ 41 ≥ 56
Electric	Steam Mode Convection Mode	≤ 0.133P+0.6400 ≤ 0.080P+0.4989	≥ 55 ≥ 76

Note: P = Pan capacity as defined in Section 1.T of the Commercial Ovens Program Requirements Version 2.2[25]

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas combination oven that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[26]

DEEMED MEASURE COST

The incremental capital cost for this measure is $4,300.[27]

[25] Pan capacity is defined as the number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.
https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf

[26] Lifetime from ENERGY STAR®® Commercial Kitchen Equipment Savings Calculator, which cites reference as "FSTC research on available models, 2009"
https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

[27] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011.

LOADSHAPE

Cooking BUS

Miscellaneous BUS (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric combination oven below.[28]

$$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec}) * Days/1{,}000$$

Where:

$\Delta CookingEnergy_{ConvElec}$ = Difference in cooking energy between baseline and efficient combination oven in convection mode

= $FoodCooked_{Elec}$ * ($EFOOD_{ConvElec}$ / $ElecEFF_{ConvBase}$ - $EFOOD_{ConvElec}$ / $ElecEFF_{ConvEE}$) * %Conv

$\Delta CookingEnergy_{SteamElec}$ = Difference in cooking energy between baseline and efficient combination oven in steam mode

= $FoodCooked_{Elec}$ * ($EFOOD_{SteamElec}$ / $ElecEFF_{SteamBase}$ – $EFOOD_{SteamElec}$ / $ElecEFF_{SteamEE}$) * $\%_{Steam}$

$\Delta IdleEnergy_{ConvElec}$ = Difference in idle energy between baseline and efficient combination oven in convection mode

= (($ElecIDLE_{ConvBase}$ * ((Hours – $FoodCooked_{Elec}$ /$ElecPC_{ConvBase}$) * $\%_{Conv}$)) - ($ElecIDLE_{ConvEE}$ * ((Hours - $FoodCooked_{Elec}$ /$ElecPC_{ConvEE}$) * $\%_{Conv}$)))

$\Delta IdleEnergy_{SteamElec}$ = Difference in idle energy between baseline and efficient combination oven in steam mode

= [($ElecIDLE_{SteamBase}$ * ((Hours – $FoodCooked_{Elec}$ /$ElecPC_{SteamBase}$) * $\%_{Steam}$)) - ($ElecIDLE_{SteamEE}$ * ((Hours - $FoodCooked_{Elec}$ /$ElecPC_{SteamEE}$) * $\%_{Steam}$))]

Days = Annual days of operation

= Custom or if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

Where:

$FoodCooked_{Elec}$ = Food cooked per day for electric combination oven

= Custom, or if unknown, use 200 lbs if P <15 or 250 lbs if P ≥ 15

$EFOOD_{ConvElec}$ = ASTM energy to food for electric combination oven in convection mode

[28] Algorithms and assumptions derived from ENERGY STAR®® Commercial Kitchen Equipment Savings Calculator

= 73.2 Wh/lb

ElecEff = Cooking energy efficiency of electric combination oven

= Custom or if unknown, use values from table below

	Base	EE
$ElecEFF_{Conv}$	72%	76%
$ElecEFF_{Steam}$	49%	55%

$\%_{Conv}$ = Percentage of time in convection mode

= Custom or if unknown, use 50%

$EFOOD_{SteamElec}$ = ASTM energy to food for electric combination oven in steam mode

= 30.8 Wh/lb

$\%_{steam}$ = Percentage of time in steam mode

= 1 - $\%_{conv}$

$ElecIDLE_{Base}$ = Idle energy rate (W) of baseline electric combination oven

= Custom or if unknown, use values from table below

Pan Capacity	Convection Mode ($ElecIDLE_{ConvBase}$)	Steam Mode ($ElecIDLE_{SteamBase}$)
< 15	1,320	5,260
≥ 15	2,280	8,710

Hours = Average daily hours of operation

= Custom or if unknown, use 12 hours per day

$ElecPC_{Base}$ = Production capacity (lbs/hr) of baseline electric combination oven

= Custom of if unknown, use values from table below

Pan Capacity	Convection Mode ($ElecPC_{ConvBase}$)	Steam Mode ($ElecPC_{SteamBase}$)
< 15	79	126
≥15	166	295

$ElecIDLE_{ConvEE}$ = Idle energy rate of ENERGY STAR® electric combination oven in convection mode

= (0.08*P + 0.4989)*1,000

$ElecPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR® electric combination oven

= Custom of if unknown, use values from table below

Pan Capacity	Convection Mode ($ElecPC_{ConvEE}$)	Steam Mode ($ElecPC_{SteamEE}$)
< 15	119	177
≥ 15	201	349

$ElecIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR® electric combination oven in steam mode

= (0.133*P + 0.64)*1,000

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001998949[29]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a gas combination oven below.[30]

$$\Delta Therms = (\Delta CookingEnergy_{ConvGas} + \Delta CookingEnergy_{SteamGas} + \Delta IdleEnergy_{ConvGas} + \Delta IdleEnergy_{SteamGas}) * Days/100{,}000$$

Where:

$\Delta CookingEnergy_{ConvGas}$ = Difference in cooking energy between baseline and efficient combination oven in convection mode

= $FoodCooked_{Gas}$ * ($EFOOD_{ConvGas}$ / $GasEFF_{ConvBase}$ - $EFOOD_{ConvGas}$/ $GasEFF_{ConvEE}$) * %Conv

$\Delta CookingEnergy_{SteamGas}$ = Difference in cooking energy between baseline and efficient combination oven in steam mode

= $FoodCooked_{Gas}$ * ($EFOOD_{SteamGas}$ / $GasEFF_{SteamBase}$ – $EFOOD_{SteamGas}$ / $GasEFF_{SteamEE}$) * $\%_{Steam}$

$\Delta IdleEnergy_{ConvGas}$ = Difference in idle energy between baseline and efficient combination oven in convection mode

= (($GasIDLE_{ConvBase}$ * ((Hours – $FoodCooked_{Gas}$ /$GasPC_{ConvBase}$) * $\%_{Conv}$)) - ($GasIDLE_{ConvEE}$ * ((Hours - $FoodCooked_{Gas}$ /$GasPC_{ConvEE}$) * $\%_{Conv}$)))

$\Delta IdleEnergy_{SteamGas}$ = Difference in idle energy between baseline and efficient combination oven in steam mode

[29] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

[30] Algorithms and assumptions derived from ENERGY STAR®® Commercial Kitchen Equipment Savings Calculator

= [($GasIDLE_{SteamBase}$ * ((Hours – $FoodCooked_{Gas}$ /$GasPC_{SteamBase}$) * $\%_{Steam}$)) - ($GasIDLE_{SteamEE}$ * ((Hours - $FoodCooked_{Gas}$ /$GasPC_{SteamEE}$) * $\%_{Steam}$))]

100,000 = Btu to therms conversion factor

Where:

$FoodCooked_{Gas}$ = Food cooked per day for gas combination oven

= Custom, or if unknown, use 200 lbs if P <15, 250 lbs if 15 ≤ P 30, or 400 lbs if P ≥30

$EFOOD_{ConvGas}$ = ASTM energy to food for gas combination oven in convection mode

= 250 Btu/lb

GasEff = Cooking energy efficiency of gas combination oven

= Custom or if unknown, use values from table below

	Base	EE
$GasEFF_{Conv}$	52%	56%
$GasEFF_{Steam}$	39%	41%

$EFOOD_{SteamGas}$ = ASTM energy to food for gas combination oven in steam mode

= 105 Btu/lb

$GasIDLE_{Base}$ = Idle energy rate (Btu/hr) of baseline gas combination oven

= Custom or if unknown, use values from table below

Pan Capacity	Convection Mode ($GasIDLE_{ConvBase}$)	Steam Mode ($GasIDLE_{SteamBase}$)
< 15	8,747	18,656
15 ≤ P 30	10,788	24,562
≥30	13,000	43,300

$GasPC_{Base}$ = Production capacity (lbs/hr) of baseline gas combination oven

= Custom of if unknown, use values from table below

Pan Capacity	Convection Mode ($GasPC_{ConvBase}$)	Steam Mode ($GasPC_{SteamBase}$)
< 15	125	195
15 ≤ P 30	176	211
≥30	392	579

$GasIDLE_{ConvEE}$ = Idle energy rate of ENERGY STAR® gas combination oven in convection mode

= 150*P + 5,425

$GasPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR® gas combination oven

= Custom of if unknown, use values from table below

Pan Capacity	Convection Mode ($GasPC_{ConvEE}$)	Steam Mode ($GasPC_{SteamEE}$)
< 15	124	172
15 ≤ P 30	210	277
≥30	394	640

$GasIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR® gas combination oven in steam mode

= 200*P +6,511

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.2.2 Commercial Steam Cooker

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR® steam cookers installed in a commercial kitchen. Commercial steam cookers contain compartments where steam energy is transferred to food by direct contact. ENERGY STAR® certified steam cookers have shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficient steam delivery.

This measure was developed to be applicable to the following program types: TOS.

If applied to other program types, measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified steam cooker meeting idle energy rate (W or Btu/hr)) and cooking efficiency (%) limits, as determined by fuel type and pan capacity.

ENERGY STAR® Requirements (Version 1.2, Effective August 1, 2003)

Pan Capacity	Electric Efficiency Requirements		Natural Gas Efficiency	
	Idle Energy Rate Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
3-pan	≤ 400 W	≥ 50%	≤ 6,250 Btu/hr	≥ 38% N/A
4-pan	≤ 530 W		≤ 8,350 Btu/hr	
5-pan	≤ 670 W		≤ 10,400 Btu/hr	
6-pan and larger	≤ 800 W		≤ 12,500 Btu/hr	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas steam cooker that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[31]

DEEMED MEASURE COST

Actual incremental cost for this measure should be used. If actuals are unavailable use $4,150.

LOADSHAPE

Cooking BUS

Miscellaneous BUS (only use this loadshape for gas savings)

[31] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009” http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric steam cooker below, otherwise use deemed value from the table that follows.[32]

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy = [(1 – SteamMode) *($IdleRate_{Base}$ + SteamMode * $Production_{Base}$ * Pans *EFOOD/Eff_{Base})* (Hours – FoodCooked/$Production_{Base}$ * Pans)] – [(1 – SteamMode) *($IdleRate_{ESTAR}$ + SteamMode * $Production_{ESTAR}$ * Pans *EFOOD/Eff_{ESTAR})* (Hours – FoodCooked/$Production_{ESTAR}$ * Pans)]

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) – (FoodCooked * EFOOD/ Eff_{ESTAR})

Where:

ΔIdleEnergy = Difference in idle energy between baseline and efficient steam cooker

ΔCookingEnergy = Difference in cooking energy between baseline and efficient steam cooker

Days = Annual days of operation

= Custom or if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

SteamMode = Time (%) in constant steam mode

= Custom or if unknown, use 40%

$IdleRate_{Base}$ = Idle energy rate (W) of baseline electric steam cooker

= 1,100 W[33]

$IdleRate_{ESTAR}$ = Idle energy rate (W) of ENERGY STAR® electric steam cooker

= Custom or if unknown, use value from table below as determined by pan capacity

Pan Capacity	$IdleRate_{ESTAR}$
3	400
4	530
5	670
6	800
10	800

$Production_{Base}$ = Production capacity (lb/hr) per pan of baseline electric steam cooker

32 Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

33 Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR® for steam generator and boiler-based cookers

= 23.3 lb/hr

$Production_{ESTAR}$ = Production capacity (lb/hr) per pan of ENERGY STAR® electric steam cooker

= Custom or if unknown, use 16.7 lb/hr

Pans = Pan capacity of steam cooker

= Custom or if unknown, use 6 pans

EFOOD = ASTM energy to food

= 30.8 Wh/lb

Eff_{Base} = Cooking efficiency (%) of baseline electric steam cooker[34]

= 28%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR® electric steam cooker

= Custom or if unknown, use 50%

Hours = Average daily hours of operation

= Custom or if unknown, use 12 hours per day

FoodCooked = Food cooked per day (lbs)

= Custom or if unknown, use 100 pounds

Savings for all pan capacities are presented in the table below.

Energy Consumption of Electric Steam Cookers			
Pan Capacity	**kWh_{Base}**	**kWh_{ESTAR}**	**Savings (kWh)**
3	18,438.9	7,637.6	10,801.3
4	23,018.6	9,784.1	13,234.5
5	27,563.8	11,953.8	15,609.9
6	32,091.7	14,100.1	17,991.6
10	50,134.5	21,384.3	28,750.1
Average	30,249.5	12,972.0	17,277.5

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001998949[35]

Other variables as defined above.

[34] Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR® Commercial Kitchen Equipment Savings Calculator for steam generator and boiler-based cookers

[35] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas steam cooker below, otherwise use deemed value from the table that follows.[36]

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = [(1 – SteamMode) *($IdleRate_{Base}$ + SteamMode * $Production_{Base}$ * Pans *EFOOD/Eff_{Base})* (Hours – FoodCooked/$Production_{Base}$ * Pans)] – [(1 – SteamMode) *($IdleRate_{ESTAR}$ + SteamMode * $Production_{ESTAR}$ * Pans *EFOOD/Eff_{ESTAR})* (Hours – FoodCooked/$Production_{ESTAR}$ * Pans)]

ΔCookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) – (FoodCooked * EFOOD/ Eff_{ESTAR})

Where:

100,000 = Btu to therms conversion factor

$IdleRate_{Base}$ = Idle energy rate (Btu/hr) of baseline gas steam cooker

= 16,500 Btu/hr[37]

$IdleRate_{ESTAR}$ = Idle energy rate (Btu/hr) of ENERGY STAR® gas steam cooker

= Custom or if unknown, use value from table below as determined by pan capacity

Pan Capacity	$IdleRate_{ESTAR}$
3	6,250
5	10,400
6	12,500
10	12,500

$Production_{Base}$ = Production capacity (lb/hr) per pan of baseline gas steam cooker

= 23.3 lb/hr

$Production_{ESTAR}$ = Production capacity (lb/hr) per pan of ENERGY STAR® gas steam cooker

= Custom or if unknown, use 20 lb/hr

EFOOD = ASTM energy to food

= 105 Btu/lb

Eff_{Base} = Cooking efficiency (%) of baseline gas steam cooker[38]

= 16.5%

Eff_{ESTAR} = Cooking efficiency (%) of ENERGY STAR® gas steam cooker

36 Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

37 Idle energy rate for baseline steam cookers is the average of rates provided by ENERGY STAR® for steam generator and boiler-based cookers

38 Cooking efficiency for baseline steam cookers is the average of efficiencies provided by ENERGY STAR® for steam generator and boiler-based cookers

= Custom or if unknown, use 38%

Other variables as defined above.

Savings for all pan capacities are presented in the table below.

Energy Consumption of Gas Steam Cookers			
Pan Capacity	**$Therms_{Base}$**	**$Therms_{ESTAR}$**	**Savings (Therms)**
3	1,301.5	492.8	808.7
5	1,842.1	795.7	1,046.4
6	2,107.2	947.8	1,159.4
10	3,157.4	1,344.5	1,812.9
Average	1,996.0	845.0	1,150.0

WATER IMPACT DESCRIPTIONS AND CALCULATION

Custom calculation below, otherwise use deemed value of 134,412.0 gallons per year.[39] Savings are the same for electric and gas steam cookers.

$$\Delta Water = (WaterUse_{Base} - WaterUse_{ESTAR}) * Hours * Days$$

Where:

$WaterUse_{Base}$ = Water use (gal/hr) of baseline steam cooker

= 40 gal/hr

$WaterUse_{ESTAR}$ = Water use (gal/hr) of ENERGY STAR® steam cooker[40]

= Custom or if unknown, use 9.3 gal/hr

Other variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

39 Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

40 Water use for ENERGY STAR® steam cookers is the average of water use values provided by ENERGY STAR® for steam generator, boiler-based, and boilerless cookers

2.2.3 Conveyor Oven

DESCRIPTION

This measure applies to a natural gas fired high efficiency gas conveyor oven installed in a commercial kitchen with a conveyor width greater than 25 inches.

Conveyor ovens are available using four different heating processes: infrared, natural convection with a ceramic baking hearth, forced convection or air impingement, or a combination of infrared and forced convection. Conveyor ovens are typically used for producing a limited number of products with similar cooking requirements at high production rates.

Some manufacturers offer an air-curtain feature at either end of the cooking chamber that helps to keep the heated air inside the conveyor oven. The air curtain operates as a virtual oven wall and helps reduce both the idle energy of the oven and the resultant heat gain to the kitchen.

This measure was developed to be applicable to the following program types: TOS.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a natural gas conveyor oven with a tested baking energy efficiency > 42% and an idle energy consumption rate < 57,000 Btu/hr utilizing ASTM standard F1817.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new, standard, natural gas conveyor oven.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 17 years.[41]

DEEMED MEASURE COST

The incremental capital cost for this measure is $4,731.[42]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A[43]

[41] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011
[42] Pacific Gas and Electric Company workpaper PGECOFST117, Commercial Conveyor Ovens, Food Service Equipment Workpaper June 1, 2009.
[43] There are currently no existing testing or efficiency standards for electric conveyor ovens.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation is shown below. In instances where site specific information is unavailable for any given variable, the following default values may be used.[44] In instances where all defaults are used, the resulting savings are 839.3 therms annually.

$$\Delta Therms = (\Delta PreheatEnergy + \Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

$\Delta PreheatEnergy = NoPreheats * (Preheat_{Base} – Preheat_{EE})$

$\Delta IdleEnergy = (IdleRate_{Base} * (Hours – (FoodCooked/Production_{Base})) – (IdleRate_{EE} * (Hours – (FoodCooked/Production_{EE}))$

$\Delta CookingEnergy = (FoodCooked * EFOOD/ Eff_{Base}) - (FoodCooked * EFOOD/ Eff_{EE})$

Where:

Days = Annual days of operation
= Custom or if unknown, use 365.25 days per year

100,000 = Btu to therms conversion factor

NoPreheats = Number of preheats per day
= Custom or if unknown, use 1 preheat per day

$Preheat_{Base}$ = Preheat energy of baseline oven
= 35,000 Btu

$Preheat_{EE}$ = Preheat energy of efficient oven
= Custom or if unknown, use 18,000 Btu

$IdleRate_{Base}$ = Idle energy rate of baseline oven
= 70,000 Btu/hr

$IdleRate_{EE}$ = Idle energy rate of efficient oven
= Custom or if unknown, use 57,000 Btu/hr

Hours = Average daily hours of operation
= Custom or if unknown, use 12 hours per day

FoodCooked = Number of pizzas cooked per day
= Custom or if unknown, use 250 pizzas per day

$Production_{Base}$ = Production capacity of baseline oven
= 150 pizzas per hour

$Production_{EE}$ = Production capacity of efficient oven

[44] Default values based on the Food Service Technology Center's online Gas Conveyor Oven Life-Cycle Cost Calculator.

= Custom or if unknown, use 220 pizzas per hour

EFOOD = ASTM energy to food

= 166 Btu/pizza[45]

Eff_{Base} = Heavy-load cooking efficiency of baseline oven

= 20%

Eff_{EE} = Heavy-load cooking efficiency of efficient oven

= Custom or if unknown, use 42%

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[45] Calibrated value to give results consistent with the Food Service Technology Center's online Gas Conveyor Oven Life-Cycle Cost Calculator. This value is consistent with values found by FSTC experimental testing and values recognized by ENERGY STAR®.

2.2.4 Fryer

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR® certified fryers installed in a commercial kitchen. ENERGY STAR® fryers offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation reduces standby losses, resulting in lower idle energy rates. Standard-sized ENERGY STAR® fryers are up to 30% more efficient, and large-vat ENERGY STAR® fryers are up to 35% more efficient, than standard fryers.

This measure was developed to be applicable to the following program type: TOS.

If applied to other program types, measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified fryer meeting idle energy rate (W or Btu/hr)) and cooking efficiency (%) limits, as determined by both fuel type and fryer capacity (standard versus large vat).

ENERGY STAR® Requirements (Version 2.0, Effective April 22, 2011)

Fryer Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency Consumption	Idle Energy Rate	Cooking Efficiency Consumption
Standard Open Deep-Fat Fryer	≤ 1,000 W	≥ 80%	≤ 9,000 Btu/hr	≥ 50%
Large Vat Open Deep-Fat Fryer	≤ 1,100 W		≤ 12,000 Btu/hr	

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas fryer that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[46]

DEEMED MEASURE COST

The incremental capital cost for this measure is $210 for standard electric, $0 for large vat electric, $0 for standard gas, and $1,120 for large vat gas fryers.[47]

LOADSHAPE

Cooking BUS

Miscellaneous BUS (only use this loadshape for gas savings)

[46] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator ,which cites reference as "FSTC research on available models, 2009 https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

[47] Measure costs from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "EPA research using AutoQuotes, 2012"

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric fryer below, otherwise use deemed value of 952.3 kWh for standard fryers and 2,537.9 kWh for large vat fryers.[48]

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy	= ($ElecIdle_{Base}$* (Hours – FoodCooked/$ElecPC_{Base}$)) – ($ElecIdle_{ESTAR}$ * (Hours – FoodCooked/$ElecPC_{ESTAR}$))
ΔCookingEnergy	= (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{Base}$) – (FoodCooked * $EFOOD_{Elec}$/$ElecEff_{ESTAR}$)

Where:

ΔIdleEnergy	= Difference in idle energy between baseline and efficient fryer
ΔCookingEnergy	= Difference in cooking energy between baseline and efficient fryer
Days	= Annual days of operation
	= Custom or if unknown, use 365.25 days per year
1,000	= Wh to kWh conversion factor
$ElecIdle_{Base}$	= Idle energy rate of baseline electric fryer
	= 1,050 W for standard fryers and 1,350 W for large vat fryers
$ElecIdle_{ESTAR}$	= Idle energy rate of ENERGY STAR® electric fryer
	= Custom or if unknown, use 1,000 W for standard fryers and 1,100 for large vat fryers
Hours	= Average daily hours of operation
	= Custom or if unknown, use 16 hours per day for a standard fryer and 12 hours per day for a large vat fryer
FoodCooked	= Food cooked per day
	= Custom or if unknown, use 150 pounds
$ElecPC_{Base}$	= Production capacity of baseline electric fryer
	= 65 lb/hr for standard fryers and 100 lb/hr for large vat fryers
$ElecPC_{ESTAR}$	= Production capacity of ENERGY STAR® electric fryer
	= Custom or if unknown, use 70 lb/hr for standard fryers and 110 lb/hr for large vat fryers
$EFOOD_{Elec}$	= ASTM energy to food
	= 167 Wh/lb

[48] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

$ElecEff_{Base}$ = Cooking efficiency of baseline electric fryer

= 75% for standard fryers and 70% for large vat fryers

$ElecEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® electric fryer

= Custom or if unknown, use 80% for both standard and large vat fryers

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW \quad = \Delta kWh * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001998949[49]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas fryer below, otherwise use deemed value of 507.9 therms/yr for standard fryers and 415.1 therms/yr for large vat fryers.[50]

$$\Delta Therms = (\Delta IdleEnergy + \ \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = ($GasIdle_{Base}$* (Hours – FoodCooked/$GasPC_{Base}$)) – ($GasIdle_{ESTAR}$ * (Hours – FoodCooked/$GasPC_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * $EFOOD_{Gas}$/ $GasEff_{Base}$) – (FoodCooked * $EFOOD_{Gas}$/$GasEff_{ESTAR}$)

Where:

100,000 = Btu to therms conversion factor

$GasIdle_{Base}$ = Idle energy rate of baseline gas fryer

= 14,000 Btu/hr for standard fryers and 16,000 Btu/hr for large vat fryers

$GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® gas fryer

= Custom or if unknown, use 9,000 Btu/hr for standard fryers and 12,000 Btu/hr for large vat fryers

$GasPc_{Base}$ = Production capacity of baseline gas fryer

= 60 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$GasPc_{ESTAR}$ = Production capacity of ENERGY STAR® gas fryer

= Custom or if unknown, use 65 lb/hr for standard fryers and 110 lb/hr for large vat fryers

$EFOOD_{Gas}$ = ASTM energy to food

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49 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference “Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf”

50 Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

= 570 Btu/lb

$GasEff_{Base}$ = Cooking efficiency of baseline gas fryer

= 35% for both standard and large vat fryers

$GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® gas fryer

= Custom or if unknown, use 50% for both standard and large vat fryers

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.2.5 Convection Oven

DESCRIPTION

This measure applies to either full or half-sized electric ENERGY STAR® convection ovens and to half-sized natural gas fired ENERGY STAR® convection ovens installed in a commercial kitchen. Convection ovens are general purpose ovens that use fans to circulate hot, dry air over the food surface. ENERGY STAR® certified convection ovens are approximately 20% more efficient than standard ovens.

This measure was developed to be applicable to the following program type: TOS.

If applied to other program types, measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified convection oven meeting idle energy rate (kW or Btu/hr)) and cooking efficiency (%) limits, as determined by both fuel type and oven capacity (full size versus half size).

ENERGY STAR® Requirements (Version 2.2, Effective October 7, 2015)

Oven Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
Full Size	≤ 1.60 kW	≥ 71%	≤ 12,000 Btu/hr	≥ 46%
Half Size	≤ 1.00 kW		N/A	N/A

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas convection oven that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[51]

DEEMED MEASURE COST

The incremental capital cost for this measure is $0.[52]

LOADSHAPE

Cooking BUS

Miscellaneous BUS (only use this loadshape for gas savings)

[51] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as "FSTC research on available models, 2009" https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator.xlsx

[52]Measure cost from ENERGY STAR® which cites reference as "EPA research on available models using AutoQuotes, 2013"

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric convection oven below, otherwise use 1,938.5 kWh for full-size ovens and 192.1 kWh for half-size ovens.[53]

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy	$= (ElecIdle_{Base} * (Hours - FoodCooked/ElecPC_{Base})) - (ElecIdle_{ESTAR} * (Hours - FoodCooked/ElecPC_{ESTAR}))$
ΔCookingEnergy	$= (FoodCooked * EFOOD_{Elec} / ElecEff_{Base}) - (FoodCooked * EFOOD_{Elec} / ElecEff_{ESTAR})$

Where:

ΔIdleEnergy	= Difference in idle energy between baseline and efficient convection oven
ΔCookingEnergy	= Difference in cooking energy between baseline and efficient convection oven
Days	= Annual days of operation
	= Custom or if unknown, use 365.25 days per year
1,000	= Wh to kWh conversion factor
$ElecIdle_{Base}$	= Idle energy rate of baseline electric convection oven
	= 2,000 W for full-size ovens and 1,030 W for half-size ovens
$ElecIdle_{ESTAR}$	= Idle energy rate of ENERGY STAR® electric convection oven
	= Custom or if unknown, use 1,600 W for full-size ovens and 1,000 W for half-size ovens
Hours	= Average daily hours of operation
	= Custom or if unknown, use 12 hours per day
FoodCooked	= Food cooked per day
	= Custom or if unknown, use 100 pounds
$ElecPC_{Base}$	= Production capacity of baseline electric convection oven
	= 90 lb/hr for full-size ovens and 45 lb/hr for half-size ovens
$ElecPC_{ESTAR}$	= Production capacity of ENERGY STAR® electric convection oven
	= Custom or if unknown, use 90 lb/hr for full-size ovens and 50 lb/hr for half-size ovens
$EFOOD_{Elec}$	= ASTM energy to food for electric convection oven
	= 73.2 Wh/lb

[53] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

$ElecEff_{Base}$ = Cooking efficiency of baseline electric convection oven

= 65% for full-size ovens and 68% for half-size ovens

$ElecEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® electric convection oven

= Custom or if unknown, use 71% for both full-size and half-size ovens

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001998949[54]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas convection oven below, otherwise use deemed value of 129.4 therms/yr.[55]

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = $(GasIdle_{Base} * (Hours - FoodCooked/GasPC_{Base})) - (GasIdle_{ESTAR} * (Hours - FoodCooked/GasPC_{ESTAR}))$

ΔCookingEnergy = $(FoodCooked * EFOOD_{Gas}/ GasEff_{Base}) - (FoodCooked * EFOOD_{Gas}/ GasEff_{ESTAR})$

Where:

100,000 = Btu to therms conversion factor

$GasIdle_{Base}$ = Idle energy rate of baseline gas convection oven

= 15,100 Btu/hr

$GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® gas convection oven

= Custom or if unknown, use 12,000 Btu/hr

$GasPC_{Base}$ = Production capacity of baseline gas convection oven

= 83 lb/hr

$GasPC_{ESTAR}$ = Production capacity of ENERGY STAR® gas convection oven

= Custom or if unknown, use 86 lb/hr

$EFOOD_{Gas}$ = ASTM energy to food for gas convection oven

[54] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

[55] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

= 250 Btu/lb

$GasEff_{Base}$ = Cooking efficiency of baseline gas convection oven

= 44%

$GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® gas convection oven

= Custom or if unknown, use 46%

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.2.6 Griddle

DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR® certified griddles installed in a commercial kitchen. ENERGY STAR® commercial griddles achieve approximately 10% higher efficiency than standard griddles with strategies such as highly conductive or reflective plate materials and improved thermostatic controls.

This measure was developed to be applicable to the following program type: TOS.

If applied to other program types, measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new ENERGY STAR® electric or natural gas fired griddle meeting idle energy rate limits as determined by fuel type.

ENERGY STAR® Requirements (Version 1.2, Effective May 8, 2009 for natural gas and January 1, 2011 for electric griddles)

Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
Idle Energy Rate	Cooking Efficiency Consumption	Idle Energy Rate	Cooking Efficiency Consumption
≤ 320 W/ft^2 ≤ 1.00 kW	Reported	≤ 2,650 Btu/hr/ft^2 N/A	Reported

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas fired griddle that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[56]

DEEMED MEASURE COST

The incremental capital cost for this measure is $0 for an electric griddle and $360 for a gas griddle.[57]

LOADSHAPE

Cooking BUS

Miscellaneous BUS (only use this loadshape for gas savings)

[56] Lifetime from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “FSTC research on available models, 2009” http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

[57] Measure costs from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator, which cites reference as “EPA research on available models using AutoQuotes, 2012” http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation for an electric griddle below, otherwise use deemed value of 1,910.4 kWh.[58]

$$\Delta kWh = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/1{,}000$$

Where:

ΔIdleEnergy	= [($ElecIdle_{Base}$* Width * Depth) * (Hours – FoodCooked/$ElecPC_{Base}$)] – [($ElecIdle_{ESTAR}$ * Width * Depth) * (Hours – FoodCooked/$ElecPC_{ESTAR}$))
ΔCookingEnergy	= (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{Base}$) – (FoodCooked * $EFOOD_{Elec}$/ $ElecEff_{ESTAR}$)

Where:

ΔIdleEnergy	= Difference in idle energy between baseline and efficient griddle
ΔCookingEnergy	= Difference in cooking energy between baseline and efficient griddle
Days	= Annual days of operation
	= Custom or if unknown, use 365.25 days per year
1,000	= Wh to kWh conversion factor
$ElecIdle_{Base}$	= Idle energy rate of baseline electric griddle
	= 400 W/ft^2
$ElecRate_{ESTAR}$	= Idle energy rate of ENERGY STAR® electric griddle
	= Custom or if unknown, use 320 W/ft^2
Width	= Griddle width
	= Custom or if unknown, use 3 feet
Depth	= Griddle depth
	= Custom or if unknown, use 2 feet
Hours	= Average daily hours of operation
	= Custom or if unknown, use 12 hours per day
FoodCooked	= Food cooked per day
	= Custom or if unknown, use 100 pounds
$ElecPC_{Base}$	= Production capacity of baseline electric griddle
	= 35 lb/hr
$ElecPC_{ESTAR}$	= Production capacity of ENERGY STAR® electric griddle
	= Custom or if unknown, use 40 lb/hr
$EFOOD_{Elec}$	= ASTM energy to food

[58] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

= 139 Wh/lb

$ElecEff_{Base}$ = Cooking efficiency of baseline electric griddle

= 65%

$ElecEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® electric griddle

= Custom or if unknown, use 70%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW \quad = \Delta kWh * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001998949[59]

Other variables as defined above.

NATURAL GAS ENERGY SAVINGS

Custom calculation for a natural gas griddle below, otherwise use deemed value of 131.4 therms.[60]

$$\Delta Therms = (\Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔIdleEnergy = [$GasIdle_{Base}$* (Width * Depth) * (Hours – FoodCooked/$GasPC_{Base}$)] – [$GasIdle_{ESTAR}$ * (Width * Depth) * (Hours – FoodCooked/$GasPC_{ESTAR}$))

ΔCookingEnergy = (FoodCooked * $EFOOD_{Gas}$/ $GasEff_{Base}$) – (FoodCooked * $EFOOD_{Gas}$/ $GasEff_{ESTAR}$)

Where:

100,000 = Btu to therms conversion factor

$GasIdle_{Base}$ = Idle energy rate of baseline gas griddle

= 3,500 Btu/hr/ft^2

$GasIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR® gas griddle

= Custom or if unknown, use 2,650 Btu/hr/ft^2

$GasPC_{Base}$ = Production capacity of baseline gas griddle

= 25 lb/hr

$GasPC_{ESTAR}$ = Production capacity of ENERGY STAR® gas griddle

= Custom or if unknown, use 45 lb/hr

$EFOOD_{Gas}$ = ASTM energy to food

= 475 Btu/lb

[59] 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

[60] Algorithms and assumptions derived from ENERGY STAR® Commercial Kitchen Equipment Savings Calculator

$GasEff_{Base}$ = Cooking efficiency of baseline gas griddle

= 32%

$GasEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR® gas griddle

= Custom or if unknown, use 38%

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.2.7 Infrared Charbroiler

DESCRIPTION

This measure applies to new natural gas fired charbroilers that utilize infrared burners installed in a commercial kitchen. Charbroilers cook food in a grid placed over a radiant heat source. Infrared broilers move heat faster and carry a higher heat intensity than non-infrared broilers.

This measure was developed to be applicable to the following program types: TOS.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas charbroiler with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas charbroiler without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years. [61]

DEEMED MEASURE COST

The incremental capital cost for this measure is $2,200.[62]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation is shown below, followed by a table of default values that may be used when a given variable is unknown.

$$\Delta Therms = (\Delta PreheatEnergy + \Delta CookingEnergy) * Days/100{,}000$$

[61] Lifetime recognized by the Food Service Technology Center, as indicated in the online Gas Broiler Life-Cycle Cost Calculator.
[62] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562

Where:

ΔPreheatEnergy	= Difference in preheating energy between baseline and infrared charbroiler
	= NoPreheats * ($Preheat_{Base}$ – $Preheat_{EE}$)
ΔCookingEnergy	= Difference in cooking energy between baseline and infrared charbroiler
	= ($InputRate_{Base}$ - $InputRate_{EE}$) * Hours
Days	= Annual days of operation
100,000	= Btu to therms conversion factor
NoPreheats	= Number of preheats per day
$Preheat_{Base}$	= Preheat energy requirement of baseline charbroiler [Btu]
$Preheat_{EE}$	= Preheat energy requirement of infrared charbroiler [Btu]
$InputRate_{Base}$	= Cooking energy input rate of baseline charbroiler [Btu/hr]
$InputRate_{EE}$	= Cooking energy input rate of infrared charbroiler [Btu/hr]
Hours	= Total average daily hours of operation minus 0.3 hours to account for preheating time [hr]. E.g. if the charbroiler is on average turned on at 12PM and shut off at 12AM, (12 – 0.3) or 11.7 hours is used in the algorithm.

In instances where site specific information is unavailable for any given variable, the following default values (based on charbroiler width) may be used.[63] In instances where all defaults are used, the resulting savings are shown as Default in the table below.

Variable	Charbroiler Width				
	2 Foot	3 Foot	4 Foot	5 Foot	6 Foot
Days	365.25	365.25	365.25	365.25	365.25
$Preheat_{Base}$	32,000 Btu	48,000 Btu	64,000 Btu	80,000 Btu	96,000 Btu
$Preheat_{ESTAR}$	27,000 Btu	40,500 Btu	54,000 Btu	67,500 Btu	81,000 Btu
NoPreheats	1	1	1	1	1
$InputRate_{Base}$	64,000 Btu/hr	96,000 Btu/hr	128,000 Btu/hr	160,000 Btu/hr	192,000 Btu/hr
$InputRate_{EE}$	48,000 Btu/hr	72,000 Btu/hr	96,000 Btu/hr	120,000 Btu/hr	144,000 Btu/hr
Hours	11.7 hr/day	11.7 hr/day	11.7 hr/day	11.7 hr/day	11.7 hr/day
Default	702.0 therms	1053.0 therms	1404.0 therms	1755.0 therms	2106.0 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[63] Default values based on the Food Service Technology Center's online Gas Broiler Life-Cycle Cost Calculator.

2.2.8 Infrared Rotisserie Oven

DESCRIPTION

This measure applies to new natural gas fired high efficiency rotisserie ovens utilizing infrared burners and installed in a commercial kitchen. Rotisserie ovens are designed for batch cooking, with individual spits arranged on a rotating wheel or drum within an enclosed cooking cavity. Infrared ovens move heat faster and carry a higher heat intensity than non-infrared ovens.

This measure was developed to be applicable to the following program types: TOS.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas rotisserie oven with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas rotisserie oven without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[64]

DEEMED MEASURE COST

The incremental capital cost for this measure is $2,700.[65]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Custom calculation is shown below. In instances where site specific information is unavailable for any given variable, the following default values may be used. In instances where all defaults are used, the resulting savings are 187.2 therms annually.

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[64] Measure life consistent with other food service equipment lifetimes as reported by the Food Service Technology Center.

[65] Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

$$\Delta Therms = \frac{InputRate_{EE}}{3} * Duty * Hours / 100{,}000$$

Where:

$InputRate_{EE}$ = Energy input rate of infrared rotisserie oven (Btu/hr)

= Custom of if unknown, use 37,500 Btu/hr[66]

Note: the difference between baseline and efficient energy input rates can be simplified when efficient rotisseries are assumed to have 75% of the energy input requirement as baseline. If $InputRate_{BASE} = InputRate_{EE} / .75$ *then the term becomes* $[(InputRate_{EE} / .75) - InputRate_{EE}]$ *which can be factored and simplified to* $[InputRate_{EE} / 3]$

Duty = Duty cycle of rotisserie oven (%)

= Custom or if unknown, use 60%[67]

Hours = Typical annual operating hours of rotisserie oven

= Custom or if unknown, use 2,496 hours[68]

100,000 = Btu to therms conversion factor

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[66] Infrared energy input rate calculated based on baseline energy input rate of 50,000 Btu/hr, the median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7.2. Input energy rates of infrared rotisseries are assumed to be 75% of that of baseline, consistent with infrared charbroilers.

[67] Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7.2

[68] Typical operating hours based on oven operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Oven Technical Assessment, Table 7.2

2.2.9 Kitchen Demand Ventilation Controls

DESCRIPTION

This measure related to the installation of commercial kitchen demand ventilation controls that vary the kitchen ventilation exhaust and make-up airflow based on cooking load and/or time of day.

This measure was developed to be applicable to the following program types: TOS, RF. For TOS applications, ASHRAE 90.1 and local codes should be applied to situations where hood exhaust rates exceed 5,000 cfm. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a control system that varies the exhaust rate of kitchen ventilation (exhaust and makeup air fans) based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a new temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed accordingly.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is kitchen ventilation system that has constant speed, continuously operating ventilation motor(s).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[69]

DEEMED MEASURE COST

The capital cost for this measure is proportional to the rated horsepower of the exhaust motor(s), based on installation classification:

$$\text{Measure Cost} = HP_{exhaust} * Cost_{HP}$$

Where:

$HP_{exhaust}$ = total rated horsepower of the exhaust motor(s)

$Cost_{HP}$ = cost per horsepower as listed in the table below

Measure Category	Incremental Cost70 , $/HP
Retrofit	$1,988
Time of Sale	$994

LOADSHAPE

Cooking BUS

Miscellaneous BUS (only use this loadshape for gas savings)

[69] Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009.
[70] Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Fan energy savings:

$$\Delta kWh = HP_{exhaust} * (0.76\ kW/HP\ ^{71}) * Hours * Days$$

Where:

Hours = Average daily hours of operation. If unknown, assume 12 hours.

Days = Annual days of operation. If unknown assume 365.25 days.

Other variables as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh * CF$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.000199894979 NATURAL GAS ENERGY SAVINGS

For applications where 100% make-up air is tempered, annual gas savings attributed to heating can be estimated as:

$$\Delta Therms = CFM * HP_{exhaust} * Hours/24 * Q * /(Eff_{heat} * 100{,}000)$$

Where:

CFM = average airflow reduction for the system, per rated horsepower of exhaust motor(s).

= custom input, or 448 cfm/HP[72] if unknown.

Q = Annual heating energy required (tabulated values represenent continuous operation) to heat kitchen make-up air, Btu/cfm dependent on location[73]:

Zone	Q, Btu/cfm
Fort Madison	136,416
Lincoln	152,258
Cape Girardeau	116,666
Kaiser	119,824
Knob Noster	124,716
Kansas City	140,920
St Louis	125,363

[71] Normalized demand savings per rated HP of exhaust motor. Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009

[72] Based on data presented in Pacific Gas & Electric Company Work Paper PGECOFST116 Demand Ventilation Controls Revision # 1, June 1, 2009. See workbook KDVC.xlsx for derivation.

[73] Assuming a base temperature of 65. It is assumed that kitchens often separate dedicated 100% outdoor air make up units and kitchen staff prefer to have outside air heated to 65 degrees. See workbook KDVC.xlsx for derivation.

Eff_{heat}	= Heating efficiency of unit supplying make-up air.
	= actual if known, otherwise assume 80%[74]
100,000	= conversion from Btu to Therm

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[74] IECC code minimum thermal efficiency requirements for a warm air duct furnace.

2.2.10 Rack Oven

DESCRIPTION

This measure applies to natural gas fired ENERGY STAR® certified rack oven (either single or double rack) installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR® certified gas rack oven meeting idle energy rate (Btu/hr)) and baking-energy efficiency (%) qualification criteria, as determined by oven capacity.

ENERGY STAR® Requirements (Version 2.2, Effective October 7, 2015)

Oven Capacity	Total Energy Idle Energy	Baking-Energy Efficiency
Single Rack	≤ 25,000 Btu/hr	≥ 48%
Double Rack	≤ 30,000 Btu/hr	≥ 52%

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas rack oven that is not ENERGY STAR® certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[75]

DEEMED MEASURE COST

The incremental capital cost for this measure is $4933.00 for a single rack oven and $5187.00 for a double rack.[76]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A[77]

[75] Lifetime recognized by the Food Service Technology Center, as indicated in the online Gas Rach Oven Life-Cycle Cost Calculator.

[76] Pacific Gas and Electric Company workpaper PGECOFST109, Commercial Rack Ovens, Food Service Equipment Workpaper June 1, 2009.

[77] ENERGY STAR® and the Food Service Technology Center do not yet rate or certify electric rack ovens.

Summer Coincident Peak Demand Savings

N/A

Natural Gas Energy Savings

Custom calculation is shown below, followed by a table of default values that may be used when a given variable is unknown.

$$\Delta Therms = (\Delta PreheatEnergy + \Delta IdleEnergy + \Delta CookingEnergy) * Days/100{,}000$$

Where:

ΔPreheatEnergy	= NoPreheats * ($Preheat_{Base}$ – $Preheat_{ESTAR}$)
ΔIdleEnergy	= ($GasIdle_{Base}$* (Hours - FoodCooked/$GasPC_{Base}$)) - ($GasIdle_{ESTAR}$ * (Hours -FoodCooked/$GasPC_{ESTAR}$))
ΔCookingEnergy	= FoodCooked * $EFOOD_{Gas}$ * (1/ $GasEff_{Base}$ - 1/ $GasEff_{ESTAR}$)

Where:

ΔPreheatEnergy	= Difference in preheating energy between baseline and efficient rack oven
ΔIdleEnergy	= Difference in idle energy between baseline and efficient rack oven
ΔCookingEnergy	= Difference in heavy-load cooking energy between baseline and efficient rack oven
Days	= Annual days of operation
100,000	= Btu to therms conversion factor
NoPreheats	= Number of preheats per day
$Preheat_{Base}$	= Preheat energy requirement of baseline rack oven [Btu]
$Preheat_{ESTAR}$	= Preheat energy requirement of efficient rack oven [Btu]
$GasIdle_{Base}$	= Idle energy rate of baseline gas rack oven [Btu/hr]
$GasIdle_{ESTAR}$	= Idle energy rate of ENERGY STAR® gas rack oven [Btu/hr]
Hours	= Average daily hours of operation [hr]
$GasPC_{Base}$	= Production capacity of baseline gas rack oven [lbs/hr]
$GasPC_{ESTAR}$	= Production capacity of ENERGY STAR® gas rack oven [lbs/hr]
FoodCooked	= Mass of food cooked daily in the rack oven [lbs]
$EFOOD_{Gas}$	= Energy transfer to food for gas rack oven
	= 226 Btu/lbs[78]
$GasEff_{Base}$	= Heavy-load cooking efficiency of baseline gas rack oven [%]
$GasEff_{ESTAR}$	= Heavy-load cooking efficiency of ENERGY STAR® gas rack oven [%]

[78] Calibrated value to give results consistent with the Food Service Technology Center's online Gas Rack Oven Life-Cycle Cost Calculator. This value is consistent with values found by FSTC experimental testing and values recognized by ENERGY STAR®.

In instances where site specific information is unavailable for any given variable, the following default values may be used.[79] In instances where all defaults are used, the resulting savings are 1096.4 therms and 2315.8 therms for single rack and double rack ovens respectively.

Variable	Single Rack	Double Rack
Days	365.25	365.25
$Preheat_{Base}$	50,000 Btu	100,000 Btu
$Preheat_{ESTAR}$	44,000 Btu	85,000 Btu
NoPreheats	1	1
$GasIdle_{Base}$	43,000 Btu/hr	65,000 Btu/hr
$GasIdle_{ESTAR}$	25,000 Btu/hr	30,000 Btu/hr
Hours	12 hr/day	12 hr/day
$GasPC_{Base}$	130 lb/hr	250 lb/day
$GasPC_{ESTAR}$	140 lb/hr	280 lb/day
FoodCooked	600 lb/day	1200 lb/day
$GasEff_{Base}$	30%	30%
$GasEff_{ESTAR}$	48%	52%

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[79] Default values based on the Food Service Technology Center's online Gas Rack Oven Life-Cycle Cost Calculator.

2.2.11 Infrared Salamander Broiler

DESCRIPTION

This measure applies to new natural gas fired high efficiency salamander broilers utilizing infrared burners installed in a commercial kitchen. Salamander broilers are medium-input overfired broilers that are typically mounted on the backshelf of a range. Infrared broilers move heat faster and carry a higher heat intensity than non-infrared broilers.

This measure was developed to be applicable to the following program types: TOS.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas fired salamander broiler with infrared burners and an efficiency rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new natural gas fired salamander broiler without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years. [80]

DEEMED MEASURE COST

The incremental capital cost for this measure is $1,000.[81]

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[80]Measure life consistent with other food service equipment lifetimes as reported by the Food Service Technology Center.
[81] Incremental cost from Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

NATURAL GAS ENERGY SAVINGS

Custom calculation is shown below. In instances where site specific information is unavailable for any given variable, the following default values may be used. In instances where all defaults are used, the resulting savings are 168.2 therms annually.

$$\Delta Therms = \frac{InputRate_{EE}}{3} * Duty * Hours / 100{,}000$$

Where:

$InputRate_{EE}$ = Rated energy input rate of infrared salamander broiler (Btu/hr)

= Custom or if unknown, use 28,875 Btu/hr[82]

Note: the difference between baseline and efficient energy input rates can be simplified when efficient salamander broilers are assumed to have 75% of the energy input requirement as baseline. If $InputRate_{BASE} = InputRate_{EE} / .75$ *then the term becomes* $[(InputRate_{EE} / .75) - InputRate_{EE}]$ *which can be factored and simplified to* $[InputRate_{EE} / 3]$

Duty = Duty cycle of salamander broiler (%)

= Custom or if unknown, use 70%[83]

Hours = Typical operating hours of salamander broiler

= Custom or if unknown, use 2,496 hours[84]

100,000 = Btu to therms conversion factor

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[82] Infrared energy input rate calculated based on baseline energy input rate of 38,500 Btu/hr, the median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3. Input energy rates of infrared salamander broilers are assumed to be 75% of that of baseline, consistent with infrared charbroilers.

[83] Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

[84] Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

2.2.12 Pre-Rinse Spray Valve

DESCRIPTION

Pre-rise valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. More efficient spray valves use less water, thereby reducing water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The primary impacts of this measure are water savings. Reduced hot water consumption saves either natural gas or electricity, depending on the type of energy the hot water heater uses.

This measure was developed to be applicable to the following program types: TOS, RF, and DI. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the new or replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment will vary based on the delivery method and is defined below:

Time of Sale	Retrofit, Direct Install
The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006.	Actual existing flow rates should be used when possible. If unknown, baseline can be assumed to be 2.23 gallons per minute.[85] If existing pre-rinse spray valve flow rate is unknown, then existing pre-rinse spray valve must have been installed prior to 2006. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. However, field data shows that not all nozzles in use have been replaced with the newer flow rate nozzle. Products predating this standard can use up to five gallons per minute.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 5 years.[86]

DEEMED MEASURE COST

When available, the actual cost of the measure should be used. If unknown, a default value of $92.90[87] may be assumed.

LOADSHAPE

Water Heating BUS

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[85] Verification measurements taken at 195 installations showed average pre flowrates of 2.23 gallons per minute. IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report", Feb 2007)

[86]Consistent with Ameren Missouri and KCPL TRM assumptions.

[87]Average of costs recognized by Ameren Missouri ($85.8) and KCPL ($100).

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS (NOTE WATER SAVINGS MUST FIRST BE CALCULATED)

$\Delta kWH = \Delta Gallons * 8.33 * 1 * (Tout - Tin) * (1/EFF\_Elec) /3,413$

Where:

ΔGallons = amount of water saved as calculated below in Water Impact Calculation

8.33 = specific mass in pounds of one gallon of water (lbm/gal)

1 = Specific heat of water: 1 Btu/lbm/°F

Tout = Water Heater Outlet Water Temperature

= custom, otherwise assume Tin + 70°F temperature rise from Tin[88]

Tin = Inlet Water Temperature

= custom, otherwise assume 57.9F [89]

EFF_Elec = Efficiency of electric water heater supplying hot water to pre-rinse spray valve

=custom, otherwise assume 97%[90]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Electric energy savings, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001998949[91]

NATURAL GAS ENERGY SAVINGS

$\Delta Therms = \Delta Gallons * 8.33 * 1 * (Tout - Tin) * (1/EFF\_Gas) /100,000$

Where (new variables only):

EFF_Gas = Efficiency of gas water heater supplying hot water to pre-rinse spray valve

= custom, otherwise assume 80%[92]

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88 If unknown, assume a 70 degree temperature rise from Tin per Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies

89 Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061

90 This efficiency value is based on IECC 2012/2015 performance requirement for electric resistant water heaters rounded without the slight adjustment allowing for reduction based on size of storage tank.

91 2016 Ameren Missouri Coincident Peak Demand Factor for Commercial Electric Cooking. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

92 IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

WATER IMPACT CALCULATION

$$\Delta Gallons = (FLObase - FLOeff) * 60 * HOURSday * DAYSyear$$

Where:

FLObase = Base case flow in gallons per minute (Gal/min). Use actual when appropriate if available, otherwise assume:

Time of Sale	Retrofit, Direct Install
1.6 gal/min[93]	2.23 gal/min[94]

FLOeff = Efficient case flow in gallons per minute (Gal/min). Use actual flow rate of installed equipment if known, otherwise assume:

Time of Sale	Retrofit, Direct Install
1.06 gal/min[95]	1.06 gal/min[96]

60 = Minutes per hour

HOURSday = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise[97]:

Application	Hours/day
Small, quick- service restaurants	1
Medium-sized casual dining restaurants	1.5
Large institutional establishments with cafeteria	3

DAYSyear = Days per year pre-rinse spray valve is used at the site, custom, otherwise 312 days/yr based on assumed 6 days/wk x 52 wk/yr = 312 day/yr.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

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[93] The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. www1.eere.energy.gov/femp/pdfs/spec_prerinsesprayvavles.pdf.

[94] Verification measurements taken at 195 installations showed average pre flowrates of 2.23 gallons per minute. IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) (“CUWCC Report”, Feb 2007)

[95] 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

[96] 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

[97] Hours primarily based on PG& E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves.

2.3 Hot Water End Use

2.3.1 Water Heater

DESCRIPTION

This measure applies to the purchase and installation of a new gas-fired storage or tankless water heater meeting program efficiency requirements in place of a unit meeting minimum federal standards, in a commercial building.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new gas-fired storage or tankless water heater meeting program efficiency requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a new, gas-fired storage or tankless water heater meeting the minimum federal efficiency standards.[98]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years for a gas storage water heater and 20 years for a gas tankless water heater.[99]

DEEMED MEASURE COST

The full install cost and incremental capital cost for this measure is dependent on the type of water heater, as listed below.[100] Actual costs should be used where available.

Equipment Type	Category	Full Install Cost	Incremental Cost
Gas Storage Water Heaters ≤ 75,000 Btu/hr, ≥20 gal and ≤55 gal	Baseline	$799	N/A
	Efficient	$1,055	$256
Gas Storage Water Heaters > 75,000 Btu/hr	0.80 Et	$4,886	N/A
	0.83 Et	$5,106	$220
	0.84 Et	$5,299	$413
	0.85 Et	$5,415	$529
	0.86 Et	$5,532	$646
	0.87 Et	$5,648	$762
	0.88 Et	$5,765	$879
	0.89 Et	$5,882	$996
	0.90 Et	$6,021	$1,135
	Baseline	$593	N/A

[98] Federal standards for ≤75,000 Btu/hr storage water heaters and <200,000 Btu/hr tankless water heaters are from 10 CFR §430.32(d). All other standards are from 10 CFR §431.110.
[99] Database for Energy-Efficiency Resources (DEER), "DEER2014 EUL Table Update," California Public Utilities Commission, February 4, 2014. Lifetime for gas storage heaters is average of lifetimes for commercial and residential storage water heaters.
[100] Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I_August2016.xls" for more information.

Equipment Type	Category	Full Install Cost	Incremental Cost
Gas Tankless Water Heaters >50,000 Btu/hr and <200,000 Btu/hr	Efficient	$1,103	$510
Gas Tankless Water Heaters ≥200,000 Btu/hr	Baseline	$1,148	N/A
	Efficient	$1,427	$278

LOADSHAPE

Water Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = (1/EF_{Base} - 1/EF_{EE}) * (HotWaterUse_{Gallon} * \gamma Water * (T_{Out} - T_{In}) * 1.0)/100{,}000$$

Where:

EF_{Base} = Efficiency of baseline water heater according to federal standards, expressed as Energy Factor (EF) or Thermal Efficiency (E_t)

= See table below

Equipment Type	Size Category	Federal Standard Minimum Efficiency
Gas Storage Water Heaters ≤ 75,000 Btu/hr	≥20 gal and ≤55 gal	0.675 – (0.0015 * Rated Storage Volume in Gallons)
	>55 gal and ≤100 gal	0.8012 – (0.00078 * Rated Storage Volume in Gallons)
Gas Storage Water Heaters > 75,000 Btu/hr	< 4000 Btu/h/gal	80% E_t Standby Loss: (Q/800 + 110√V)
Gas Tankless Water Heaters >50,000 Btu/hr and <200,000 Btu/hr	< 4000 Btu/h/gal and <2 gal tank	0.82 – (0.0019 * Rated Storage Volume in Gallons)
Gas Tankless Water Heaters ≥200,000 Btu/hr	≥ 4000 Btu/h/gal and <10 gal tank	80% E_t
Gas Tankless Water Heaters ≥200,000 Btu/hr	≥ 4000 Btu/h/gal and ≥10 gal tank	80% E_t Standby Loss: (Q/800 + 110√V)

EF_{EE} = EF of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (E_t)

= Actual

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per water heater capacity

   = Consumption/cap * Capacity

   Where:

   Consumption/cap = Estimate of consumption per gallon of tank capacity, dependent on building type:[101]

Building Type	Consumption/cap
Grocery, Convenience Store, and Restaurant	803
Lodging, Hospital, and Multifamily	630
Health Clinic, Church, Warehouse	433
Education, Office, and Retail	594
Industrial	558
Agriculture	558
Average Non Residential	558

   Capacity = Capacity of hot water heater in gallons

   = Actual[102]

2. Consumption by facility size[103]

Building Type	Gallons hot water per unit per day	Unit	Units/1000 ft^2	Days per year	Gallons/1000 ft^2 floor area
Small Office	1	person	2.3	250	575
Large Office	1	person	2.3	250	575
Fast Food Rest	0.7	meal/day	784.6	365	200,458
Sit-Down Rest	2.4	meal/day	340	365	297,840
Retail	2	employee	1	365	730
Grocery	2	employee	1.1	365	803
Warehouse	2	employee	0.5	250	250

[101] Based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2003) consumption data for West North Central (removed outliers of 1,000 kBtu/hr or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and “Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting,” Lawrence Berkeley National Library, December 1995. VEIC considers these values to be relatively conservative estimates that may benefit from future evaluation.

[102] If the replaced unit is a tankless water heater, an estimate of the required storage tank capacity for the application is required.

[103] Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting,” Lawrence Berkeley National Library, December 1995.

Building Type	Gallons hot water per unit per day	Unit	Units/1000 ft^2	Days per year	Gallons/1000 ft^2 floor area
Elementary School	0.6	person	9.5	200	1,140
Jr High/High School	1.8	person	9.5	200	3,420
Health	90	patient	3.8	365	124,830
Motel	20	room	5	365	36,500
Hotel	14	room	2.2	365	11,242
Other	1	employee	0.7	250	175

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{Out} = Unmixed tank outlet water temperature

= custom, otherwise assume 125°F [104]

T_{In} = Incoming water temperature from well or municipal system

= 57.898°F[105]

1.0 = Heat capacity of water (1 Btu/lb*°F)

100,000 = Conversion factor from Btu to therms

Additional Standby Loss Savings

Gas storage water heaters with an input rating >75,000 Btu/hr and gas tankless water heaters with an input rating ≥200,000 Btu/hr and storage capacity ≥10 gallons can claim additional savings due to lower standby losses.

$$\Delta Therms_{Standby} = \frac{(SL_{base} - SL_{eff}) * 8{,}766}{100{,}000}$$

Where:

SL_{base} = Standby loss of baseline water heater

$= Q/800 + 110\sqrt{V}$

Where

Q =Nameplate input rating in Btu/hr

V = Rated volume in gallons

SL_{eff} = Nameplate standby loss of new water heater, in BTU/hr

8,766 = Hours per year

[104] Ideally, the actual set point of the water heater should be used. If not available, 125 degrees is provided as an estimate of unmixed output temperature. While plumbing code generally limits temperatures at the end use, it typically does not limit the water heater system, which can be anywhere in the range 120 -201 degrees. For applications such as laundry and dishwashing, health and safety regulations may require water to be initially heated to higher temperatures. Since temperature setpoints can vary widely, market, program, or site-specific data should be used whenever possible.

[105] Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.3.2 Low Flow Faucet Aerator

DESCRIPTION

This measure relates to the direct installation of a low flow faucet aerator in a commercial building. Expected applications include small business, office, restaurant, or motel. For multifamily or senior housing, the residential low flow faucet aerator should be used.

This measure was developed to be applicable to the following program types, DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an energy efficient faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.25 GPM or more, or a standard kitchen faucet aerator rated at 2.75 GPM or more.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 9 years.[106]

DEEMED MEASURE COST

The incremental cost for this measure is $8[107] or program actual

LOADSHAPE

Water Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[108].

ΔkWh = %ElectricDHW * ((GPM_base - GPM_low)/GPM_base) * Usage * EPG_electric * ISR

Where:

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[106] Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf"

[107] Direct-install price per faucet assumes cost of aerator and install time. (2011, Market research average of $3 and assess and install time of $5 (20min @ $15/hr)

[108] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture. Due to the distribution of water consumption by fixture type, as well as the different number of fixtures in a building, several variables must be incorporated.

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	43%[109]

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used"

= 1.2[110] or custom based on metering studies[111]

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used"

= 0.94[112] or custom based on metering studies[113]

Usage = Estimated usage of mixed water (mixture of hot water from water heater line and cold water line) per faucet (gallons per year)

= If data is available to provide a reasonable custom estimate it should be used, if not use the following defaults (or substitute custom information in to the calculation):

Building Type	Gallons hot water per unit per day[114] (A)	Unit	Estimated % hot water from Faucets[115] (B)	Multiplier[116] (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Small Office	1	person	100%	10	employees per faucet	250	2,500
Large Office	1	person	100%	45	employees per faucet	250	11,250
Fast Food Rest	0.7	meal/day	50%	75	meals per faucet	365	9,581

---

109 Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region, see 'HC8.9 Water Heating in Midwest Region.xls'. If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

110 Representative baseline flow rate for kitchen and bathroom faucet aerators from sources 1, 2, 3, and 4. This accounts for all throttling and differences from rated flow rates. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use.

111 Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

112 Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 1, 2, 3, and 4. This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

113 Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

114 Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications.

115 Estimated based on data provided in Appendix E; "Waste Not, Want Not: The Potential for Urban Water Conservation in California"; http://www.pacinst.org/reports/urban_usage/appendix_e.pdf

116 Based on review of the Illinois plumbing code (Employees and students per faucet). Retail, grocery, warehouse and health are estimates. Meals per faucet estimated as 4 bathroom and 3 kitchen faucets and average meals per day of 250 (based on California study above) – 250/7 = 36. Fast food assumption estimated.

Building Type	Gallons hot water per unit per day[114] (A)	Unit	Estimated % hot water from Faucets[115] (B)	Multiplier[116] (C)	Unit	Days per year (D)	Annual gallons mixed water per faucet (A*B*C*D)
Sit-Down Rest	2.4	meal/day	50%	36	meals per faucet	365	15,768
Retail	2	employee	100%	5	employees per faucet	365	3,650
Grocery	2	employee	100%	5	employees per faucet	365	3,650
Warehouse	2	employee	100%	5	employees per faucet	250	2,500
Elementary School	0.6	person	50%	50	students per faucet	200	3,000
Jr High/High School	1.8	person	50%	50	students per faucet	200	9,000
Health	90	patient	25%	2	Patients per faucet	365	16,425
Motel	20	room	25%	1	faucet per room	365	1,825
Hotel	14	room	25%	1	faucet per room	365	1,278
Other	1	employee	100%	20	employees per faucet	250	5,000

EPG_electric = Energy per gallon of mixed water used by faucet (electric water heater)

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (90 – 57.9)) / (0.98 * 3412)

= 0.0800 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-F)

WaterTemp = Assumed temperature of mixed water

= 90F [117]

SupplyTemp = Assumed temperature of water entering building

= 57.9F [118]

RE_electric = Recovery efficiency of electric water heater

= 98% [119]

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators

=Assumed to be 1.0

[117] Temperature cited from SBW Consulting, Evaluation for the Bonneville Power Authority, 1994, http://www.bpa.gov/energy/n/reports/evaluation/residential/faucet_aerator.cfm. This is a variable that would benefit from further evaluation.

[118] Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061

[119] Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

ΔkWh = calculated value above on a per faucet basis

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001811545

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

ΔTherms = %FossilDHW * ((GPM_base - GPM_low)/GPM_base) * Usage * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by fossil fuel heating

DHW fuel	%Fossil_DHW
Electric	0%
Fossil Fuel	100%
Unknown	57%[120]

EPG_gas = Energy per gallon of mixed water used by faucet (gas water heater)

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00772 Therm/gal

Where:

RE_gas = Recovery efficiency of gas water heater

` = 67%[121]

100,000 = Converts Btus to Therms (Btu/Therm)

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

Δgallons = ((GPM_base - GPM_low)/GPM_base) * Usage * ISR

Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[120] Default assumption for unknown fuel is based on EIA Commercial Building Energy Consumption Survey (CBECS) 2012 for Midwest North Central Region, see 'HC8.9 Water Heating in Midwest Region.xls'. If utilities have specific evaluation results providing a more appropriate assumption for buildings in a particular market or geographical area, then they should be used.

[121] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

SOURCES USED FOR GPM ASSUMPTIONS

Source ID	Reference
1	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
2	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
3	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
4	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.

2.3.3 Circulator Pump

DESCRIPTION

Demand control recirculation pumps seek to reduce inefficiency by combining control via temperature and demand inputs, whereby the controller will not activate the recirculation pump unless both (a) the recirculation loop return water has dropped below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

This measure was developed to be applicable to the following program types: TOS, RF, NC. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Re-circulating pump shall cycle on based on (a) the recirculation loop return water dropping below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure category is an existing, un-controlled recirculation pump on a gas-fired Central Domestic Hot Water System.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The effective useful life is 15 years[122].

DEEMED MEASURE COST

The assumed measure cost is $1,200 per pump[123].

LOADSHAPE

Miscellaneous BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

Savings shown are per pump.

ELECTRIC ENERGY SAVINGS

Deemed at 651 kWh[124].

[122] Benningfield Group. (2009). *PY 2009 Monitoring Report: Demand Control for Multifamily Central Domestic Hot Water.* Folsom, CA: Prepared for Southern California Gas Company, October 30, 2009.

[123] Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report.* Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

[124] Based on results from the Nicor Gas Emerging Technology Program study, this value is the average kWh saved per pump. Note this value does not reflect savings from electric units but electrical savings from gas-fired units.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Summer coincident peak demand savings are expected to be negligible.

NATURAL GAS SAVINGS

ΔTherms = 55.9 * number of dwelling units[125]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

125 Based on results from the Nicor Gas Emerging Technology Program study, this value is the average therms saved per dwelling unit.

2.4 HVAC End Use

Table: Effective Full Load Heating and Cooling Hours, by building type.

	Whiteman AFB (Avg)		Lincoln, NE (NW)		Fort Madison, IA (NE)		Kaiser (SW)		Cape Girardeau (SE)		St Louis		Kansas City	
Building Type	**Heating EFLH**	**Cooling EFLH**	**Heating EFLH**	**Cooling EFLH**	**Heating EFLH**	**Cooling EFLH**	**Heating EFLH**	**Cooling EFLH**	**Heating EFLH**	**Cooling EFLH**	**Heating EFLH**	**Cooling EFLH**	**Heating EFLH**	**Cooling EFLH**
Large Office	1039	1846	1141	1756	1088	1539	997	1918	861	1784	988	1869	1056	1792
Medium Office	649	1350	740	1245	728	1146	567	1412	528	1323	645	1386	708	1325
Small Office	946	1114	1030	1041	1029	975	926	1165	769	1082	893	1159	989	1097
Warehouse	991	415	1201	380	1227	357	1189	457	851	391	1059	433	1207	400
Stand-alone Retail	1012	1000	1125	903	1139	808	968	1076	891	965	994	986	1036	946
Strip Mall	1030	970	1124	884	1148	794	984	1044	905	944	1001	956	1039	916
Primary School	806	1019	892	958	898	852	798	1155	666	1016	785	1195	840	971
Secondary School	719	812	803	724	867	677	754	911	603	800	712	873	779	779
Supermarket	1279	875	1367	800	1405	672	1330	902	1120	837	1248	846	1344	820
Quick Service Restaurant	1233	1013	1414	916	1513	819	1316	1127	1025	973	1262	1035	1387	970
Full Service Restaurant	1367	1119	1499	1014	1655	952	1442	1234	1156	1114	1380	1124	1473	1059
Hospital	3388	3318	3205	3055	3467	2733	3891	3448	2913	3312	3170	3413	3372	3215
Outpatient Health Care	3203	3113	3261	2834	3150	2627	3128	3217	3001	3109	3013	3265	3164	2994
Small Hotel - Building	602	2247	697	2097	760	1914	620	2386	436	2304	575	2277	669	2207
Large Hotel - Building	1656	2148	1472	2016	1980	1916	1943	2369	1202	2186	1551	2363	1692	2155
Midrise Apartment - Building	1462	1132	1599	1028	1710	901	1590	1214	1208	1085	1433	1171	1580	1090
C&I Average[126]	1067	1018	1196	937	1217	865	1118	1085	910	996	1060	1053	1164	986

[126] See Volume 1 for details on modeling calculations and assumptions.cek

Schedule LMW-D5

2.4.1 Boiler

DESCRIPTION

This measure applies to the installation of a high-efficiency, gas-fired steam or hot water boiler in a commercial or multifamily space. High-efficiency boilers achieve gas savings through the use of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained.

This measure was developed to be applicable to the following program type: TOS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new boiler that is used 80% or more for space heating instead of process heating. Boiler annual fuel utilization efficiency (AFUE), thermal efficiency (E_T), or combustion efficiency (E_C) ratings must meet the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new boiler with an AFUE, E_T, or E_C rating that meets minimum federal energy efficiency standards.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 26.5 years for hot water gas-fired boilers and 23.6 years for steam gas-fired boilers.[127]

DEEMED MEASURE COST

The incremental capital cost for this measure depends on boiler type (hot water or steam), capacity, and efficiency, as listed in the table below.[128]

Incremental Costs for Hot Water Boilers		
Boiler Capacity	Efficiency	Incremental Equipment Cost (Per Unit)
<300,000 Btu/hr	83% AFUE	$16
	84% AFUE	$31
	85% AFUE	$187
	90% AFUE	$776
	92% AFUE	$1,126
	96% AFUE	$3,899
≥300,000 & ≤2,500,000 Btu/hr	81% E_T	$856
	82% E_T	$1,779

[127] Average lifetime from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. U.S. Department of Energy, December 22, 2015.

[128] For boilers with input <300,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. U.S. Department of Energy, December 22, 2015. For boilers ≥300,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers. U.S. Department of Energy, March 4, 2016.

Incremental Costs for Hot Water Boilers		
Boiler Capacity	**Efficiency**	**Incremental Equipment Cost (Per Unit)**
	84% E_T	$4,261
	85% E_T	$5,532
	93% E_T	$15,788
	95% E_T	$16,529
	99% E_T	$22,036
>2,500,000 Btu/hr	83% E_C	$5,467
	84% E_C	$11,967
	85% E_C	$19,040
	94% E_C	$73,087
	97% E_C	$82,242

Incremental Costs for Steam Boilers		
Boiler Capacity	**Efficiency Category**	**Incremental Equipment Cost (Per Unit)**
<300,000 Btu/hr	82% AFUE	$40
	83% AFUE	$319
≥300,000 & ≤2,500,000 Btu/hr	78% E_T	$790
	79% E_T	$1,644
	80% E_T	$2,567
	81% E_T	$3,565
	83% E_T	$5,810
>2,500,000 Btu/hr	78% E_T	$2,371
	79% E_T	$4,878
	80% E_T	$7,529
	81% E_T	$10,332
	82% E_T	$13,296
	84% E_T	$19,743

LOADSHAPE

Heating BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{EFF_{EE} - EFF_{Base}}{EFF_{Base}}\right)}{100{,}000}$$

Where:

EFLH = Equivalent full load hours for heating

= See table at the beginning of section 2.4 HVAC End Use. A custom value may also be used.

Capacity = Nominal heating input capacity (Btu/hr) of efficient boiler

= Actual

EFF_{EE} =Efficiency rating of high efficiency boiler

= Actual

EFF_{Base} = Efficiency rating of baseline boiler

= See tables below.[129] Baseline efficiency depends on boiler type (hot water or steam) and capacity.

Federal Standards for Hot Water Boilers	
Boiler Capacity	**Efficiency Rating**
<300,000 Btu/hr	82% AFUE
≥300,000 & ≤2,500,000 Btu/hr	80% E_T
>2,500,000 Btu/hr	82% E_c

Federal Standards for Steam Boilers	
Boiler Capacity	**Efficiency Rating**
<300,000 Btu/hr	80% AFUE
All except natural draft ≥300,000 & ≤2,500,000 Btu/hr	79% E_T
Natural draft ≥300,000 & ≤2,500,000 Btu/hr	77% E_T
All except natural draft >2,500,000 Btu/hr	79% E_T
Natural draft >2,500,000 Btu/hr	77% E_T

100,000 = Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[129] For boilers with input <300,000 Btu/hr, efficiency standards are from 10 CFR 431.87. For boilers ≥300,000 Btu/hr, efficiency standards are from 10 CFR 430.32.

2.4.2 Boiler Averaging Controls

DESCRIPTION

Also known as "ALM" or Advanced Load Monitoring controls, this measure derives energy savings by dynamically managing boiler operation through use of a microprocessor controller augmenting existing boiler controls. The ALM monitors and records boiler cycling data including water temperature data that reduces the boiler from firing for a period of time to limit cycling losses during perceived low-load conditions. The ALM controller works with hydronic heating systems with "primary/secondary" or single loop piping arrangements by monitoring primary loop temperatures. When the boiler aquastat calls for heat, the ALM controller may delay this firing by up to 15 minutes depending on temperature data. The ALM controller does not activate a standby boiler, nor does it stop a firing boiler. Rather, it limits cycling losses by temporarily and dynamically lowering the boiler firing temperature resulting in lengthening of boiler firing times or lengthening time between firing cycles. Savings are proportional to the boiler's oversizing and configuration of the building distribution system. The ALM is compatible with existing controls including multistage/modulating combustion and existing OTR. Features such as envelope and pipe insulation improvements may increase the savings potential. At this time, ALM controllers are not compatible with central steam boilers because they monitor temperatures only, with no pressure data collected by the unit.[130]

This measure was developed to be applicable to the following program types: RF.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler(s) must be retrofitted to incorporate an ALM control system.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a hot water boiler system without ALM controls.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 20 years.[131]

DEEMED MEASURE COST

As a retrofit measure, the actual installed cost should be used for screening purposes. If unknown, a cost of $7,700[132] can be used for screening purposes.

LOADSHAPE

Heating BUS

[130] Description as well as definition of baseline equipment sourced by a manufacturer of ALM device.
[131] The Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.
[132] Building America Case Study: Advanced boiler Load Monitoring Controllers, Chicago, Illinois (Fact Sheet), Technology Solutions for New and Existing Homes, Energy Efficiency & Renewable Energy (EERE)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = B_{input} * SF * EFLH_{heating} /(100,000)$$

Where:

B_{input}	= Boiler Input Capacity (Btu/hr)
	= actual input capacity of existing boiler
SF	= Savings factor
	= 10%[133] or custom input if it can be substantiated
$EFLH_{heating}$	= See table at the beginning of section 2.4 HVAC End Use. A custom value may also be used.
100,000	= conversion from Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[133] Field Test of Boiler Primary Loop Controller, U.S. DOE Building Technology Office, Energy Efficiency & Renewable Energy, September 2014. Of the case studies presented, the lowest annualized savings was chosen as a default savings factor to acknowledge that ALM controllers are an emerging technology with limited research. Savings are anticipated to be proportional with how much boilers are oversized, but additional research and evaluation is needed to confirm this relationship.

2.4.3 Boiler Lockout/Reset Controls

DESCRIPTION

This measure relates to improving combustion efficiency by adding controls to non-residential building space heating hot water boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. Energy is saved by increasing the temperature difference between the water temperature entering the boiler in the boiler's heat exchanger and the boiler's burner flame temperature. The flame temperature remains the same while the water temperature leaving the boiler decreases with the decrease in heating load due to an increase in outside air temperature. A lockout temperature is also set to prevent the boiler from turning on when it is above a certain temperature outdoors.

This measure was developed to be applicable to the following program types: Retrofit. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Natural gas customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse linear fashion with outdoor air temperature. Boiler lockout temperatures should be set at this time as well, to turn the boiler off when the temperature goes above an appropriate setpoint.

DEFINITION OF BASELINE EQUIPMENT

Existing hot water boiler without boiler reset controls, any size with constant hot water flow.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 20 years[134]

DEEMED MEASURE COST

The cost of this measure is $612[135]

LOADSHAPE

Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[134]CLEAResult references the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.
[135] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = B_{input} * SF * EFLH_{heating} /(100,000)$$

Where:

B_{input} = Boiler Input Capacity (Btu/hr)

= actual input capacity of existing boiler

SF = Savings factor

= 8%[136] or custom

$EFLH_{heating}$ = See table at the beginning of section 2.4 HVAC End Use. A custom value may also be used.

100,000 = conversion from Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[136] Savings factor is the estimate of annual gas consumption that is saved due to adding boiler reset controls. The CLEAResult uses a boiler tuneup savings value derived from Xcel Energy "DSM Biennial Plan-Technical Assumptions," Colorado. Focus on Energy uses 8%, citing multiple sources. Vermont Energy Investment Corporation's boiler reset savings estimates for custom projects further indicate 8% savings estimate is better reflection of actual expected savings.

2.4.4 High Temperature Heating & Ventilating (HTHV) Direct Fired Heater

DESCRIPTION

High Temperature Heating & Ventilating (HTHV) Direct Fired Heaters are a newly classified technology class of products that are capable of providing heating, ventilation and de-stratification solutions for commercial and industrial applications. Using high pressure blowers, HTHV heaters draw 100% outside air, combust fuel in the airstream, and then direct the heated air at high velocities into the space. With air-fuel ratios typically 50 times the stoichiometric requirement, complete combustion results in emissions that consist primarily of water vapor and carbon dioxide.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

A 100% Outside Air, non-recirculating direct-fired gas heater capable of greater than 140 degree temperature rise and greater than 150 degree discharge temperature, with fully modulating temperature controls to meet both ventilation and space heating requirements. To qualify for this measure the installed equipment must be a HTHV direct fired natural gas heater.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard indirect-fired unit natural gas heater. Additionally, the HTHV heater is assumed to replace a separate make-up air unit that would have been required to meet space ventilation requirements.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[137]

DEEMED MEASURE COST

The incremental capital cost for this measure,[138] based on rated input capacity, is assumed to be $0.007428 / Btu/hr.

LOADSHAPE

Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A. Although HTHV heaters require more powerful supply fans than a traditional indirect-fired baseline unit and consequently consume more electricity, this measure assumes that the HTHV heater also replaces the need for a separate make-up air unit that would require fan energy that is assumed to equal that of the HTHV unit. Thus, no electric impact is assumed.

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[137] Measure life based upon service records of a HTHV manufacturer for comparable condensing unit heaters.

[138] Calculated from incremental costs outlined in DOE publication "Field Demonstration of High-Efficiency Gas Heaters," October 2014.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = H_{input} * SF * EFLH_{heating} /(100{,}000)$$

Where:

H_{input} = Infrared Heater Input Capacity (Btu/hr)

= actual input capacity of incentived unit

SF = Savings factor

= 15%[139] or custom input if it can be substantiated

$EFLH_{heating}$ = See table at the beginning of section 2.4 HVAC End Use. A custom value may also be used.

100,000 = conversion from Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[139] Savings factor is the resultant of (0.92/0.8) – 1 = 0.15; where 0.92 is the efficiency of the HTHV heater, taken to be 0.92 which represents the LHV of natural gas, appropriate for direct firing applications; and 0.8 is the efficiency of the baseline unit heater, as per DOE Commercial Warm Air Furnace Standard DOE 10 CFR, Part 431.

2.4.5 High Turndown Burner for Spacing Heating Boilers

DESCRIPTION

This measure applies to the retrofit of non-residential, boilers equipped with burners that have a turndown higher than 10:1. Turndown is the ratio of the high firing rate to the low firing rate. When boilers are subjected to loads below the low firing rate, the boiler must cycle on/off to meet load requirements. A higher turndown ratio reduces burner startups, provides better load control, saves wear-and-tear on the burner, and reduces purge-air requirements, resulting in a higher overall energy efficiency. The default values provided by the following algorithm assume that boiler(s) are used predominantly for space heating. Custom inputs should be derived for instances where they supply process heating.

This measure was developed to be applicable to the following program type: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the efficient equipment must be a non-residential boiler with a burner turndown higher than 10:1.[140]

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a non-residential boiler with a burner turndown of 6:1[141] or lower.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[142]

DEEMED MEASURE COST

The deemed installed measure cost including labor is approximately $3,800/MMBtu/hr.[143]

LOADSHAPE

Heating BUS

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

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140 Safe turndown for high-performance gas-fired boilers from Understanding Fuel Savings in the Boiler Room. ASHRAE, December 2008.

141 Typical turndown for gas-fired boilers from Understanding Fuel Savings in the Boiler Room. ASHRAE, December 2008.

142 Measure life from the 2013-2015 Triennial Plan for the Minnesota Electric and Natural Gas Conservation Improvement Program. Xcel Energy, June 2, 2012.

143 Average of capital costs for burner repair/upgrade from Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers. EPA Office of Air and Radiation, October 2010.

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{EFLH * Capacity * \%Save}{100{,}000}$$

Where:

EFLH = Equivalent full load hours for heating

= See table at the beginning of section 2.4 HVAC End Use. A custom value may also be used.

Capacity = Nominal heating input capacity (Btu/hr) of existing boiler

= Actual

%Save = Reduction in gas consumption (%) as a result of high turndown burner installation

= Custom or if unknown, assume 4%[144]

100,000 = Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[144] Average of savings assumptions for burner repair/upgrade from Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers. EPA Office of Air and Radiation, October 2010 and for modulating burners from 2013-2015 Triennial Plan for the Minnesota Electric and Natural Gas Conservation Improvement Program. Xcel Energy, June 2, 2012.

2.4.6 Infrared Heaters

DESCRIPTION

This measure applies to natural gas fired low-intensity infrared heaters with an electric ignition. This measure includes replacement of failed or working standard indirect-fired heating systems within existing commercial and industrial buildings with natural gas fired infrared heaters, as well as installation of infrared heaters in new buildings. Low-intensity heaters have an enclosed flame. When heat is called for, the air/fuel mixture is combusted in a burner control box and the hot gases are forced through steel radiant tubing by an internal blower. The hot gasses heat the tubing assembly, which emit a portion of the energy as infrared energy. This infrared energy is directed toward the floor by highly polished reflectors that sit atop the tubing assembly. Infrared energy is absorbed by the floor, machinery, or anything else in its path, which in turn re-radiate this heat to create a comfort zone at the floor level.

This measure was developed to be applicable to the following program types: Time of Sale, New Construction. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a low-intensity infrared natural gas heater with an electric ignition.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard indirect-fired unit natural gas heater.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[145]

DEEMED MEASURE COST

The incremental capital cost for this measure is as follows, based on size category[146]

Size Category	Incremental Cost
Up to 50,000 BTUh	$469.97
> 50,000 BTUh up to 150,000 BTUh	$421.74
> 150,000 BTUh up to 175,000 BTUh	$380.40
Greater than 175,000 BTUh	$352.84

LOADSHAPE

Heating BUS

COINCIDENCE FACTOR

N/A

[145]Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.
[146]Incremental Cost Study Phase Four Final Report, Northeast Energy Efficiency Partnerships, June 15, 2015

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = H_{input} * SF * EFLH_{heating} /(100{,}000)$$

Where:

H_{input} = Infrared Heater Input Capacity (Btu/hr)

= actual input capacity of incentived unit

SF = Savings factor

= 17.6%[147] or custom input if it can be substantiated

$EFLH_{heating}$ = Equivalent Full Load Hours for heating are provided in section HVAC End Use. A custom value may also be used.

100,000 = conversion from Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[147] Although infrared heaters do not achieve savings by delivering heat more efficiently (i.e., equipment efficiencies are similar to conventional baseline unit heaters), savings from less stratification as well as more "targeted" heating means that comfort can be achieved with a 15% reduction in heat load (Minimum load reduction cited in 2008 ASHRAE® HANDBOOK: Heating, Ventilating, and Air-Conditioning SYSTEMS AND EQUIPMENT, Inch-Pound Edition, Chapter 15, pg. 15.1, "Energy Conservation," 2008, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.). Accordingly, the savings factor is calculated as (1/0.85 – 1). Savings may be greater and are dependent on proper heater layout design.

2.4.7 Small Commercial Learning Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new Learning Thermostat for reduced cooling and heating energy consumption through temperature set-back during unoccupied or reduced demand times as well as automatic adjustments based on occupancy patterns and various independent variables such as weather. This measure is limited to small businesses as defined by programs[148], as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid- to large-sized businesses will typically have a building automation system or some other form of automated HVAC controls. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for learning thermostats installed in multi-zone systems.

This measure was developed to be applicable to the following program types: RF, DI, TOS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control with one that has the capability to adjust temperature set-points according to various independent variables without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change the temperature set-point.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a learning thermostat is assumed to be 10 years[149] based upon equipment life only[150].

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be $224[151].

LOADSHAPE

Cooling BUS

Heating BUS (only use this loadshape for gas savings)

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[148] The square footage of the small office prototype building modeled in is 7,500 sf.

[149] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

[150] Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer term impacts should be assessed.

[151] 2012Ameren Missouri Technical Resource Manual – Effective January 1, 2018.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{1}{eff} * EFLH_{COOL} * \frac{Btuh_{COOL}}{1000} * ESF_{COOL}$$

Where:

eff	= Efficiency of HVAC unit
	= Actual; If not available, assume 10 SEER
$EFLH_{COOL}$	= Effective Full Load Cooling Hours
	= Actual; If not available, refer to section 2.4 HVAC
$Btuh_{COOL}$	= Cooling System Capacity
	= Actual
ESF_{COOL}	= Cooling energy savings factor
	= Assume 0.139 [152]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = kWh * CF$$

Where:

kWh	= Electric energy savings, as calculated above
CF	= Summer peak coincidence demand (kW) to annual energy (kWh) factor
	= 0.0009106840

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{Sqft * Savings\ Factor * PF}{100 * AFUE(exist)}$$

Where:

Sqft	= square footage of building controlled by thermostat
AFUE (exist)	= efficiency rating of existing heating equipment (AFUE), in decimal form.
100	= converts kBtu to therms, 1 therm = 100 kBtu
Savings Factor	= 9.940 kBtu/sf-yr[153]

[152] Cadmus (Aarish, C., M. Perussi, A. Rietz, and D. Korn). *Evaluation of the 2013–2014 Programmable and Smart Thermostat Program.* Prepared for Northern Indiana Public Service Company and Vectren Corporation. 2015.

[153] Heating Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the prototype building (5,500 sf) and converted to kBtu.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.4.8 Small Commercial Programmable Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses as defined by programs[154], as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid- to large-sized businesses will typically have a building automation system or some other form of automated HVAC controls. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for programmable thermostats installed in multi-zone systems.

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control with one that has the capability to adjust temperature set-points according to a schedule without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change the temperature set-point.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 8 years[155] based upon equipment life only[156].

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown, the capital cost for this measure is assumed to be $181[157].

LOADSHAPE

Cooling BUS

Heating BUS

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[154] The square footage of the small office prototype building modeled in is 7,500 sf.

[155] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

[156] Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer term impacts should be assessed.

[157] Based upon Nicor, Illinois Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013. If Missouri average costs are available, they should be used.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{Sqft * \ Savings\ Factor * PF}{EER(exist)}$$

Where:

Sqft	= square footage of building controlled by thermostat
EER(exist)	= efficiency rating of existing cooling equipment EER (btu hr/W)
Savings Factor	= 0.578 kWh/sf-yr[158]
PF	= Persistence Factor to account for thermostat being placed on hold, reset or bypassed.
	= Actual if provided in program evaluation, else assume 50% [159]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{Sqft * Savings\ Factor * PF}{100 * AFUE(exist)}$$

Where:

Sqft	= square footage of building controlled by thermostat
AFUE (exist)	= efficiency rating of existing heating equipment (AFUE), in decimal form.
100	= converts kBtu to therms, 1 therm = 100 kBtu
Savings Factor	= 9.940 kBtu/sf-yr[160]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[158] Cooling Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the small office prototype building (5,500 sf).

[159] This factor is based on consideration of the findings from a number of evaluations, including Sachs et al, *"Field Evaluation of Programmable Thermostats",* US DOE Building Technologies Program, December 2012, p35; "low proportion of households that ended up using thermostat-enabled energy saving settings" http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/field_eval_thermostats.pdf%20, and Meier et al., *"Usability of residential thermostats: Preliminary investigations",* Lawrence Berkeley National Laboratory, March 2011, p1; "The majority of occupants operated thermostats manually, rather than relying on their programmable features and almost 90% of respondents reported that they rarely or never adjusted the thermostat to set a weekend or weekday program. Photographs of thermostats were collected in one on-line survey, which revealed that about 20% of the thermostats displayed the wrong time and that about 50% of the respondents set their programmable thermostats on "long term hold" (or its equivalent)." http://eec.ucdavis.edu/files/Usability_of_residential_thermostats.pdf

[160] Heating Savings Factors for the programmable thermostat are calculated as the savings in annual building load divided by the square footage of the prototype building (5,500 sf) and converted to kBtu.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.4.9 Steam Trap Replacement or Repair

DESCRIPTION

This measure applies to the repair or replacement of faulty steam traps on HVAC steam distribution systems. Faulty steam traps allow excess steam to escape, wasting the energy used to generate steam and increasing the amount of steam generated. The measure is applicable to steam systems in commercial, industrial, and multifamily buildings.

This measure was developed to be applicable to the following program type: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is a repaired, rebuilt, or replaced steam trap.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a faulty steam trap that needs to be repaired, rebuilt, or replaced as confirmed by a steam trap survey. No minimum leak rate is required.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 6 years[161]

DEEMED MEASURE COST

Measure cost depends on customer (commercial or industrial) and maximum steam system operating pressure (psig).

Steam System	Total Installed Cost (per Steam Trap)[162]
Commercial (all operating pressures)	$177
Industrial, ≤ 15 psig	$280
Industrial, > 15 ≤ 30 psig	$300
Industrial, > 30 ≤ 125 psig	$323
Industrial, > 125 ≤ 200 psig	$415
Industrial, > 200 ≤ 250 psig	$275
Industrial, > 250 psig	Custom

LOADSHAPE

Miscellaneous BUS

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[161] Measure life from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

[162] Steam trap costs from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011. Measure cost includes installation cost of $100 per trap, from Implement a Sustainable Steam-Trap Management Program, America Institute of Chemical Engineers, January 2014.

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = LeakRate \ x \ H_{vap} \ x \ Hours_{Heat} \ x \ \%Leak / \ EFF_{Heat} \ /100{,}000$$

Where:

LeakRate = Average steam loss rate (lb/hr) per leaking trap

= 24.24 x (P_{Inlet} + 14.7) x D^2 x %Adjust

Where:

24.24 = Constant from Napier's equation (lb/(hr-psia-in^2))

P_{Inlet} = Steam trap inlet pressure (psig)

= Actual

14.7 = Atmospheric pressure (psia)

D = Diameter of steam trap orifice (in)

= Actual

%Adjust = Adjustment factor (%) to reduce the maximum theoretical steam flow to the average steam flow

= 50%[163]

H_{vap} = Heat of vaporization of steam (Btu/lb)

= Use values from table below, based on steam trap inlet pressure (psig)[164]

P_{Inlet} (psig)	H_{vap} (Btu/lb)
2	966
5	960
10	952
15	945
20	939
25	934
30	929
40	926
50	912

163 Enbridge adjustment factor, from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.

164 Heat of vaporization values from Steam Tables, Power Plant Service, Inc.

P_{Inlet} (psig)	H_{vap} (Btu/lb)
60	905
70	898
80	892
90	886
100	880
110	875
120	871
125	868
130	866
140	862
150	857
160	853
180	845
200	834
225	829
250	820

$Hours_{Heat}$ = Custom entry, annual operating hours of steam plant

%Leak = Percentage of leaking or blow-through steam traps

= 1.0 when applied to the replacment of an individual leaking trap. If a number of steam traps are replaced and the system has not been audited, %Leak is applied to reflect the assumed percentage of steam traps that were actually leaking and in need of replacement. Use 27% for commerical customers and 16% for industrial customers.[165]

EFF_{Heat} = Boiler efficiency (%)

= Custom or if unknown assume 71.9% AFUE.[166]

100,000 = Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[165] % Leak values from Work Paper: Steam Traps Revision #1. Resource Solutions Group, August 2011.
[166] Average nameplate efficiencies of all existing boilers in Ameren, IL PY3-PY4 (2010-2012).

2.4.10 Demand Controlled Ventilation

DESCRIPTION

Demand control ventilation (DCV) automatically adjusts building ventilation rates based on occupancy. DCV is part of a building's ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building's ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (CO_2) sensor, occupancy sensor, or turnstile counter. This measure is modeled to assume night time set backs are in operation and minimum outside air is being used when the building is unoccupied.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by new CO_2 sensors installed on return air systems where no other sensors were previously installed. Additionally, commissioned control logic and installed hardware must be capable of reducing ventilation rates based on sensor input. For heating savings, this measure does not apply to any system with terminal reheat (constant volume or variable air volume). For terminal reheat system a custom savings calculation should be used.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure is a space with no demand control capability. The current code minimum for outside air (OA) is 17 CFM per occupant (ASHRAE 62.1) which is the value assumed in this measure.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 10 years.[167]

DEEMED MEASURE COST

As a retrofit measure, the actual cost of installation should be used for screening. Costs should include the hardware and labor costs to install the sensors. Additional purchase and installation costs for any other component of the DCV system that was not previously existing should also be included.

LOADSHAPE

Cooling BUS

Heating BUS (only use this loadshape for gas savings)

Algorithm

[167] Based on CO_2 sensor estimated life, determined through conversations with contractors to have a minimum lifetime of 10 years. It is recommended that they are part of a normal preventive maintenance program, as calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they can fall out of tolerance over time.

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas, cooling savings are:

$$\Delta kWh = SQFT_{cond}/1000 * SF_{cooling}$$

For facilities heated by heat pumps, heating and cooling savings are:

$$\Delta kWh = SQFT_{cond}/1000 * SF_{cooling} + SQFT_{cond}/1000 * SF_{Heat\ HP}$$

For facilities heated by electric resistance heating and cooling savings are:

$$\Delta kWh = SQFT_{cond}/1000 * SF_{cooling} + SQFT_{cond}/1000 * SF_{Heat\ ER}$$

Where:

$SQFT_{cond}$ = Square footage of conditioned space commissioned with DCV

$SF_{cooling}$ = Cooling Savings Factor, including cooling and fan energy savings

$SF_{Heat\ HP}$ = Heating Savings factor for facilities heated by Heat Pump (HP)

$SF_{Heat\ ER}$ = Heating Savings factor for facilities heated by Electric Resistance (ER)

All Savings Factors are based on building type and weather zone, as listed in the following tables:[168]

Building Type	$SF_{cooling}$ (kWh/1000 SqFt)						
	North East (Fort Madison, IA)	North West (Lincoln, NE)	South East (Cape Girardeau, MO)	South West (Kaiser, MO)	St Louis, MO	Kansas City, MO	Average/Unknown (Knob Noster, MO)
Office - Low-rise	475	533	535	634	649	555	579
Office - Mid-rise	448	502	504	597	611	523	545
Office - High-rise	468	525	527	624	639	547	570
Religious Building	567	635	639	756	774	662	690
Restaurant	561	629	632	748	765	655	683
Retail - Department Store	654	734	737	873	893	764	797
Retail - Strip Mall	399	447	449	532	544	466	486
Convenience Store	631	708	711	842	862	737	769
Elementary School	353	395	397	470	481	412	430
High School	340	382	384	454	465	398	415
College/University	442	495	498	589	603	516	538
Healthcare Clinic	384	431	433	513	525	449	468
lodging	605	679	682	808	827	707	738
Manufacturing	500	560	563	666	682	584	609
Special Assembly Auditorium	476	534	536	635	650	556	580

[168] Energy savings factors were calculated using weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given weather zone in Missouri. Original energy savings for DCV were developed for Illinois utilizing standards, inputs and approaches as set forth by ASHRAE 62.1and 90.1. These savings factors were then translated into Missouri-specific values using adjustment factors based on differences in heating and cooling degree hours. See DCV savings factors v1.xlsx for derivation.

Building Type	SF Heat HP (kWh/1000 SqFt)						
	North East (Fort Madison, IA)	North West (Lincoln, NE)	South East (Cape Girardeau, MO)	South West (Kaiser, MO)	St Louis, MO	Kansas City, MO	Average/Unknown (Knob Noster, MO)
Office - Low-rise	171	191	145	151	156	176	159
Office - Mid-rise	114	128	97	100	104	117	106
Office - High-rise	154	172	130	135	140	158	143
Religious Building	1,118	1,248	945	983	1,018	1,149	1,036
Restaurant	799	892	675	702	727	821	740
Retail - Department Store	277	310	234	244	252	285	257
Retail - Strip Mall	184	205	155	161	167	189	170
Convenience Store	134	150	114	118	122	138	125
Elementary School	475	531	402	418	433	488	440
High School	465	519	393	409	423	478	431
College/University	923	1,031	780	812	840	949	856
Healthcare Clinic	331	370	280	291	301	340	307
lodging	157	175	132	138	143	161	145
Manufacturing	122	136	103	107	111	125	113
Special Assembly Auditorium	1,335	1,490	1,128	1,173	1,215	1,371	1,236

Building Type	SF Heat ER (kWh/1000 SqFt)						
	North East (Fort Madison, IA)	North West (Lincoln, NE)	South East (Cape Girardeau, MO)	South West (Kaiser, MO)	St Louis, MO	Kansas City, MO	Average/Unknown (Knob Noster, MO)
Office - Low-rise	514	574	434	452	468	528	476
Office - Mid-rise	343	383	290	301	312	352	318
Office - High-rise	461	515	390	406	420	474	428
Religious Building	3,354	3,744	2,835	2,948	3,053	3,446	3,108
Restaurant	2,396	2,675	2,025	2,106	2,181	2,462	2,220
Retail - Department Store	832	929	703	731	757	855	771
Retail - Strip Mall	551	615	465	484	501	566	510
Convenience Store	403	450	341	354	367	414	374
Elementary School	1,426	1,592	1,205	1,253	1,298	1,465	1,321
High School	1,395	1,557	1,179	1,226	1,270	1,433	1,292
College/University	2,770	3,093	2,341	2,435	2,521	2,846	2,567
Healthcare Clinic	993	1,109	839	873	904	1,020	920
lodging	470	525	397	413	428	483	436
Manufacturing	365	408	309	321	332	375	338
Special Assembly Auditorium	4,004	4,470	3,384	3,519	3,644	4,114	3,709

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Energy savings from DCV occurs when occupancy levels are below design levels. Given that occupancy patterns may not always be predictable and the general expectation is that the coincident peak demand period will coincide with periods of highest occupancy, no peak demand savings should be assumed to result from this DCV measure. In instances where peak demand savings can be substantiated, a custom analysis should be used.

NATURAL GAS SAVINGS

$$\Delta Therms = SQFT_{cond}/1000 * SF_{Heat\ Gas}$$

Where:

$SF_{Heat\ Gas}$ = Savings factor for facilities heated by natural gas, as listed in the following table:

Building Type	$SF_{Heat\ Gas}$ (Therm/1000 sq ft)						
	North East (Fort Madison, IA)	North West (Lincoln, NE)	South East (Cape Girardeau, MO)	South West (Kaiser, MO)	St Louis, MO	Kansas City, MO	Average/Unknown (Knob Noster, MO)
Office - Low-rise	22	24	19	19	20	23	20
Office - Mid-rise	15	16	12	13	13	15	14
Office - High-rise	20	22	17	17	18	20	18
Religious Building	143	160	121	126	130	147	133
Restaurant	102	114	86	90	93	105	95
Retail - Department Store	35	40	30	31	32	36	33
Retail - Strip Mall	23	26	20	21	21	24	22
Convenience Store	17	19	15	15	16	18	16
Elementary School	61	68	51	53	55	62	56
High School	60	66	50	52	54	61	55
College/University	118	132	100	104	108	121	109
Healthcare Clinic	42	47	36	37	39	44	39
lodging	20	22	17	18	18	21	19
Manufacturing	16	17	13	14	14	16	14
Special Assembly Auditorium	171	191	144	150	155	175	158

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.4.11 Furnace

DESCRIPTION

This measure applies to the installation of a high-efficiency, gas furnace in a commercial or multifamily space. High-efficiency gas furnaces achieve savings through the use of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained.

This measure was developed to be applicable to the following program type: TOS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new furnace with an annual fuel utilization efficiency (AFUE) or thermal efficiency (E_T) rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new furnace with an AFUE or E_T rating that meets minimum federal energy efficiency standards.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 19 years.[169]

DEEMED MEASURE COST

The incremental capital cost for this measure depends on furnace efficiency and capacity, as listed in the table below.[170]

Furance Capacity	Efficiency	Incremental Equipment Cost (Per Unit)	Incremental Total Installed Cost (Per Unit)
<225,000 Btu/hr	90% AFUE	$163.16	$477.93
	92% AFUE	$179.19	$493.96
	95% AFUE	$313.45	$628.22
	98% AFUE	$505.76	$820.53
≥225,000 Btu/hr	92% E_T	$1,371.96	$1,752.75

LOADSHAPE

Heating BUS

169 Average of 15-year lifetime from Residential Heating and Cooling Systems Initiative Description. Consortium for Energy Efficiency, May 28, 2015 and 23-year lifetime from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces. U.S. Department of Energy, December 15, 2015.

170 For furnaces with input <225,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces. U.S. Department of Energy, February 10, 2015. For furnaces ≥225,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces. U.S. Department of Energy, December 15, 2015.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{EFF_{EE} - EFF_{Base}}{EFF_{Base}}\right)}{100{,}000}$$

Where:

EFLH	= Equivalent full load hours for heating
	= See table at the beginning of section 2.4 HVAC End Use. A custom value may also be used.
Capacity	= Nominal heating input capacity (Btu/hr) of efficient furnace
	= Actual
EFF_{EE}	= Efficiency rating of high efficiency furnace
	= Actual
EFF_{Base}	= Efficiency rating of baseline furnace
	= 80% AFUE for furnaces <225,000 Btu/hr[171] and 85% E_T for furnaces ≥225,000 Btu/hr[172]
100,000	= Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[171] Federal efficiency standard for furnaces <225,000 Btu/hr from 10 CFR 430.32 is 80% AFUE.
[172] Federal efficiency standard for furnaces ≥225,000 Btu/hr from 10 CFR 431.77 is 85% E_T.

2.4.12 Boiler/Furnace Tune-up

DESCRIPTION

This measure entails a tune-up for a natural gas boiler or furnace that provides space and/or process heating in a nonresidential application. The tune-up will improve boiler/furnace efficiency and verify safe operation through a culmination of service procedures. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The recommended actions the tune up technician should take are as follows:

Boiler:

- Measure combustion efficiency using an electronic flue gas analyzer.
- Adjust airflow and reduce excessive stack temperatures.
- Adjust burner and gas input, manual or motorized draft control.
- Check for proper venting.
- Complete visual inspection of system piping and insulation.
- Check safety controls.
- Check adequacy of combustion air intake.
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel.
- Verify boiler delta T is within system design limits.

Furnace:

- Measure combustion efficiency using an electronic flue gas analyzer.
- Check and clean blower assembly and components per manufacturer's recommendations.
- Where applicable, lubricate motor and inspect and replace fan belt if required.
- Inspect for gas leaks.

- Clean burner per manufacturer's recommendations and adjust as needed.
- Check ignition system and safety systems and clean and adjust as needed.
- Check and clean heat exchanger per manufacturer's recommendations.
- Inspect exhaust/flue for proper attachment and operation.
- Inspect control box, wiring, and controls for proper connections and performance.
- Check air filter and clean or replace per manufacturer's recommendations.
- Inspect duct work connected to furnace for leaks or blockages.
- Measure temperature rise and adjust flow as needed.
- Check for correct line and load volts/amps.
- Check that thermostat operation is per manufacturer's recommendations.
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits.
- Check and adjust gas input.
- Check high limit and other safety controls.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a boiler or furnace that has not had a tune-up in the past 24 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Measure life is considered to be two years, although annual tune-ups are generally a recommended best-practice.

DEEMED MEASURE COST

The cost of this measure is the actual tune up cost, which can vary based on the extent of the service required.

LOADSHAPE

Heating BUS

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{(Eff_{pre} + E_i)}{Eff_{pre}} - 1\right)}{100{,}000}$$

Where:

EFLH = Equivalent full load hours for heating

	= See table at the beginning of section 2.4 HVAC End Use. A custom value may also be used.
Capacity	= Nominal heating input capacity (Btu/hr) of efficient furnace
	= Actual
Eff_{pre}	= Combustion Efficiency of the boiler before the tune-up
	= Actual
E_i	= Combustion Efficiency Improvement of the boiler tune-up measure[173]
	= Actual, informed by flue gas analysis and any additional considerations[174]
100,000	= Converts Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

While there is likely to be some O&M cost savings due to reduced service calls, increased equipment life, etc., these will only be realized with a regular maintenance schedule, which cannot be assumed for each individual tune-up measure. This benefit is therefore conservatively excluded.

[173] The percentage improvement in combustion efficiency is deemed a reasonable proxy for the system improvement. If a full thermal efficiency test is performed instead, that should be used.

[174] Fuel-air ratios of furnaces and boilers can be either too lean or too rich, either of which reduces the combustion efficiency of the gas-fired equipment. When fuel-air ratios are too rich, correcting the mixture to improve combustion efficiency can actually lead to a decrease in the post-tune up efficiency reading of electronic flue gas analyzer tests (maybe analyzer dependent). When rich fuel-air ratios are corrected, detectable carbon monoxide (CO) or unburned hydrocarbons (HC) levels will decrease, indicating a more complete combustion. Yet the excess air needed for the complete combustion can often be registered as a decrease in the efficiency reading of the flue gas analyzer. Thus, flexibility is given to use other suitable mechanisms to assess pre/post combustion efficiencies.

2.5 Shell End Use

2.5.1 Air Sealing

DESCRIPTION

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. An estimate of savings is provided in two ways. It is highly recommended that leaks be detected and pre- and post-sealing leakage rates measured with the assistance of a blower-door by qualified/certified inspectors.[175] Where this occurs, an algorithm is provided to estimate the site specific savings. Where test in/test out has not occurred, a conservative deemed assumption is provided.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

DEFINITION OF BASELINE EQUIPMENT

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly affects the opportunity for cost-effective energy savings through air sealing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[176]

DEEMED MEASURE COST

The actual capital cost for this measure should be used.

LOADSHAPE

Heating BUS

Algorithm

Calculation of Savings

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

$$\Delta Therms = \frac{\frac{(CFM50_{Pre} - CFM50_{Post})}{N\_heat} * 60 * 24 * HDD * 0.018}{(\eta Heat * 100{,}000)}$$

[175] Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.
[176] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on location and building height:[177]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
North East (Fort Madison, IA)	24.9	22.1	20.2	17.9
North West (Lincoln, NE)	23.0	20.4	18.7	16.6
South East (Cape Girardeau, MO)	25.7	22.8	20.9	18.5
South West (Kaiser, MO)	26.6	23.6	21.6	19.2
St Louis, MO	24.0	21.3	19.5	17.3
Kansas City, MO	22.6	20.0	18.4	16.3
Average/Unknown (Knob Noster)	23.8	21.1	19.3	17.1

HDD = Heating Degree Days

= Dependent on location:[178]

Climate Zone (City based upon)	HDD[179]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas (Weighted Columbia and Cape Girardeau)	4,866

[177] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets.

[178] The calculations made in this measure have been based on using Climate Normals data with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[179] HDD values based on 60 degrees except for St. Louis and Ameren Missouri Natural Gas which are based on 65 degrees

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[180] - If not available, use 71%[181]

Other factors as defined above

Conservative Deemed Approach

$$\Delta Therms = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[182]

Building Type	HVAC System	SavingsPerUnit (Therms/ft)
Small Business	Gas Furnace	0.013
Manufactured	Gas Boiler	0.022
Multifamily	Gas Boiler	0.018
Single Family	Gas Boiler	0.016
Manufactured	Gas Furnace	0.017
Multifamily	Gas Furnace	0.012
Single Family	Gas Furnace	0.013

SqFt = Building square footage

= Actual

[180] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf or by performing duct blaster testing.

[181] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

[182] The values in the table represent estimates of savings from a 15% improvement in air leakage. The values are half those provided by Cadmus for the Iowa Joint Assessment, based on building simulations performed. While 30% savings are certainly achievable, this represents a thorough job in both the attic and basements and could not be verified without testing. The conservative 15% estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.5.2 Windows

DESCRIPTION

Energy and demand saving are realized through the installation of windows that offer performance improvements over baseline windows. Savings may be realized from reducing air infiltration, improved insulating properties, and changes to solar heat gain through the glazed surfaces of the building.

This measure was developed to be applicable to the following program types: RF and NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline is assumed to meet the efficiency requirements set forth by local jurisdictions. In most cases, this will be some version of International Energy Conservation Code (IECC). For retrofit applications, the baseline condition is the existing condition and requires assessment of the existing window assemblies.

Local code shall be referenced to define baseline where applicable. As an example, the following is set forth by IECC 2012. An efficient window would have specifications not exceeding these values.

	Climate Zones 4 & 5
U-Factor	
Fixed Windows	0.38 Btu/ft^2.°F.h
Operable Windows	0.45 Btu/ft^2.°F.h
SHGC	0.40

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[183]

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used, including both material and labor costs to install the windows.

In all other scenarios, the incremental cost for this measure is assumed to be $1.50 per square foot of window area.[184]

LOADSHAPE

Cooling BUS

Heating BUS (only use this loadshape for gas savings)

183 Consistent with window measure lives specified by Ameren Missouri and KCP&L.
184 Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007. Consistent with other market reports.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

Heating and cooling savings are composed of three components: infiltration, conduction and solar gains. In instances where infiltration savings do not apply or are not eligible, it may be disregarded.

If central cooling, the electric energy saved in annual cooling due to the added insulation is:

$$\Delta kWh_{cooling} = Infltration_{cooling} + Conduction_{cooling} + Solar_{cooling}$$

$$Infiltration_{cooling} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{cooling} * \Delta T_{AVG,cooling} * 0.018 * LM}{(1000 * \eta_{cooling})}$$

CFM_{Pre} = Infiltration at natural conditions as estimated by blower door testing before window upgrade

= Actual

CFM_{Post} = Infiltration at natural conditions as estimated by blower door testing after window upgrade

= Actual

60 = Converts Cubic Feet per Minute to Cubic Feet per Hour

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 2.4, HVAC End Use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{0}F] during cooling season between outdoor air temperature and assumed 75^{0}F indoor air temperature, dependent on location:

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][185]	$\Delta T_{AVG,cooling}$ [°F]
North East (Fort Madison, IA)	76.2	1.2
North West (Lincoln, NE)	78.8	3.8
South East (Cape Girardeau, MO)	79.4	4.4
South West (Kaiser, MO)	81.3	6.3
St Louis, MO	80.8	5.8
Kansas City, MO	79.0	4.0
Average/Unknown (Knob Noster)	80.7	5.7

[185] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

0.018 = Specific Heat Capacity of Air (Btu/ft^3 °F)

LM = Latent multiplier to account for latent cooling demand

= dependent on location: [186]

Climate Zone (City based upon)	LM
North East (Fort Madison, IA)	5.1
North West (Lincoln, NE)	3.5
South East (Cape Girardeau, MO)	4.5
South West (Kaiser, MO)	3.7
St Louis, MO	3.0
Kansas City, MO	4.0
Average/Unknown (Knob Noster)	3.2

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)

= Actual

$$Conduction_{\text{cooling}} = \frac{(U_{base} - U_{eff}) * A_{window} * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

U_{base} = U-factor value of baseline window assembly (Btu/ft^2.°F.h)

= Dependent on climate zone and window type. See table below for IECC2012 requirements:

U_{eff} = U-factor value of the efficient window assembly (Btu/ft^2.°F.h)

= Actual.

A_{window} = Area of insulated window (including visible frame and glass) (ft^2)

Other variables as defined above.

$$Solar_{\text{cooling}} = \frac{(SHGC_{base} - SHGC_{eff}) * A_{window} * \psi_{cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

$SHGC_{base}$ = Solar Heat Gain Coefficient of the baseline window assembly (fractional)

186 The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015 and is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.

$SHGC_{eff}$ = Solar Heat Gain Coefficient of the efficient window assembly (fractional)

$\Psi_{cooling}$ = Incident solar radiation during the cooling season (Btu/ft^2)

= Based on location:[187]

Climate Zone (City based upon)	$\Psi_{cooling}$
North East (Fort Madison, IA)	42062
North West (Lincoln, NE)	42322
South East (Cape Girardeau, MO)	40266
South West (Kaiser, MO)	45222
St Louis, MO	40996
Kansas City, MO	44843
Average/Unknown (Knob Noster)	45892

Other variables as defined above.

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the window upgrade is:

$$\Delta kWh_{heating} = Infltration_{heating} + Conduction_{heating} - Solar_{heating}$$

$$Infiltration_{heating} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(3{,}412 * \eta_{heating})}$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 2.4, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^{0}F] during heating season between outdoor air temperature and assumed 55^{0}F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][188]	$\Delta T_{AVG,heating}$ [°F]
North East (Fort Madison, IA)	42.1	12.9
North West (Lincoln, NE)	39.0	16.0
South East (Cape Girardeau, MO)	45.7	9.3
South West (Kaiser, MO)	45.0	10.0
St Louis, MO	43.2	11.8
Kansas City, MO	40.3	14.7
Average/Unknown (Knob Noster)	43.4	11.6

[187] See "Windows SHG.xlsx" for derivation.

[188] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

3,412 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system

= Actual. Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%

Other variables as defined above.

$$Conduction_{\text{heating}} = \frac{(U_{base} - U_{eff}) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

Variables as defined above.

$$Solar_{\text{heating}} = \frac{(SHGC_{base} - SHGC_{eff}) * A_{window} * \psi_{heating}}{(3{,}412 * \eta_{heating})}$$

Where:

$\Psi_{heating}$ = Incident solar radiation during the heading season (Btu/ft^2)

= Based on location:

Climate Zone (City based upon)	$\Psi_{cooling}$
North East (Fort Madison, IA)	70736
North West (Lincoln, NE)	74390
South East (Cape Girardeau, MO)	72519
South West (Kaiser, MO)	70498
St Louis, MO	66592
Kansas City, MO	78501
Average/Unknown (Knob Noster)	68653

Other variables as defined above.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWH_{cooling} * CF$$

Where:

$\Delta kWH_{cooling}$ = Annual electricity savings for cooling, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling

= 0.000910684

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the window assembly is calculated with the following formula.

$$\Delta \text{Therms} = Infltration_{gasheating} + Conduction_{gasheating} - Solar_{gasheating}$$

$$Infiltration_{\text{gasheating}} = \frac{(CFM_{Pre} - CFM_{Post}) * 60 * EFLH_{heating} * \Delta T_{AVG,heating} * 0.018}{(100{,}000 * \eta_{heat})}$$

Where:

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

Other variables as defined above.

$$Conduction_{\text{gasheating}} = \frac{(U_{base} - U_{eff}) * A_{window} * EFLH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

$$Solar_{\text{gasheating}} = \frac{(SHGC_{base} - SHGC_{eff}) * A_{window} * \psi_{heating}}{(100{,}000 * \eta_{heat})}$$

Variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

2.5.3 Ceiling and Wall Insulation

DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling and heating loads.

This measure was developed to be applicable to the following program types: RF and NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline is assumed to meet the efficiency requirements set forth by local jurisdictions. In most cases, this will be some version of International Energy Conservation Code (IECC). For retrofit applications, the baseline condition is the existing condition and requires assessment of the existing insulation. It should be based on the entire wall assembly.

Local code shall be referenced to define baseline where applicable. As an example, the following is set forth by IECC 2012:

	ASHRAE/IECC Climate Zone 5 (A, B, C) Nonresidential	
	Assembly Maximum	Insulation Min. R-Value
Mass	U-0.078	R-11.4 ci
Metal Building	U-0.052	R-13 + R-13 ci
Metal Framed	U-0.064	R-13 + R-7.5 ci
Wood Framed and Other	U-0.064	R-13 + R-3.8 ci or R-20

	ASHRAE/IECC Climate Zone 6 (A, B, C) Nonresidential	
	Assembly Maximum	Insulation Min. R-Value
Mass	U-0.078	R-13.1 ci
Metal Building	U-0.052	R-13 + R-13 ci
Metal Framed	U-0.064	R-13 + R-7.5 ci
Wood Framed and Other	U-0.051	R-13 + R-7.5 ci or R-20 + R-3.8 ci

Note: ci = continuous insulation

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E's 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC's Energy Efficiency Policy Manual v.2, and GDS's Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

DEEMED MEASURE COST

For retrofit projects, full installation costs should be used.

For new construction projects, costs should be limited to incremental material and labor costs associated with the portion of insulation that exceeds code requirements.

LOADSHAPE

HVAC BUS

Heating BUS (only use this loadshape for gas savings)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heating}$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh_{cooling} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{cooling} * \Delta T_{AVG,cooling}}{(1{,}000 * \eta_{cooling})}$$

Where:

$R_{existing}$ = Assembly heat loss coefficient with existing insulation [(hr-^{0}F-ft^2)/Btu]

R_{new} = Assembly heat loss coefficient with new insulation [(hr-^{0}F-ft^2)/Btu]

Area = Area of the surface in square feet.

CRF = Correction Factor. Adjustment to account for the effects the framing has on the overall assembly R-value, when cavity insulation is used.

= 100% if Spray Foam or External Rigid Foam

= 50% if studs and cavity insulation[189]

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 2.4, HVAC End Use

$\Delta T_{AVG,cooling}$ = Average temperature difference [^{0}F] during cooling season between outdoor air temperature and assumed 75^{0}F indoor air temperature

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][190]	$\Delta T_{AVG,cooling}$ [°F]
North East (Fort Madison, IA)	76.2	1.2
North West (Lincoln, NE)	78.8	3.8
South East (Cape Girardeau, MO)	79.4	4.4
South West (Kaiser, MO)	81.3	6.3
St Louis, MO	80.8	5.8
Kansas City, MO	79.0	4.0
Average/Unknown (Knob Noster)	80.7	5.7

1,000 = Conversion from Btu to kBtu

$\eta_{cooling}$ = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh)

= Actual

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWh_{heating} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(3{,}412 * \eta_{heating})}$$

[189] Consistent with the information listed in ASHRAE, 2001, Table 5-1 Wall Sections with Steel Studs Parallel Path Correction Factors and experimental findings by the Oak Ridge National Laboratory, "Couple Secrets about How Framing is Effecting the Thermal Performance of Wood and Steel-Framed Walls."

[190] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 2.4, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^{0}F] during heating season between outdoor air temperature and assumed 55^{0}F heating base temperature

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][191]	$\Delta T_{AVG,heating}$ [°F]
North East (Fort Madison, IA)	42.1	12.9
North West (Lincoln, NE)	39.0	16.0
South East (Cape Girardeau, MO)	45.7	9.3
South West (Kaiser, MO)	45.0	10.0
St Louis, MO	43.2	11.8
Kansas City, MO	40.3	14.7
Average/Unknown (Knob Noster)	43.4	11.6

3,412 = Conversion from Btu to kWh.

$\eta_{heating}$ = Efficiency of heating system

= Actual. *Note: electric resistance heating and heat pumps will have an efficiency greater than or equal to 100%*

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh_{heating} = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%[192]

29.3 = Conversion from therms to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWH_{cooling} * CF$$

Where:

$\Delta kWH_{cooling}$ = Annual electricity savings for cooling, as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor for Cooling

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191 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

192 F_e is not one of the AHRI certified ratings provided for furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14% for residential units. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. Assumed to be consistent with C&I applications.

= 0.0004439830

NATURAL GAS SAVINGS

If building uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * CRF * EFLH_{heating} * \Delta T_{AVG,heating}}{(100{,}000 * \eta_{heat})}$$

Where:

$R_{existing}$ = Assembly heat loss coefficient with existing insulation [(hr-^{0}F-ft^2)/Btu]

R_{new} = Assembly heat loss coefficient with new insulation [(hr-^{0}F-ft^2)/Btu]

Area = Area of the surface in square feet. Assume 1000 sq ft for planning.

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating are provided in Section 2.4, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [^{0}F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_{heat} = Efficiency of heating system

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

Natural Gas Technical Resource Manual

Volume 3: Residential Gas Measures

Ameren Missouri TRM – Volume 3: Residential Measures Revision Log

Revision	Date	Description
1.0	12/01/2018	Initial version filed for Commission approval.

Volume 3: Residential Measures

3.1 Appliances End Use

3.1.1 Clothes Dryer

DESCRIPTION

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR® criteria. ENERGY STAR® qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers[1]. ENERGY STAR® provides criteria for both gas and electric clothes dryers.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Clothes dryer must meet the ENERGY STAR® criteria, as required by the program.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years.[2]

DEEMED MEASURE COST

Dryer Size	Incremental Cost[3]
Standard	$75
Compact	$105

LOADSHAPE

Loadshape - Miscellaneous RES

[1] ENERGY STAR® Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

[2] Based on an average estimated range of 12-16 years. ENERGY STAR® Market & Industry Scoping Report. Residential Clothes Dryers. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

[3] Cost based on ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Appliances. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * \%Electric$$

Where:

Load = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.

Dryer Size	Load (lbs)[4]
Standard	8.45
Compact	3

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR® analysis[5]. If product class unknown, assume electric, standard.

Product Class	CEFbase
Vented Electric, Standard (≥ 4.4 ft^3)	3.11
Vented Electric, Compact (120V) (< 4.4	3.01
Vented Electric, Compact (240V) (<4.4	2.73
Ventless Electric, Compact (240V) (<4.4	2.13
Vented Gas	2.84[6]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR® unit based on ENERGY STAR® requirements.[7] If product class unknown, assume electric, standard.

Product Class	CEFeff
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	3.93
Vented or Ventless Electric, Compact (120V) (< 4.4	3.80
Vented Electric, Compact (240V) (< 4.4 ft^3)	3.45
Ventless Electric, Compact (240V) (< 4.4 ft^3)	2.68
Vented Gas	3.48[8]

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year. [9]

[4] Based on ENERGY STAR® test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[5] ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis
[6] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[7] ENERGY STAR® Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers
[8] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[9] Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dryers.

%Electric = The percent of overall savings coming from electricity

= 100% for electric dryers, 5% for gas dryers[10]

Using defaults provided above:

Product Class	kWh
Vented Electric, Standard (≥ 4.4 ft^3)	145.7
Vented Electric, Compact (120V) (< 4.4 ft^3)	53.8
Vented Electric, Compact (240V) (<4.4 ft^3)	58.9
Ventless Electric, Compact (240V) (<4.4 ft^3)	74.3
Vented Gas	7.0

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0001148238

Using defaults provided above:

Product Class	kW
Vented Electric, Standard (≥ 4.4 ft^3)	0.0251
Vented Electric, Compact (120V) (< 4.4	0.0092
Vented Electric, Compact (240V) (<4.4 ft^3)	0.0101
Ventless Electric, Compact (240V) (<4.4	0.0128
Vented Gas	0.0012

NATURAL GAS ENERGY SAVINGS

Natural gas savings only apply to ENERGY STAR® vented gas clothes dryers.

$$\Delta Therm = \left(\frac{Load}{CEFbase} - \frac{Load}{CEFeff}\right) * Ncycles * Therm\_convert * \%Gas$$

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03413

%Gas = Percent of overall savings coming from gas

[10] %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 5% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis. Value reported in 2015 EPA EnergySTAR appliance calculator.

= 0% for electric units and 84% for gas units[11]

Using defaults provided above:

ΔTherm = (8.45/2.84 – 8.45/3.48) * 257 * 0.03413 * 0.84

= 4.03 therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[11] %Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR® Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

3.1.2 Clothes Washer

DESCRIPTION

This measure relates to the installation of a clothes washer meeting the ENERGY STAR® (CEE Tier1), ENERGY STAR® Most Efficient (CEE Tier 2) or CEE Tier 3 minimum qualifications. Note if the Domestic Hot Water (DHW) and dryer fuels of the installations are unknown (for example through a retail program) savings are based on a weighted blend using RECS data (the resultant values (kWh, therms and gallons of water) are provided). The algorithms can also be used to calculate site specific savings where DHW and dryer fuels are known.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Clothes washer must meet the ENERGY STAR® (CEE Tier1), ENERGY STAR® Most Efficient (CEE Tier 2), or CEE Tier 3 minimum qualifications (provided in the table below), as required by the program.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard-sized clothes washer meeting the minimum federal baseline as of March 2015[12].

Efficiency Level		Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft
Baseline	Federal Standard	≥1.29 IMEF, ≤8.4 IWF	≥1.84 IMEF, ≤4.7 IWF
Efficient	ENERGY STAR®, CEE Tier 1	≥2.06 IMEF, ≤4.3 IWF	≥2.38 IMEF, ≤3.7 IWF
	ENERGY STAR® Most Efficient, CEE Tier 2	≥2.76 IMEF, ≤3.5 IWF	≥2.74 IMEF, ≤3.2 IWF
	CEE Tier 3	≥2.92 IMEF, ≤3.2 IWF	

The Integrated Modified Energy Factor (IMEF) includes unit operation, standby, water heating, and drying energy use, with the higher the value the more efficient the unit; "The quotient of the cubic foot (or liter) capacity of the clothes container divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, the energy required for removal of the remaining moisture in the wash load, and the combined low-power mode energy consumption."

The Integrated Water Factor (IWF) indicates the total water consumption of the unit, with the lower the value the less water required; "The quotient of the total weighted per-cycle water consumption for all 67 wash cycles in gallons divided by the cubic foot (or liter) capacity of the clothes washer" [13].

[12] See http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

[13] Definitions provided in ENERGY STAR® v7.1 specification on the ENERGY STAR® website.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years.[14]

DEEMED MEASURE COST

The incremental cost assumptions are provided below[15]:

Efficiency Level	Incremental Cost
ENERGY STAR®, CEE Tier 1	$32
ENERGY STAR® Most Efficient, CEE TIER 2	$393
CEE TIER 3	$454

LOADSHAPE

Miscellaneous RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \left[\left(Capacity * \frac{1}{IMEFbase} * Ncycles\right) * \left(\%CWbase + (\%DHWbase * \%Electric_{DHW}) + \left(\%Dryerbase * \%Electric_{Dryer}\right)\right)\right] - \left[\left(Capacity * \frac{1}{IMEFeff} * Ncycles\right) * \left(\%CWeff + (\%DHWeff * \%Electric_{DHW}) + \left(\%Dryereff * \%Electric_{Dryer}\right)\right)\right]$$

Where:

Capacity = Clothes Washer capacity (cubic feet)

= Actual - If capacity is unknown, assume 3.45 cubic feet [16]

IMEFbase = Integrated Modified Energy Factor of baseline unit

Efficiency Level	IMEFbase		
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft	Weighted Average[17]
Federal Standard	1.29	1.84	1.66

[14] Based on DOE Chapter 8 Life-Cycle Cost and Payback Period Analysis.

[15] Based on weighted average of top loading and front loading units (based on available product from the California Energy Commission (CEC) Appliance database; https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool. See '2015 Clothes Washer Analysis.xls' for details.

[16] Based on the average clothes washer volume of all units that pass the new Federal Standard on the CEC database of Clothes Washer products (accessed on 08/28/2014). If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

[17] Weighted average IMEF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR® product in the CEC database (accessed 08/28/2014). The relative weightings are as follows, see more information in "2015 Clothes Washer Analysis.xlsx":

IMEFeff = Integrated Modified Energy Factor of efficient unit

= Actual. If unknown, assume average values provided below.

Efficiency Level	IMEFeff		
	Top loading >2.5 Cu ft	Front Loading >2.5 Cu ft	Weighted Average[18]
ENERGY STAR®, CEE Tier 1	2.06	2.38	2.26
ENERGY STAR® Most Efficient, CEE Tier 2	2.76	2.74	2.74
CEE Tier 3	2.92		2.92

Ncycles = Number of Cycles per year

= 271[19]

%CW = Percentage of total energy consumption for Clothes Washer operation (different for baseline and efficient unit – see table below)

%DHW = Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)

%Dryer = Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)

	Percentage of Total Energy Consumption[20]		
	%CW	%DHW	%Dryer
Federal Standard	8%	31%	61%
ENERGY STAR®, CEE Tier 1	8%	23%	69%
ENERGY STAR® Most Efficient, CEE Tier 2	14%	10%	76%
CEE Tier 3	14%	10%	76%

Efficiency Level	Front	Top
Baseline	67%	33%
ENERGY STAR®, CEE Tier 1	62%	38%
ENERGY STAR® Most Efficient, CEE Tier 2	98%	2%
CEE Tier 3	100%	0%

[18] Weighting is based upon the relative top v front loading percentage of available product in the CEC database (accessed 08/28/2014).

[19] Weighted average of 271 clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region for state of MO): http://www.eia.gov/consumption/residential/data/2009/. See '2015 Clothes Washer Analysis.xls' for details.
If utilities have specific evaluation results providing a more appropriate assumption for single-family or multi-family homes, in a particular market, or geographical area then that should be used.

[20] The percentage of total energy consumption that is used for the machine, heating the hot water, or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units based on data from DOE Life-Cycle Cost and Payback Analysis. See '2015 Clothes Washer Analysis.xls' for details.

$\%Electric_{DHW}$ = Percentage of DHW savings assumed to be electric

DHW fuel	$\%Electric_{DHW}$
Electric	100%
Natural Gas	0%
Unknown	43%[21]

$\%Electric_{Dryer}$ = Percentage of dryer savings assumed to be electric

Dryer fuel	$\%Electric_{Dryer}$
Electric	100%
Natural Gas	0%
Unknown	90%[22]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below[23]:

Front Loaders:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	149.3	52.6	96.4	-0.2
ENERGY STAR® Most Efficient, CEE Tier 2	222.1	85.9	132.2	-4.0
CEE Tier 3	243.1	104.8	137.2	-1.1

Top Loaders:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	149.3	97.0	77.0	24.8
ENERGY STAR® Most Efficient, CEE Tier 2	222.1	132.6	117.1	27.5
CEE Tier 3	243.1	374.4	230.5	42.0

Weighted Average:

[21] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of MO. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used

[22] Default assumption for unknown is based on percentage of homes with clothes washers that use an electric dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of MO. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

[23] Note that the baseline savings for all cases (Front, Top and Weighted Average) is based on the weighted average baseline IMEF (as opposed to assuming Front baseline for Front efficient unit and Top baseline for Top efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	149.3	70.6	88.0	9.4
ENERGY STAR® Most Efficient, CEE Tier 2	222.1	80.9	137.5	-3.7
CEE Tier 3	243.1	98.4	143.2	-1.5

If the DHW and dryer fuel is unknown the prescriptive kWH savings based on defaults provided above should be:

	ΔkWH		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR®, CEE Tier 1	112.8	89.6	99.0
ENERGY STAR® Most Efficient, CEE Tier 2	161.5	136.6	134.3
CEE Tier 3	424.6	154.8	151.8

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Energy Savings as calculated above

CF = Summer Peak Coincidence Factor for measure

= 0.0001148238

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

Front Loaders:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.022	0.008	0.015	0.000
ENERGY STAR® Most Efficient, CEE Tier 2	0.033	0.013	0.020	-0.001
CEE Tier 3	0.037	0.016	0.021	0.000

Top Loaders:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.022	0.015	0.012	0.004
ENERGY STAR® Most Efficient, CEE Tier 2	0.033	0.020	0.018	0.004
CEE Tier 3	0.037	0.056	0.035	0.006

Weighted Average:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.022	0.011	0.013	0.001
ENERGY STAR® Most Efficient, CEE Tier 2	0.033	0.012	0.021	-0.001
CEE Tier 3	0.037	0.015	0.022	0.000

If the DHW and dryer fuel is unknown, the prescriptive kW savings should be:

	ΔkW		
Efficiency Level	Front Loaders	Top Loaders	Weighted Average
ENERGY STAR®, CEE Tier 1	0.013	0.017	0.015
ENERGY STAR® Most Efficient, CEE Tier 2	0.021	0.024	0.020
CEE Tier 3	0.023	0.064	0.023

NATURAL GAS SAVINGS

$$\Delta Therms = \Big[\Big[\Big(Capacity * \frac{1}{IMEFbase} * Ncycles\Big) * \Big((\%DHWbase * \%Natural\ Gas_{DHW} * R\_eff) + (\%Dryerbase * \%Gas_{Dryer}\%Gas\ \_Dryer)\Big)\Big] - \Big[\Big(Capacity * \frac{1}{IMEFeff} * Ncycles\Big) * \Big((\%DHWeff * \%Gas_{DHW}\%Natural\ Gas\_DHW * R\_eff) + (\%Dryereff * \%Gas_{Dryer}\%Gas\_Dryer)\Big)\Big]\Big] * Therm\_convert$$

Where:

$\%Gas_{DHW}$ = Percentage of DHW savings assumed to be Natural Gas

DHW fuel	$\%Gas_{DHW}$
Electric	0%
Natural Gas	100%
Unknown	57%[24]

R_eff = Recovery efficiency factor

= 1.26[25]

[24] Default assumption for unknown fuel is based EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of MO. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[25] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

$\%Gas_{Dryer}$ = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	$\%Gas_{Dryer}$
Electric	0%
Natural Gas	100%
Unknown	10%[26]

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

Other factors as defined above.

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

Front Loaders:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.0	2.2	2.5	4.7
ENERGY STAR® Most Efficient, CEE Tier 2	0.0	3.8	3.6	7.4
CEE Tier 3	0.0	8.1	11.3	19.4

Top Loaders:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.0	4.2	1.8	6.0
ENERGY STAR® Most Efficient, CEE Tier 2	0.0	5.9	3.1	8.9
CEE Tier 3	0.0	5.9	3.6	9.6

Weighted Average:

	ΔTherms			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR®, CEE Tier 1	0.0	3.4	2.1	5.5
ENERGY STAR® Most Efficient, CEE Tier 2	0.0	6.1	2.9	9.0
CEE Tier 3	0.0	6.2	3.4	9.6

If the DHW and dryer fuel is unknown, the prescriptive Therm savings should be:

[26] Default assumption for unknown fuel is based EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of MO. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

	ΔTherms		
Efficiency Level	**Front Loaders**	**Top Loaders**	**Weighted Average**
ENERGY STAR®, CEE Tier 1	1.51	2.52	2.11
ENERGY STAR® Most Efficient, CEE Tier 2	2.52	3.60	3.71
CEE Tier 3	5.66	3.70	3.84

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water\ (gallons) = Capacity * (IWFbase - IWFeff) * Ncycles$$

Where:

IWFbase = Integrated Water Factor of baseline clothes washer

= 5.92[27]

IWFeff = Water Factor of efficient clothes washer

= Actual - If unknown assume average values provided below

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

	IWF[28]			ΔWater (gallons per year)		
Efficiency Level	**Front Loaders**	**Top Loaders**	**Weighted Average**	**Front Loaders**	**Top Loaders**	**Weighted Average**
Federal Standard	4.7	8.4	5.92	N/A		
ENERGY STAR®, CEE Tier 1	3.7	4.3	3.93	934	3,828	1,857
ENERGY STAR® Most Efficient, CEE Tier 2	3.2	3.5	3.21	1,400	4,575	2,532
CEE Tier 3	3.2		3.20	1,400	7,842	2,538

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[27] Weighted average IWF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR® product in the CEC database.

[28] IWF values are the weighted average of the new ENERGY STAR® specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR® and ENERGY STAR® Most Efficient product in the CEC database. See “2015 Clothes Washer Analysis.xls” for the calculation.

3.2 Hot Water End Use

3.2.1 Low Flow Faucet Aerator

This measure relates to the installation of a low flow faucet aerator in a household kitchen or bath faucet fixture.

This measure may be used for units provided through Efficiency Kit's however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI, KITS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a low flow faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.25 GPM or greater, or a standard kitchen faucet aerator rated at 2.75 GPM or greater. Average measured flow rates are used in the algorithm and are lower, reflecting the penetration of previously installed low flow fixtures (and therefore the freerider rate for this measure should be 0), use of the faucet at less than full flow, debris buildup, and lower water system pressure than fixtures are rated at.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[29]

DEEMED MEASURE COST

The incremental cost for this measure is $11.33[30] or program actual.

For faucet aerators provided in Efficiency Kits, the actual program delivery costs should be utilized.

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[31] (unless faucet type is unknown, then it is per household).

[29] Measure lifetime is derived from the California DEER Effective Useful Life Table – 2014 Table Update, "http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx"

[30] Direct-install price per showerhead assumes cost of showerhead (Market research average of $3 and assess and install cost of $8.33 (20min at $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor).

[31] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	43%[32]

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used." This includes the effect of existing low flow fixtures and therefore the freerider rate for this measure should be 0.

= 1.39[33] or custom based on metering studies[34] or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[35]

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used"

= 0.94[36] or custom based on metering studies[37] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[38]

L_base = Average baseline daily length faucet use per capita for faucet of interest in minutes

= if available custom based on metering studies, if not use:

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[32] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of MO. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[33] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[34] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[35] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

[36] Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7(see source table at end of characterization). This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

[37] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[38] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

Faucet Type	L_base (min/person/day)
Kitchen	4.5[39]
Bathroom	1.6[40]
If location unknown (total for household): Single-Family	7.8[41]
If location unknown (total for household): Multi-Family	6.7[42]

L_low = Average retrofit daily length faucet use per capita for faucet of interest in minutes

= if available custom based on metering studies, if not use:

Faucet Type	L_low (min/person/day)
Kitchen	4.5[43]
Bathroom	1.6[44]
If location unknown (total for household): Single-Family	7.8[45]
If location unknown (total for household): Multi-Family	6.7[46]

Household = Average number of people per household

Household Unit Type	Household
Single-Family - Deemed	2.67[47]
School Kits	4.3[48]
Multi-Family - Deemed	2.07[49]
Custom	Actual Occupancy or Number of Bedrooms[50]

[39] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.
[40] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.
[41] One kitchen faucet plus 2.04 bathroom faucets. Based on findings from a 2012 Ameren Missouri potential study for single family homes.
[42] One kitchen faucet plus 1.4 bathroom faucets. Based on findings from an Ameren Missouri PY13 data for multifamily homes.
[43] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[44] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[45] One kitchen faucet plus 2.04 bathroom faucets. Based on findings from a 2012 Ameren Missouri potential study for single family homes.
[46] One kitchen faucet plus 1.4 bathroom faucets. Based on findings from an Ameren Missouri PY13 data for multifamily homes.
[47] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.
[48] Ameren Missouri Energy Efficient Kits Program Impact and Process Evalualtion: Program Year 2016.
[49] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.
[50] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in

365.25 = Days in a year, on average.

DF = Drain Factor

Faucet Type	Drain Factor[51]
Kitchen	75%
Bath	90%
Unknown	79.5%

FPH = Faucets Per Household

Faucet Type	FPH
Kitchen Faucets Per Home (KFPH)	1
Bathroom Faucets Per Home (BFPH): Single-Family	2.04[52]
Bathroom Faucets Per Home (BFPH): School Kits	2.4[53]
Bathroom Faucets Per Home (BFPH): Multi-Family	1.4[54]
If location unknown (total for household): Single-Family	3.04
If location unknown (total for household): Multi-Family	2.4

EPG_electric = Energy per gallon of water used by faucet supplied by electric water heater

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°F)

WaterTemp = Assumed temperature of mixed water

residency and non-adult population impacts.

[51] Because faucet usages are at times dictated by volume (e.g., filling a cooking pot), only usage of the sort that would go straight down the drain will provide savings. VEIC is unaware of any metering study that has determined this specific factor and so recommends these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*0.75)+(0.3*0.9)=0.795.

[52] Based on findings from a 2012 Ameren Missouri potential study for single family homes.

[53] Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: Program Year 2016.

[54] Based on findings from an Ameren Missouri PY13 data for multifamily homes

= 86F for Bath, 93F for Kitchen 91F for Unknown[55]

SupplyTemp = Assumed temperature of water entering house

= 60.83F [56]

RE_electric = Recovery efficiency of electric water heater

= 98% [57]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below

Selection	ISR
Direct Install	0.977[58]
Efficiency Kit—Single Family	0.52[59]
Efficiency Kit—Multi Family	1.0[60]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

ΔkWh = as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0000887318[61]

NATURAL GAS SAVINGS

ΔTherms = %GasDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_gas * ISR

Where:

%GasDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%GasHW
Electric	0%
Natural Gas	100%
Unknown	48%[62]

55 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*93)+(0.3*86)=0.91.

56 Based on the DOE's Building America Standard DHW Event Schedule calculator. Average annual water main temperatures were determined for each defined weather zone in Missouri. The overall average of 60.83 is taken to represent the statewide average input water temperature.

57 Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

58 Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015

59 Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

60 Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

61 Based on Ameren Missouri 2016 Loadshape for Residential Water Heating End-Use.

62 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of MO. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[63]

= 67% For MF homes[64]

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

Δgallons = ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * ISR

Variables as defined above.

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[63] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[64] Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.

3.2.2 Low Flow Showerhead

DESCRIPTION

This measure relates to the installation of a low flow showerhead in a single or multi-family household.

This measure may be used for units provided through Efficiency Kit's however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, RF, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a low flow showerhead, typically rated at 2.0 gallons per minute (GPM) or less. Savings are calculated on a per showerhead fixture basis.

DEFINITION OF BASELINE EQUIPMENT

For Direct-install programs, the baseline condition is assumed to be a standard showerhead rated at 2.5 GPM[65] or greater.

For retrofit and time-of-sale programs, the baseline condition is assumed to be a representative average of existing showerhead flow rates of participating customers including a range of low flow showerheads, standard-flow showerheads, and high-flow showerheads.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[66]

DEEMED MEASURE COST

The incremental cost for time of sale, new construction or efficiency kits is $7[67] or program actual.

For low flow showerheads provided in retrofit or direct install programs, the actual program delivery costs should be utilized, if unknown assume $15.33.[68]

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture

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[65] Maximum showerhead flow rate at 80 PSI is 2.5 GPM in accordance with Federal Standard 10 CFR Part 430.32(p) See Docket filed at "https://www.regulations.gov/document?D=EERE-2011-BT-TP-0061-0039"

[66] Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family , "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf"

[67] Based on online pricing market research 2/6/2017.

[68] Direct-install price per showerhead assumes cost of showerhead (Market research average of $7 and assess and install cost of $8.33 (20min at $25 per hour, which is in line with the typical prevailing wage of a General Laborer, as per the Annual Wage Order No. 23 published by the Missouri Department of Labor).

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	43%[69]

GPM_base = Flow rate of the baseline showerhead

Program	GPM_base
Direct-install	2.35[70]
Retrofit, Efficiency Kits, NC or TOS	2.35[71]

GPM_low = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaulations deviate from rated flows, see table below:

Rated Flow
2.0 GPM
1.75 GPM
1.5 GPM
Custom or Actual[72]

L_base = Shower length in minutes with baseline showerhead

= 7.8 min[73]

L_low = Shower length in minutes with low-flow showerhead

[69] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of MO. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[70] Based on Ameren MO PY14 program data for direct-install measures. A delta of 0.85 GPM is assumed, derived from confirmed retrofitted aerator flow rates of 1.5 GPM and assuming existing showerheads were consuming 2.35 GPM, based on average of DOE-reported values for homes with domestic water pressures of 60psi and 80psi. http://energy.gov/energysaver/articles/reduce-hot-water-use-energy-savings.

[71] Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

[72] Note that actual values may be either a) program-specific minimum flow rate, or b) program-specific evaluation-based value of actual effective flow-rate due to increased duration or temperatures. The latter increases in likelihood as the rated flow drops and may become significant at or below rated flows of 1.5 GPM. The impact can be viewed as the inverse of the throttling described in the footnote for baseline flowrate.

[73] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

= 7.8 min[74]

Household = Average number of people per household

Household Unit Type[75]	Household
Single-Family - Deemed	2.67[76]
School Kits	4.3
Multi-Family - Deemed	2.07[77]
Custom	Actual Occupancy or Number of Bedrooms[78]

SPCD = Showers Per Capita Per Day

= 0.6[79]

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

Household Type	SPH
Single-Family	2.05[80]
School Kits	2.1[81]
Multi-Family	1.4[82]
Custom	Actual

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 60.83)) / (0.98 * 3412)

= 0.100 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

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74 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

75 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

76 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.

77 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus

78 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

79 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

80 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.

81 Ameren Missouri Energy Efficient Kits Program Impact and Process Evaluation: Program Year 2016.

82 Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, provided by Cadmus.

= 101.0 F [83]

SupplyTemp = Assumed temperature of water entering house

= 60.83 F [84]

RE_electric = Recovery efficiency of electric water heater

= 98% [85]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependant on program delivery method as listed in table below

Selection	ISR
Direct Install	0.98[86]
Efficiency Kit—Single Family	0.47[87]
Efficiency Kit—Multi Family	0.86[88]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh * CF

Where:

ΔkWh = as calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0000887318[89]

NATURAL GAS SAVINGS

ΔTherms = %GasDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%GasDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%GasDHW
Electric	0%
Natural Gas	100%
Unknown	48%[90]

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[83] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[84] Based on the DOE's Building America Standard DHW Event Schedule calculator. Average annual water main temperatures were determined for each defined weather zone in Missouri. The overall average of 60.83 is taken to represent the statewide average input water temperature.

[85] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

[86] Ameren Missouri Home Energy Analysis Program Impact and Process Evaluation: Program Year 2015

[87] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

[88] Ameren Missouri Efficient Products Impact and Process Evaluation: Program Year 2015

[89] Based on Ameren Missouri 2016 Loadshape for Residential Water Heating End-Use.

[90] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00429 Therm/gal for SF homes

= 0.00499 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[91]

= 67% For MF homes[92]

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

Δgallons = ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[91] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[92] Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.

3.2.3 Water Heater

DESCRIPTION

This measure applies to gas water heaters under the following program types:

a) Time of Sale or New Construction:
The purchase and installation of a new, residential gas-fired storage or tankless water heater meeting program energy factor (EF) requirements, in place of a unit meeting federal standards.

b) Early Replacement:
The early removal of an existing and functioning, residential gas-fired storage or tankless water heater, prior to its natural end of life, and replacement with a new unit meeting program EF requirements. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a residential gas-fired storage water heater with a maximum heat input rating of 75,000 Btu/hr or a tankless water heater meeting the EF requirements within the table below.[93]

Water Heater Type	EF
Gas Storage ≥20 gal and ≤55 gal	0.67
Gas Storage >55 gal and ≤100 gal	0.77
Gas Tankless	0.90

DEFINITION OF BASELINE EQUIPMENT

Time of Sale or New Construction: The baseline equipment is assumed to be a new, gas-fired storage or tankless residential water heater meeting the minimum federal efficiency standards.[94] For 20 to 55 gallon tanks, the federal standard is calculated as 0.675 – (0.0015 * rated storage size in gallons), for 55 - 100 gallon tanks, the calculation is 0.8012 – (0.00078 * rated storage size in gallons), and for tankless units, the calculation is 0.82 – (0.0019 * rated storage size in gallons).

Early Replacement: The baseline is the efficiency of the existing gas water heater for the remaining useful life of the unit and the efficiency of a new gas water heater meeting minimum federal efficiency standards for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Time of Sale or New Construction: The expected measure life is assumed to be 13 years for a gas storage water heater and 20 years for a gas tankless water heater.[95]

For Early Replacement: The remaining life of existing equipment is assumed to be 3.67 for gas storage

[93] ENERGY STAR® Product Specification for Residential Water Heaters, Version 3.0, effective April 16, 2015
[94] Minimum federal standard as of 4/16/2015;
http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf
[95] 2010 Residential Heating Products Final Rule Technical Support Document, U.S. DOE, Table 8.7.1.

water heaters and 6.67 years for gas tankless water heaters.[96]

DEEMED MEASURE COST

Time of Sale or New Construction: The incremental capital cost for this measure is dependent on the type of water heater, as listed below.[97]

Early Replacement: The full installed cost is provided in the table below. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $799 for storage units 20 gal and ≤55 gal, and $593 for tankless units.[98] This cost should be discounted to present value using the utility's discount rate.

Actual costs should be used where available.

Water Heater Type	Incremental Cost	Full Install Cost[99]
Gas Storage ≥20 gal and ≤55 gal	$256	$1,055
Gas Tankless	$510	$1,103

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = (1/EF_{Base} - 1/EF_{EE}) * (GPD * Household * 365.25 * \gamma Water * (T_{Out} - T_{In}) * 1.0)/100{,}000$$

Early Replacement:[100]

ΔTherms for remaining life of existing unit (1st 3.67 years for gas storage unit and 1st 6.67 years

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96 Database for Energy-Efficiency Resources (DEER), "DEER2014 EUL Table Update," California Public Utilities Commission, February 4, 2014.

97 Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I_August2016.xls" for more information.

98 Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I.xls" for more information.

99 Full install costs reflect 4.54 hours of labor at a labor rate of $78.19 per hour.

100 The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may require a first year savings calculation (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input, which would be the (new base to efficient savings)/(existing to efficient savings).

for gas tankless unit):

$$\Delta Therms = (1/EF_{Existing} - 1/EF_{EE}) * (GPD * Household * 365.25 * \gamma Water * (T_{Out} - T_{In}) * 1.0)/100{,}000$$

ΔTherms for remaining measure life (next 7.33 years for gas storage unit and next 13.33 years for gas tankless unit):

$$\Delta Therms = (1/EF_{Base} - 1/EF_{EE}) * (GPD * Household * 365.25 * \gamma Water * (T_{Out} - T_{In}) * 1.0)/100{,}000$$

Where:

EF_{Base} = EF of standard gas water heater according to federal standards

= For gas storage water heaters with storage capacity ≥20 gallons and ≤55 gallons: 0.675 – (0.0015 * storage capacity in gallons)

= For gas storage water heaters with storage capacity >55 gallons and ≤100 gallons: 0.8012 – (0.00078 * storage capacity in gallons)

= For gas tankless water heaters: 0.82 – (0.0019 * storage capacity in gallons)

= If tank size is unknown, assume 0.600 for a gas storage water heater with a 50-gallon storage capacity and 0.82 for a gas tankless water heater with a 0-gallon storage capacity

EF_{EE} = EF of efficient gas water heater

= Actual or if unknown, assume 0.67 for gas storage water heaters ≤55 gallons, 0.77 for gas storage water heaters >55 gallons and 0.90 for gas tankless water heaters[101]

$EF_{Existing}$ = EF of existing gas water heater

= Actual or if unknown, assume 0.52 [102]

GPD = Gallons per day of hot water use per person

= 17.6[103]

Household = Average number of people per household

Household Unit Type[104]	Household
Single-Family - Deemed	2.67[105]
Multi-Family - Deemed	2.07[106]
Custom	Actual Occupancy or Number of Bedrooms[107]

[101] ENERGY STAR® Product Specification for Residential Water Heaters, Version 3.0, effective April 16, 2015
[102] Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.
[103] GPD based on 45.5 gallons of hot water per day per household and 2.59 people per household, from Residential End Uses of Water Study 2013 Update. Prepared by Deoreo, B., and P. Mayer for the Water Research Foundation, 2014.
[104] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.
[105] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, prepared by Cadmus.
[106] Ameren Missouri Efficient Products Impact and Process Evaluation: Planning Year 2015, prepared by Cadmus.
[107] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

365.25 = Number of days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{Out} = Tank temperature

= Actual, if unknown assume 125°F

T_{In} = Incoming water temperature from well or municipal system

= 57.898°F[108]

1.0 = Heat capacity of water (1 Btu/lb*°F)

100,000 = Conversion factor from Btu to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[108] Using 40" deep soil temp as a proxy at Powell Gardens SCAN site. Average by month of available data from 3/28/02–10/11/14: 12 month average is 57.898. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2061

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3.2.4 Water Heater Wrap

DESCRIPTION

This measure applies to a tank wrap or insulation "blanket" that is wrapped around the outside of an electric or gas domestic hot water (DHW) tank to reduce stand-by losses.

This measure was developed to be applicable to the following program types: DI, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is an electric or gas DHW tank with wrap installed that has an R-value that meets program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is an uninsulated, electric or gas DHW tank.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years.[109]

DEEMED MEASURE COST

The measure cost is the actual cost of material and installation. If actual costs are unknown, assume $58[110] for material and installation.

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below for electric DHW tanks, otherwise use default values from table that follows:

$$\Delta kWh = ((A_{Base}/R_{Base} - A_{EE}/R_{EE}) * \Delta T * Hours)/(\eta DHW_{Elec} * 3{,}412)$$

Where:

A_{Base} = Surface area (ft^2) of storage tank prior to adding tank wrap[111]

= Actual or if unknown, use default based on tank capacity (gal) from table below

R_{Base} = Thermal resistance coefficient (hr-°F-ft^2/BTU) of uninsulated tank

[109] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014. Average of values for electric DHW (13 years) and gas DHW (11 years).

[110] Average cost of R-10 tank wrap installation from the National Renewable Energy Laboratory's National Residential Efficiency Measures Database. http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=270

[111] Area includes tank sides and top to account for typical wrap coverage.

= Actual or if unknown, assume 14[112]

A_{EE} = Surface area (ft^2) of storage tank after addition of tank wrap[113]

= Actual or if unknown, use default based on tank capacity (gal) from table below

R_{EE} = Thermal resistance coefficient ((hr-°F-ft2/BTU) of tank after addition of tank wrap (R-value of uninsulated tank + R-value of tank wrap)

= Actual or if unknown, assume 24

ΔT = Average temperature difference (°F) between tank water and outside air

= Actual or if unknown, assume 60°F [114]

Hours = Hours per year

= 8,766

ηDHW_{Elec} = Recovery efficiency of electric hot water heater

= Actual or if unknown, assume 0.98 [115]

3,412 = Conversion factor from Btu to kWh

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft^2)[116]	A_{EE} (ft^2)[117]	ΔkWh	ΔkW
30	19.16	20.94	78.0	0.00890
40	23.18	25.31	94.6	0.01079
50	24.99	27.06	103.4	0.01180
80	31.84	34.14	134.0	0.01528

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh * CF$$

Where:

ΔkWh = Electric energy savings, as calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0000887318[118]

The table above contains default kW savings for various tank capacities.

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112 Baseline R-value based on information from Chapter 6 of The Virginia Energy Savers Handbook, Third Edition: The best heaters have 2 to 3 inches of urethane foam, providing R-values as high as R-20. Other less expensive models have fiberglass tank insulation with R-values ranging between R-7 and R-10.

113 Area includes tank sides and top to account for typical wrap coverage.

114 Assumes 125°F hot water tank temperature and average basement temperature of 65°F.

115 Electric water heater recovery efficiency from AHRI database: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

116 Surface area assumptions from the June 2016 Pennsylvania TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

117 Surface area assumptions from the June 2016 Pennsylvania TRM. A_{EE} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

118 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Water Heating. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

NATURAL GAS SAVINGS

Custom calculation below for gas DHW tanks, otherwise use default values from table that follows:

$$\Delta Therms = ((A_{Base}/R_{Base} - A_{EE}/R_{EE}) * \Delta T * Hours)/(\eta DHW_{Gas} * 100{,}000)$$

Where:

ηDHW_{Gas} = Recovery efficiency of gas hot water heater

= 0.78[119]

100,000 = Conversion factor from Btu to therms

Other variables as defined above

The following table contains default savings for various tank capacities.

Capacity (gal)	A_{Base} (ft^2)[120]	A_{EE} (ft^2)[121]	ΔTherms	ΔPeakTherms
30	19.16	20.94	3.3	0.0092
40	23.18	25.31	4.1	0.0111
50	24.99	27.06	4.4	0.0121
80	31.84	34.14	5.7	0.0157

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

119 Review of AHRI directory suggests range of recovery efficiency ratings for new gas DHW units of 70-87%. Average of existing units is estimated at 78%.

120 Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage. Recommend updating with MO-specific data when available.

121 A_{EE} was calculated by assuming that the water heater wrap is a 2" thick fiberglass material. Recommend updating with MO-specific data when available.

3.2.5 Hot Water Pipe Insulation

DESCRIPTION

This measure applies to the addition of insulation to uninsulated domestic hot water (DHW) pipes. The measure assumes the pipe wrap is installed on the first length of both the hot and cold pipe up to the first elbow. This is the most cost-effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow, which acts as a heat trap. Insulating this section helps to reduce standby losses.

This measure was developed to be applicable to the following program types: DI, RF

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is a domestic hot or cold water pipe with pipe wrap installed that has an R value that meets program requirements.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is an uninsulated, domestic hot or cold water pipe.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[122]

DEEMED MEASURE COST

The measure cost is the actual cost of material and installation. If the actual cost is unknown, assume a default cost of $7.10 [123] per linear foot, including material and installation.

LOADSHAPE

Water Heating RES

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Custom calculation below for electric systems, otherwise assume 24.7 kWh per 6 linear feet of ¾ in, R-4 insulation or 35.4 kWh per 6 linear feet of 1 in, R-6 insulation:

$$\Delta kWh = ((C_{Base}/R_{Base} - C_{EE}/R_{EE}) * L * \Delta T * Hours)/(\eta DHW_{Elec} * 3{,}412)$$

Where:

C_{Base} = Circumference (ft) of uninsulated pipe

[122] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, "Cost Values and Summary Documentation", California Public Utilities Commission, January, 2014. Average of values for electric DHW (13 years) and gas DHW (11 years).
[123] Average cost of R-5 pipe wrap installation from the National Renewable Energy Laboratory's National Residential Efficiency Measures Database. http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=323

	= Diameter (in) * π/12
	= Actual or if unknown, assume 0.131 ft for a pipe with a 0.50 inch diameter
R_{Base}	= Thermal resistance coefficient (hr-°F-ft^2)/Btu) of uninsulated pipe
	= 1.0[124]
C_{EE}	= Circumference (ft) of insulated pipe
	= Diameter (in) * π/12
	= Actual or if unknown, assume 0.524 ft for a 0.50 in diameter pipe insulated with 3/4 in, R-4 wrap ((0.5 + 3/4 + 3/4) * π/12) or 0.654 ft for a 0.50 in diameter pipe insulated with 1 in, R-6 wrap ((0.5 + 1 + 1) * π/12)[125]
R_{EE}	= Thermal resistance coefficient (hr-°F-ft^2)/Btu) of insulated pipe
	= 1.0 + R value of insulation
	= Actual or if unknown, assume 5.0 for R-4 wrap or 7.0 for R-6 wrap
L	= Length of pipe from water heating source covered by pipe wrap (ft)
	= Actual or if unknown, assume 6 ft
ΔT	= Average temperature difference (°F) between supplied water and outside air
	= Actual or if unknown, assume 60°F [126]
Hours	= Hours per year
	= 8,766
ηDHW_{Elec}	= Recovery efficiency of electric hot water heater
	= Actual or if unknown, assume 0.98 [127]
3,412	= Conversion factor from Btu to kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW \quad = \Delta kWh * CF$$

Where:

ΔkWh	= Electric energy savings, as calculated above.
CF	= Summer peak coincidence demand (kW) to annual energy (kWh) factor
	= 0.0000887318

NATURAL GAS SAVINGS

Custom calculation below for gas DHW systems, otherwise assume 1.1 therms per 6 linear feet of ¾ in, R-4 insulation or 1.5 therms per 6 linear feet of 1 in, R-6 insulation:

124 "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets," Navigant, April 2009.
125 Pipe wrap thicknesses based on review of available products on Grainger.com
126 Assumes 125°F water leaving the hot water tank and average basement temperature of 65°F.
127 Electric water heater recovery efficiency from AHRI database: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

$$\Delta Therms = ((C_{Base}/R_{Base} - C_{EE}/R_{EE}) * L * \Delta T * Hours)/(\eta DHW_{Gas} * 100{,}000)$$

Where:

ηDHW_{Gas} = Recovery efficiency of gas hot water heater

= 0.78[128]

100,000 = Conversion factor from Btu to therms

Other variables as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[128] Review of AHRI directory suggests range of recovery efficiency ratings for new gas DHW units of 70-87%. Average of existing units is estimated at 78%.

3.2.6 Thermostatic Restrictor Shower Valve

DESCRIPTION

The measure is the installation of a thermostatic restrictor shower valve in a single or multi-family household. This is a valve attached to a residential showerhead which restricts hot water flow through the showerhead once the water reaches a set point (generally 95F or lower).

This measure was developed to be applicable to the following program types: RF, NC, DI. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a thermostatic restrictor shower valve installed on a residential showerhead.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the residential showerhead without the restrictor valve installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years. [129]

DEEMED MEASURE COST

The incremental cost of the measure should be the actual program cost (including labor if applicable) or $30[130] plus $20 labor[131] if not available.

LOADSHAPE

Water Heating RES

COINCIDENCE FACTOR

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0000887318

[129] Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead

[130] Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.

[131] Estimate for contractor installation time.

Algorithm

Calculation of Energy Savings

Electric Energy Savings

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	16%[132]

GPM_base_S = Flow rate of the base case showerhead, or actual if available

Program	GPM
Direct-install, device only	1.5[133]
New Construction or direct install of device and low flow showerhead	Rated or actual flow of program-installed showerhead
Retrofit or TOS	2.35[134]

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes[135]

Household = Average number of people per household

132 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

133 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0. pp. 184. 2016. Available Online: http://ilsagfiles.org/SAG_files/Technical_Reference _Manual/Version_5/Final/IL-TRM_Version_5.0_dated_February-11-2016_Final_Compiled_Volumes_1-4.pdf. Assumes low flow showerhead is included in direct installation.

134 Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

135 Average of the following sources: ShowerStart LLC survey; "Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart", City of San Diego Water Department survey; "Water Conservation Program: ShowerStart Pilot Project White Paper", and PG&E Work Paper PGECODHW113.

Household Unit Type[136]	Household
Single-Family - Deemed	2.67[137]
Multi-Family - Deemed	2.07[138]
Custom	Actual Occupancy or Number of Bedrooms[139]

SPCD = Showers Per Capita Per Day

= 0.66[140]

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

Household Type	SPH
Single-Family	2.05[141]
Multi-Family	1.4[142]
Custom	Actual

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (105 – 61.3)) / (0.98 * 3412)

= 0.109 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

= 105F [143]

SupplyTemp = Assumed temperature of water entering house

136 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.
137 MO TRM 2017 - Low Flow Showerheads 3.3.2
138 MO TRM 2017 - Low Flow Showerheads 3.3.2
139 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
140 DeOreo, William, P. Mayer, L. Martien, M. Hayden, A. Funk, M. Kramer-Duffield, and R. Davis (2011). "California SingleFamily
Water Use Efficiency Study."
141 MO TRM 2017 - Low Flow Showerheads 3.3.2
142 MO TRM 2017 - Low Flow Showerheads 3.3.2
143 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0. 2016. pp 103. Available Online: http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Version_5.0_dated_February-11-2016_Final_Compiled_Volumes_1-4.pdf

= 61.3F [144]

RE_electric = Recovery efficiency of electric water heater

= 98% [145]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependent on program delivery method as listed in table below

Selection	ISR
Direct Install - Single Family	0.91
Direct Install – Multi Family	0.91[146]
Efficiency Kits	To be determined through evaluation

EXAMPLE

For example, a direct installed valve in a single-family home with electric DHW:

ΔkWh = 1.0 * (2.67 * 0.89 * 1.5 * 0.66 * 365.25 / 2.05) * 0.108 * 0.91

= 42 kWh

Summer Coincident Peak Demand Savings

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25) * 0.712[147] / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

= 34.4 for SF Direct Install; 28.3 for MF Direct Install

= 30.3 for SF Retrofit and TOS; 24.8 for MF Retrofit and TOS

Water Heating RES

[144] Ameren Missouri 2012 Technical Resource Manual. Appendix A. pp. 43. Available online: https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935658483
[145] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx
[146] Based upon Ameren Missouri Community Savers Evaluation
[147] 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

EXAMPLE

For example, a direct installed thermostatic restrictor device in a single family home with electric DHW where the number of showers is not known.

ΔkW = 85.3/34.4 * 0.0022

= 0.0055 kW

Natural Gas Savings

ΔTherms = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	84%[148]

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[149]

= 67% For MF homes[150]

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

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[148] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[149] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[150] Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.

EXAMPLE

For example, a direct installed thermostatic restrictor device in a gas fired DHW single family home where the number of showers is not known:

ΔTherms = 1.0 * ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98

= 3.7 therms

Water Impact Descriptions and Calculation

Δgallons = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

EXAMPLE

For example, a direct installed thermostatic restrictor device in a single family home where the number of showers is not known:

Δgallons = ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98

= 730 gallons

Deemed O&M Cost Adjustment Calculation

N/A

Sources

Source ID	Reference
1	2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011.
2	2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.
3	1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999.
4	2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003.
5	2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.
6	2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011.
7	2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.
8	2011, Lutz, Jim. "Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems", Energy Analysis Department Lawrence Berkeley National Laboratory, September 2011.
9	2008, Water Conservation Program: ShowerStart Pilot Project White Paper, City of San Diego,

Source ID	Reference
	CA.
10	2012, Pacific Gas and Electric Company, Work Paper PGECODHW113, Low Flow Showerhead and Thermostatic Shower Restriction Valve, Revision # 4, August 2012.
11	2008, "Simply & Cost Effectively Reducing Shower Based Warm-Up Waste: Increasing Convenience & Conservation by Attaching ShowerStart to Existing Showerheads", ShowerStart LLC.
12	2014, New York State Record of Revision to the TRM, Case 07-M-0548, June 19, 2014.

3.2.7 Hot Water Measure Kit

This measure was not characterized for Version 1 of the Natural Gas Statewide TRM.

3.3 HVAC End Use

3.3.1 Advanced Thermostat

DESCRIPTION

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[151] This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Like programmable thermostats, it is not suitable to assume that heating and cooling savings follow a similar pattern of usage and savings opportunity, and so here too this measure treats these savings independently. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed.[152] That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations. Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple advanced thermostats per home does not accrue additional savings.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[153] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default

[151] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home's thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

[152] The ENERGY STAR® program discontinued its support for basic programmable thermostats effective 12/31/09, and is presently developing a new specification for 'Residential Climate Controls'.

[153] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. It is recommended that program implementations incorporate this data into their planning and operation activities to improve understanding of the measure to manage risks and enhance savings results.

capabilities described above.

DEFINITION OF BASELINE EQUIPMENT

The baseline is either the actual type (manual or programmable) if it is known,[154] or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may be assumed[155].

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years[156] based upon equipment life only.[157]

DEEMED MEASURE COST

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. For retail, Bring Your Own Thermostat (BYOT) programs[158], or other program types actual costs are still preferable[159] but if unknown then the average incremental cost for the new installation measure is assumed to be $175[160].

LOADSHAPE

Cooling RES

Heating RES (use only this loadshape for gas savings)

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[154] If the actual thermostat is programmable and it is found to be used in override mode or otherwise effectively being operated like a manual thermostat, then the baseline may be considered to be a manual thermostat

[155] Value for blend of baseline thermostats comes from an IL Potential Study conducted by ComEd in 2013; Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013.

[156] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

[157] Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a number of savings studies that only lasted a single year or less, the longer term impacts should be assessed.

[158] In contrast to program designs that utilize program affiliated contractors or other trade ally partners that support customer participation through thermostat distribution, installation and other services, BYOT programs enroll customers after the time of purchase through online rebate and program integration sign-ups.

[159] Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

[160] Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh^{161} = \Delta kWh_{heating} + \Delta kWh_{cooling}$$

$$\Delta kWh_{heating} = \%ElectricHeat * HeatingConusmption_{Electric} * HF * HeatingReduction * Eff\_ISR + (\Delta Therms * Fe * 29.3)$$

$$\Delta kWh_{cool} = \%AC * ((EFLHcool * CapacityCool * 1/SEER)/1000) * CoolingReduction * Eff\_ISR$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Natural Gas	0%
Unknown	35%[162]

$HeatingConsumption_{Electric}$ = Estimate of annual household heating consumption for electrically heated single-family homes[163].

Climate Region (City based upon)	Elec_Heating_ Consumption (kWh)		
	Electric Resistance	Electric Heat Pump	Unknown Electric[164]
North East (Fort Madison, IA)	17,940	10,553	17,017
North West (Lincoln, NE)	19,664	11,567	18,652
South East (Cape Girardeau, MO)	13,502	7,943	12,807
South West (Kaiser, MO)	14,276	8,398	13,541
St Louis, MO	14,144	8,320	13,416
Kansas City, MO	16,272	9,572	15,435
Average/Unknown (Knob Noster)	16,184	9,520	15,351

161 Electrical savings are a function of both heating and cooling energy usage reductions. For heating this is a function of the percent of electric heat (heat pumps) and fan savings in the case of a natural gas furnace.

162 Average (default) value of 35% electric space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

163 Values in table are based on converting an average household heating load (834 therms) for Chicago based on Illinois furnace metering study ('Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013) to an electric heat load (divide by 0.03413) to electric resistance and ASHP heat load (resistance load reduced by 15% to account for distribution losses that occur in furnace heating but not in electric resistance while ASHP heat is assumed to suffer from similar distribution losses) and then to electric consumption assuming efficiencies of 100% for resistance and 200% for HP (see 'Thermostat_FLH and Heat Load Calcs.xls'). The other climate region values are calculated using Climate Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions..

164 Assumption that 12.5% of electrically heated homes in Missouri have Heat Pumps, based on 2009 Residential Energy Consumption Survey for Missouri.

HF = Household factor, to adjust heating consumption for non-single-family households.

Household Type	HF
Single-Family	100%
Multi-Family	65%[165]
Actual	Custom[166]

HeatingReduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat

Existing Thermostat Type	Heating_Reduction[167]
Manual	8.8%
Programmable	5.6%
Unknown (Blended)	7.4%

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication

= If programs are evaluated during program deployment then custom ISR assumptions should be applied. If in service rate is captured within the savings percentage, ISR should be 100%. If using default savings, use 100%[168] .

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[169]

29.3 = kWh per therm

%AC = Fraction of customers with thermostat-controlled air-conditioning

Thermostat control of air conditioning?	%AC
Yes	100%

165 Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% reduction factor is applied to MF homes with electric resistance, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes

166 Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

167 These values represent adjusted baseline savings values for different existing thermostats as presented in Navigant's IL TRM Workpaper on Impact Analysis from Preliminary Gas savings findings (page 28). The unknown assumption is calculated by multiplying the savings for manual and programmable thermostats by their respective share of baseline. Further evaluation and regular review of this key assumption is encouraged.

168 As a function of the method for determining savings impact of these devices, in-service rate effects are already incorporated into the savings value for heating reduction above.

169 F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

Thermostat control of air conditioning?	%AC
No	0%
Unknown	Actual population data, or 91%[170]

$EFLH_{cool}$ = Equivalent full load hours of air conditioning

= dependent on location[171]:

Climate Region (City based upon)	$EFLH_{cool}$ (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

CapacityCool = Capacity of Air Cooling system (Btu/hr) (Note: One ton is equal to 12,000 Btu/hr.)

= Actual installed - If actual size unknown, assume 36,000 Btu/h

SEER = the cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)

= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 13[172].

1/1000 = kBtu per Btu

CoolingReduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat

= If programs are evaluated during program deployment then custom savings assumptions should be applied. Otherwise use:

= 8.0%[173]

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170 91% of homes have central cooling in Missouri (based on 2009 Residential Energy Consumption Survey, see "RECS 2009 Air Conditioning_hc7.9.xls").

171 Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other climate region values are calculated using the relative Climate Normals Cooling Degree Day ratios (at 65F set point).

172 Based on Minimum Federal Standard; http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html.

173 This assumption is based upon the review of many evaluations from other regions in the US. Cooling savings are more variable than heating due to significantly more variability in control methods and potential population and product capability.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW \quad = \Delta kWh_{cooling} * CF$$

Where:

$kWh_{cooling}$ = Electric energy savings for cooling, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[174]

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \%FossilHeat * HeatingConusmption_{Gas} * HF * HeatingReduction * Eff\_ISR$$

Where:

%FossilHeat = Percentage of heating savings assumed to be Natural Gas

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	65%[175]

$HeatingConsumption_{Gas}$

= Estimate of annual household heating consumption for gas heated single-family homes[176].

Climate Region (City based upon)	Gas_Heating_ Consumption (Therms)
North East (Fort Madison, IA)	863
North West (Lincoln, NE)	946
South East (Cape Girardeau, MO)	649
South West (Kaiser, MO)	686
St Louis, MO	680

[174] 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

[175] Average (default) value of 65% gas space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

[176] Values in table are based on average household heating load (834 therms) for Chicago based on Illinois furnace metering study ('Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013) and adjusted for Missouri climate region values using the relative Climate Normal HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions. This load value is then divided by standard assumption of existing unit efficiency of 83.5% (estimate based on 29% of furnaces purchased in Missouri were condensing in 2000 (based on data from GAMA, provided to Department of Energy) (see 'Thermostat_FLH and Heat Load Calcs.xls'). The resulting values are generally supported by data provided by Laclede Gas that showed an average pre-furnace replacement consumption of 1009 therms for St Louis, and a post-replacement consumption of 909. Assuming a typical hot water consumption at 225 therms (using defaults from http://energy.gov/eere/femp/energy-cost-calculator-electric-and-gas-water-heaters-0#output), this indicates a heating load of 684-784 therms.

Climate Region (City based upon)	Gas_Heating_ Consumption (Therms)
Kansas City, MO	783
Average/Unknown (Knob Noster)	778

Other variables as provided above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

3.3.2 Boiler

DESCRIPTION

High-efficiency boilers achieve most gas savings through the use of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gases. Because multiple heat exchangers are used to remove waste heat from the escaping flue gases, some of the flue gases condense and must be drained.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

a) Time of Sale or New Construction:

The installation of a new, residential sized (<300,000 Btu/hr), high-efficiency, gas-fired hot water boiler in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

The early removal of an existing, functional boiler from service, prior to its natural end of life, and replacement with a new, residential sized (<300,000 Btu/hr), high-efficiency, gas-fired hot water boiler in a residential location. Savings are based on the difference between the existing unit and efficient unit's consumption during the remaining life of the existing unit, and between the new baseline unit and efficient unit's consumption for the remainder of the measure life.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new, residential sized (<300,000 Btu/hr), gas-fired hot water boiler with an annual fuel utilization efficiency (AFUE) rating that meets the minimum standards according to utility program requirements.

DEFINITION OF BASELINE EQUIPMENT

Time of Sale or New Construction: The baseline equipment is a new, residential sized (<300,000 Btu/hr), gas-fired hot water boiler with an AFUE rating that meets minimum federal energy efficiency standards.

Early Replacement: The baseline is the existing boiler, for the remaining useful life of the unit. For the remainder of the measure life, the baseline is a new boiler with an AFUE rating that meets minimum federal energy efficiency standards.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Time of Sale or New Construction: The expected measure life is assumed to be 26.5 years.[177]

Early Replacement: The remaining life of the existing boiler is assumed to be 9 years.[178]

DEEMED MEASURE COST

The incremental cost for this measure depends on boiler type (hot water or steam) and efficiency, as listed in the table below.[179]

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[177] Average lifetime from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. U.S. Department of Energy, December 22, 2015.

[178] Assumed to be approximately one third of effective useful life.

[179] For boilers with input <300,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. U.S. Department of Energy, December 22, 2015.

Incremental Costs for Hot Water Boilers		
Efficiency	**Incremental Equipment Cost (Per Unit)**	**Incremental Total Installed Cost (Per Unit)**
83% AFUE	\$16	\$16
84% AFUE	\$31	\$31
85% AFUE	\$187	\$278
90% AFUE	\$776	\$884
92% AFUE	\$1,126	\$1,234
96% AFUE	\$3,899	\$1,924

Incremental Costs for Steam Boilers		
Efficiency	**Incremental Equipment Cost (Per Unit)**	**Incremental Total Installed Cost (Per Unit)**
82% AFUE	\$40	\$64
83% AFUE	\$319	\$370

LOADSHAPE

Heating RES

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Early Replacement:

ΔTherms for remaining life of existing unit (first 9 years):

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Exist}}{AFUE_{Exist}}\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 17.5 years):

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Where:

EFLH = Equivalent full load hours for heating

= Dependent on location:[180]

Climate Region (City based upon)	EFLH (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

Capacity = Nominal heating input capacity (Btu/hr) of efficient boiler

= Actual

$AFUE_{EE}$ =Efficiency rating of high efficiency boiler

= Actual

$AFUE_{Base}$ = Efficiency rating of baseline boiler

= 82% AFUE[181]

$AFUE_{Exist}$ = Efficiency rating of existing boiler

= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown, assume 61.6% AFUE.[182]

100,000 = Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE:

[180] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other climate region values are calculated using the relative Climate Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions

[181] Federal efficiency standard for hot water, gas-fired residential boilers with input <300,000 Btu/hr from 10 CFR 431.87.

[182] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

3.3.3 Duct Sealing and Duct Repair

DESCRIPTION

This measure describes evaluating the savings associated with performing duct sealing to the distribution system of homes with central cooling and/or a ducted heating system. While sealing ducts in conditioned space can help with control and comfort, energy savings are largely limited to sealing ducts in unconditioned space where the heat loss is to outside the thermal envelope. Therefore, for this measure to be applicable, at least 30% of ducts should be within unconditioned space (e.g., attic with floor insulation, vented crawlspace, unheated garages. Basements should be considered conditioned space).

Three methodologies for estimating the savings associate from sealing the ducts are provided.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p. 44 of the Energy Conservatory Blower Door Manual; http://dev.energyconservatory.com/wp-content/uploads/2014/07/Blower-Door-model-3-and-4.pdf.
   It involves performing a whole house depressurization test and repeating the test with the ducts excluded.
2. **Duct Blaster Testing** - as described in RESNET Test 803.7: http://www.resnet.us/standards/DRAFT_Chapter_8_July_22.pdf

   This involves using a blower door to pressurize the house to 25 Pascals and pressurizing the duct system using a duct blaster to reach equilibrium with the inside. The air required to reach equilibrium provides a duct leakage estimate.
3. **Deemed Savings per Linear Foot** – this method provides a deemed conservative estimate of savings and should only be used where performance testing described above is not possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is sealed duct work throughout the unconditioned space in the home.

DEFINITION OF BASELINE EQUIPMENT

The existing baseline condition is leaky duct work with at least 30% of the ducts within the unconditioned space in the home.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of this measure is 20 years.[183]

DEEMED MEASURE COST

The actual duct sealing measure cost should be used.

LOADSHAPE

HVAC RES for electric savings

Heating RES (Use this loadshape for gas savings)

[183] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Modified Blower Door Subtraction

a. Determine Duct Leakage rate before and after performing duct sealing:

$$Duct\ Leakage\ (CFM50_{DL}) = (CFM50_{Whole\ House} - CFM50_{Envelope\ Only}) * SCF$$

Where:

$CFM50_{Whole\ House}$ = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential

$CFM50_{Envelope\ Only}$ = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed

SCF = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure with respect to the building in the sealed duct system, with the building pressurized to 50 Pascals with resepct to the outside. Use the following look up table provided by Energy Conservatory to determine the appropriate subtraction correction factor:

House to Duct Pressure	Subtraction Correction Factor
50	1.00
49	1.09
48	1.14
47	1.19
46	1.24
45	1.29
44	1.34
43	1.39
42	1.44
41	1.49
40	1.54
39	1.60
38	1.65
37	1.71
36	1.78
35	1.84
34	1.91
33	1.98
32	2.06
31	2.14

House to Duct Pressure	Subtraction Correction Factor
30	2.23
29	2.32
28	2.42
27	2.52
26	2.64
25	2.76
24	2.89
23	3.03
22	3.18
21	3.35
20	3.54
19	3.74
18	3.97
17	4.23
16	4.51
15	4.83
14	5.20
13	5.63
12	6.12
11	6.71

b. Calculate duct leakage reduction, convert to $CFM25_{DL}$[184], and factor in Supply and Return Loss Factors:

$$Duct\ Leakage\ Reduction\ (\Delta CFM25_{DL}) = (Pre\ CFM50_{DL} - Post\ CFM50_{DL}) * 0.64 * (SLF + RLF)$$

Where:

0.64 = Converts $CFM50_{DL}$ to $CFM25_{DL}$[185]

SLF = Supply Loss Factor[186]

= % leaks sealed located in Supply ducts * 1

Default = 0.5[187]

RLF = Return Loss Factor[188]

= % leaks sealed located in Return ducts * 0.5

Default = 0.25[189]

c. Calculate electric savings

$$\Delta kWh = \Delta kWhCooling + \Delta kWhHeating$$

$$\Delta kWhCooling = \frac{\frac{\Delta CFM25_{DL}}{(CapacityCool/12000 * 400)} * EFLHcool * CapacityCool}{1000 * SEER}$$

$$\Delta kWhHeating_{Electric} = \frac{\frac{\Delta CFM25_{DL}}{(CapacityHeat/12000 * 400)} * EFLHheat * CapacityHeat}{COP * 3412}$$

$$\Delta kWhHeating_{Gas} = (\Delta Therms * Fe * 29.3)$$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM2 as calculated above

CapacityCool = Capacity of Air Cooling system (Btu/hr)

= Actual

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184 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions.

185 To convert CFM50 to CFM25, multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).

186 Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from Energy Conservatory Blower Door Manual.

187 Assumes 50% of leaks are in supply ducts.

188 Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than "average" (e.g., pulling return air from a super-heated attic), or can be adjusted downward to represent significantly less energy loss (e.g., pulling return air from a moderate temperature crawl space). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from Energy Conservatory Blower Door Manual.

189 Assumes 50% of leaks are in return ducts.

12,000 = Converts Btu/H capacity to tons

400 = Conversion of Capacity to CFM (400CFM / ton) [190]

EFLHcool = Equivalent Full Load Cooling Hours

= Dependent on location[191]:

Climate Region (City based upon)	EFLHcool (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

1000 = Converts Btu to kBtu

SEER = Efficiency in SEER of Air Conditioning equipment

= Actual - If not available, use[192]:

Equipment Type	Age of Equipment	SEER Estimate
Central AC	Before 2006	10
	After 2006	13
Heat Pump	Before 2006	10
	2006-2014	13
	2015 on	14

CapacityHeat = Heating output capacity (Btu/hr) of electric heat

= Actual

EFLHheat = Equivalent Full Load Heating Hours

= Dependent on location[193]:

[190] This conversion is an industry rule of thumb; e.g., see http://www.hvacsalesandsupply.com/Linked%20Documents/Tech%20Tips/61-Why%20400%20CFM%20per%20ton.pdf

[191] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other climate region values are calculated using the relative Climate Normals Cooling Degree Day ratios (at 65F set point).

[192] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[193] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other climate region values are calculated using the relative Climate Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

Climate Region (City based upon)	EFLHheat (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

COP = Efficiency in COP of Heating equipment

= Actual - If not available, use[194]:

System Type	Age of Equipment	HSPF Estimate	COP (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

3412 = Converts Btu to kWh

ΔTherms = Therm savings as calculated in Natural Gas Savings

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[195]

29.3 = kWh per therm

<u>Methodology 2: Duct Blaster Testing</u>

$$\Delta kWh = \Delta kWhCooling + \Delta kWhHeating$$

$$\Delta kWhCooling = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityCool/12000 * 400} * EFLHcool * CapacityCool}{1000 * SEER}$$

[194] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

[195] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e.

$$\Delta kWhHeating_{Electric} = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityCool/12000 * 400} * EFLHheat * CapacityHeat}{COP * 3412}$$

$$\Delta kWhHeating_{Gas} = (\Delta Therms * Fe * 29.3)$$

Where:

Pre_CFM25 = Duct leakage in CFM25 as measured by duct blaster test before sealing

Post_CFM25 = Duct leakage in CFM25 as measured by duct blaster test after sealing

All other variables as provided above

Methodology 3: Deemed Savings[196]

$$\Delta kWh = \Delta kWhcooling + \Delta kWhHeating$$

$$\Delta kWhcooling = CoolSavingsPerUnit * Duct_{Length}$$

$$\Delta kWhHeating_{Electric} = HeatSavingsPerUnit * Duct_{Length}$$

$$\Delta kWhHeating_{Gas} = (\Delta Therms * Fe * 29.3)$$

Where:

CoolSavingsPerUnit = Annual cooling savings per linear foot of duct

Building Type	HVAC System	CoolSavingsPerUnit (kWh/ft)
Multifamily	Cool Central	0.70
Single-family	Cool Central	0.81
Multifamily	Heat Pump—Cooling	0.70
Single-family	Heat Pump—Cooling	0.81

$Duct_{Length}$ = Linear foot of duct

= Actual

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

Building Type	HVAC System	HeatSavingsPerUnit (kWh/ft)
Manufactured	Heat Pump—Heating	5.06
Multifamily	Heat Pump - Heating	3.41
Single-family	Heat Pump— Heating	4.11

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

[196] Savings per unit are based upon analysis performed by Cadmus for the 2011 IA Joint Assessment of Potential. It was based on 10% savings in system efficiency. This would represent savings from homes with significant duct work outside of the thermal envelope. With no performance testing or verification, a deemed savings value should be very conservative and therefore the values provided in this section represent half of the savings – or 5% improvement. These values are provided as a conservative deemed estimate for Missouri, while encouraging the use of performance testing and verification for determination of more accurate savings estimates.

$kWh_{cooling}$ = Electric energy savings for cooling, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[197]

NATURAL GAS SAVINGS

For homes with Natural Gas Heating:

Methodology 1: Modified Blower Door Subtraction

$$\Delta Therm = \frac{\frac{\Delta CFM25_{DL}}{CapacityHeat * 0.0136} * EFLHheat * CapacityHeat * \frac{\eta Equipment}{\eta System}}{100{,}000}$$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25

= As calculated in Methodology 1 under electric savings

CapacityHeat = Heating input capacity (Btu/hr)

= Actual

0.0125 = Conversion of Capacity to CFM (0.0125CFM / Btu/hr)[198]

ηEquipment = Heating Equipment Efficiency

= Actual[199] - If not available, use 83.5%[200]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[201]

= Actual - If not available use 71.0%[202]

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197 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

198 Based on Natural Draft Furnaces requiring 100 CFM per 10,000 Btu, Induced Draft Furnaces requiring 130CFM per 10,000Btu and Condensing Furnaces requiring 150 CFM per 10,000 Btu (rule of thumb from http://contractingbusiness.com/enewsletters/cb_imp_43580/). Data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggested that in 2000, 29% of furnaces purchased in Missouri were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 125 per 10,000Btu or 0.0125/Btu.

199 The Equipment Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.
If there is more than one heating system, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

200 In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the state. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: (0.29*0.92) + (0.71*0.8) = 0.835.

201 The Distribution Efficiency can be estimated via a visual inspection and by referring to a look-up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

202 Estimated as follows: 0.835 * (1-0.15) = 0.710.

100,000 = Converts Btu to therms

Methodology 2: Duct Blaster Testing

$$\Delta Therms = \frac{\frac{Pre\_CFM25 - Post\_CFM25}{CapacityHeat * 0.0136} * EFLHgasheat * CapacityHeat * \frac{\eta Equipment}{\eta System}}{100{,}000}$$

Where:

All variables as provided above

Methodology 3: Deemed Savings[203]

$$\Delta Therms = HeatSavingsPerUnit * Duct_{Length}$$

Where:

HeatSavingsPerUnit = Annual heating savings per linear foot of duct

Building Type	HVAC System	HeatSavingsPerUnit (Therms/ft)
Multifamily	Heat Central Furnace	0.19
Single-family	Heat Central Furnace	0.21

$Duct_{Length}$ = Linear foot of duct

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[203] Savings per unit are based upon analysis performed by Cadmus for the 2011 Joint Assessment of Potential. It was based on 10% savings in system efficiency. This would represent savings from homes with significant duct work outside of the thermal envelope. With no performance testing or verification, a deemed savings value should be very conservative and therefore the values provided in this section represent half of the savings – or 5% improvement. These values are provided as a conservative deemed estimate for Missouri, while encouraging the use of performance testing and verification for determination of more accurate savings estimates.

3.3.4 Furnace

Description

High-efficiency gas furnaces achieve savings through the use of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained.

This measure was developed to be applicable to the following program type: TOS, NC, EREP:

a) Time of Sale or New Construction:

The installation of a new, residential sized (<225,000 Btu/hr), high-efficiency gas furnace in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

The early removal of an existing, functional furnace from service, prior to its natural end of life, and replacement with a new, residential sized (<225,000 Btu/hr), high-efficiency, gas furnace in a residential location. Savings are based on the difference between the existing unit and efficient unit's consumption during the remaining life of the existing unit, and between the new baseline unit and efficient unit's consumption for the remainder of the measure life.

If applied to other program types, the measure savings should be verified.

Definition of Efficient Equipment

To qualify for this measure, the installed equipment must be a new, residential sized (<225,000 Btu/hr) gas furnace with an annual fuel utilization efficiency (AFUE) rating that meets the minimum standards according to utility program requirements.

Definition of Baseline Equipment

Time of Sale or New Construction: The baseline equipment is a new residential sized (<225,000 Btu/hr) gas furnace with an AFUE rating that meets minimum federal energy efficiency standards.

Early Replacement: The baseline is the existing furnace, for the remaining useful life of the unit. For the remainder of the measure life, the baseline is a new furnace with an AFUE rating that meets minimum federal energy efficiency standards.

Deemed Lifetime of Efficient Equipment

Time of Sale or New Construction: The expected measure life is assumed to be 19 years.[204]

Early Replacement: The remaining life of the existing furnace is assumed to be 6 years.[205]

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[204] Average of 15-year lifetime from Residential Heating and Cooling Systems Initiative Description. Consortium for Energy Efficiency, May 28, 2015 and 23-year lifetime from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces. U.S. Department of Energy, December 15, 2015.

[205] Assumed to be approximately one third of effective useful life.

DEEMED MEASURE COST

The incremental cost for this measure depends on furnace efficiency, as listed in the table below.[206]

Furance Capacity	Efficiency	Incremental Equipment Cost (Per Unit)	Incremental Total Installed Cost (Per Unit)
<225,000 Btu/hr	90% AFUE	$163.16	$477.93
	92% AFUE	$179.19	$493.96
	95% AFUE	$313.45	$628.22
	98% AFUE	$505.76	$820.53

LOADSHAPE

Heating RES

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Early Replacement:

ΔTherms for remaining life of existing unit (first 6 years):

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Exist}}{AFUE_{Exist}}\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 13 years):

$$\Delta Therms = \frac{EFLH * Capacity * \left(\frac{AFUE_{EE} - AFUE_{Base}}{AFUE_{Base}}\right)}{100{,}000}$$

Where:

[206] For furnaces with input <225,000 Btu/hr, incremental costs are from Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces. U.S. Department of Energy, February 10, 2015.

EFLH = Equivalent full load hours for heating

= Dependent on location[207]:

Climate Region (City based upon)	EFLH(Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

Capacity = Nominal heating input capacity (Btu/hr) of efficient furnace

= Actual

$AFUE_{EE}$ = Efficiency rating of high efficiency furnace

= Actual

$AFUE_{Base}$ = Efficiency rating of baseline furnace

= 80% AFUE[208]

$AFUE_{Exist}$ = Efficiency rating of existing furnace

= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown, assume 64.4 AFUE%[209]

100,000 = Factor to convert Btus to therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[207] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other climate region values are calculated using the relative Climate Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.
[208] Federal standard for furnaces <225,000 Btu/hr from 10 CFR 430.32.
[209] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren, IL PY3-PY4 (2010-2012).

3.3.5 Standard Programmable Thermostat

DESCRIPTION

This measure characterizes the household energy savings from the installation of a new standard programmable thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times.

Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple programmable thermostats per home does not accrue additional savings.

If the home has a Heat Pump, a programmable thermostat specifically designed for heat pumps should be used to minimize the use of backup electric resistance heat systems.

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature set point.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected equipment life of a programmable thermostat is assumed to be 10 years[210].

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown (e.g. through a retail program), the capital cost for the new installation is assumed to be $70[211].

LOADSHAPE

Cooling RES

Heating RES (use only this loadshape for gas savings)

Algorithm

[210] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007. Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer term impacts should be assessed.

[211] Market prices vary significantly in this category, generally increasing with thermostat capability and sophistication. The basic functions required by this measure's eligibility criteria are available on units readily available in the market for $30. Labor is assumed to be one hour at $40 per hour.

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

For central air conditioners and air source heat pumps:

$$\Delta kWhcool = EFLHcool * Capacitycooling * \left(\frac{1}{SEER}\right) * SBdegrees * SF * EF/1000$$

For air source heat pumps there are additional heating savings:

$$\Delta kWhheat = EFLHheat * Capacityheating * \left(\frac{1}{HSPF}\right) * SBdegrees * SF * EF/1000$$

Where:

EFLHcool = Full load cooling hours

=Actual or if unknown, assume

Climate Region (City based upon)	$EFLH_{cool}$ (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

CapacityCooling = Cooling capacity of system in BTU/hr (1 ton = 12,000 BTU/hr)

=Actual or if unknown, assume 21,100[212]

Household Type	Capacity Cool
Single-Family	36,000
Multi-Family	23,400

SEER = SEER efficiency of central air conditioner or air source heat pump

Unit Type	SEER[213]
CAC	10
ASHP	10

HSPF = Heating Season Performance Factor of system

[212] Ameren Missouri Community Savers Impact and Process Evaluation: Program Year 2017

[213] Ameren Missouri Community Savers Impact and Process Evaluation: Program Year 2017: IL-TRM (Based on minimum federal standards between 1992 and 2006)

Unit Type	SEER[214]
Electric Resistance	3.41
ASHP	7.0

FLHheat = Full load heating hours

=Actual or if unknown, assume

Climate Region (City based upon)	$EFLH_{heat}$ (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

CapacityHeating = Heating capacity of system in BTU/hr (1 ton = 12,000 BTU/hr)

=Actual per unit serviced

Unit Type	Capacity Heating[215]	
	Single Family	Multi family
Electric Resistance	48,259	21,000
ASHP	58,240	21,000
Gas	0	0
Unknown	42,250	21,000

SBdegrees = weighted sum of setback degrees to comfort temperature

=Actual per unit serviced **Type**	SBdegrees
SBdegrees-cooling	3.67[216]
SBdegrees-heating	8.0[217]

SF = Savings factors from ENERGY STAR® calculator

Type	SF[218]

[214] Ameren Missouri Community Savers Impact and Process Evaluation: Program Year 2017: IL-TRM (Based on minimum federal standards between 1992 and 2006)

[215] Ameren Missouri Community Savers Impact and Process Evaluation: Program Year 2017: Program data

[216] PY2017 Site Visit Thermostat SB Data

[217] EnergyStar setpoints – MO TRM

[218] EnergyStar Calculator

SF-cooling	6%
SF-heating	3%

EF = Efficiency ratio from Cadmus metering study

Type	SF[219]
EF-cooling	18%
EF-heating	13%

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{cooling} * CF$

Where:

CF = 0.0009474181

N/A due to no savings from cooling during the summer peak period.

NATURAL GAS ENERGY SAVINGS

$$\Delta Therms = \%FossilHeat * HeatingConusmption_{Gas} * HF * Heating_{Reduction} * Eff_{ISR} * PF$$

Where:

%FossilHeat = Percentage of heating savings assumed to be Natural Gas

Heating fuel	%FossilHeat
Electric	0%
Natural Gas	100%
Unknown	65%[220]

$HeatingConsumption_{Gas}$ = Estimate of annual household heating consumption for gas heated single-family homes[221].

Climate Region	Gas_Heating_

[219] Ameren Missouri Low Income and Process Evaluation: program year 2014, p.31

[220] Average (default) value of 65% gas space heating from 2009 Residential Energy Consumption Survey for Missouri. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area, then they should be used.

[221] Values in table are based on average household heating load (834 therms) for Chicago based on Illinois furnace metering study (‘Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013) and adjusted for Missouri climate region values using the relative Climate Normals HDD data with a base temp ratio of 60°F. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. The calculations made in this measure have been based on HDD60. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions. This load value is then divided by standard assumption of existing unit efficiency of 83.5% (estimate based on 29% of furnaces purchased in Missouri were condensing in 2000 (based on data from GAMA, provided to Department of Energy) (see ‘Thermostat_FLH and Heat Load Calcs.xls’). The resulting values are generally supported by data provided by Laclede Gas that showed an average pre-furnace replacement consumption of 1009 therms for St Louis, and a post-replacement consumption of 909. Assuming a typical hot water consumption at 225 therms (using defaults from http://energy.gov/eere/femp/energy-cost-calculator-electric-and-gas-water-heaters-0#output), this indicates a heating load of 684-784 therms.

(City based upon)	Consumption (Therms)
North East (Fort Madison, IA)	863
North West (Lincoln, NE)	946
South East (Cape Girardeau, MO)	649
South West (Kaiser, MO)	686
St Louis, MO	680
Kansas City, MO	783
Average/Unknown (Knob Noster)	778

Other variables as provided above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

3.3.6 Blower Motor

Description

A new furnace with a brushless permanent magnet (BPM) blower motor is installed instead of a new furnace with a lower efficiency motor. This measure characterizes only the electric savings associated with the fan and could be coupled with gas savings associated with a more efficient furnace. Savings decrease sharply with static pressure so duct improvements, and clean, low pressure drop filters can maximize savings. Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-BPM motor would have been used for continuous ventilation too. If the resident runs the BPM blower continuously because it is a more efficient motor and would not run a non-BPM motor that way, savings are near zero and possibly negative. This characterization uses a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin, which accounted for the effects of this behavioral impact.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

Definition of Efficient Equipment

A furnace with a brushless permanent magnet (BPM) blower motor, also known by the trademark ECM, BLDC, and other names.

Definition of Baseline Equipment

A furnace with a non-BPM blower motor.

Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[222]

Deemed Measure Cost

The capital cost for this measure is assumed to be:

Incremental Cost ($)	
$97[223]	Time of Sale
$119.21[224]	Early Replacement

Loadshape

HVAC RES

[222] Consistent with assumed life of a new gas furnace. Table 8.3.3 The Technical support documents for federal residential appliance standards: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf

[223] Adapted from Tables 8.2.3 and 8.2.13 in http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/hvac_ch_08_lcc_2011-06-24.pdf

[224] This represents the delta between a future $475 installation cost (6 years @.0595 rate) & the NPV of that $475. Minnesota TRM, https://www.energy.gov/sites/prod/files/2014/02/f7/case_study_variablespeed_furnacemotor.pdf, https://energy.mo.gov/sites/energy/files/evaluation-of-retrofit-variable-speed-furnace-fan-motors.pdf

Heating RES (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh_{Heating\ Mode} = (1 - \%\ with\ New\ ASHP) \times \left(400\frac{kWh}{year} \times \frac{Heating\ EFLH}{Wisconsin\ Heating\ EFLH}\right)*\mathrm{HF}$$

$$\Delta kWh_{Cooling\ Mode} = (1 - \%\ with\ New\ Central\ Cooling) \times \left(70\frac{kWh}{year} \times \frac{Cooling\ EFLH}{Wisconsin\ CoolingEFLH}\right)*\mathrm{HF}$$

$$\Delta kWh_{Auto\ Circulation} = \left(25\frac{kWh}{year} \times \frac{CoolingEFLH}{Wisconsin\ CoolingEFLH} + 2960\frac{kWh}{year} \times 10\% - 30\frac{kWh}{year}\right) * HF$$

$$\Delta kWh_{Continous\ Circulation} = \left(25\frac{kWh}{year} \times \frac{CoolingEFLH}{Wisconsin\ CoolingEFLH} + 2960\frac{kWh}{year} - 30\frac{kWh}{year}\right) * HF$$

Where:

Parameter	Value
Wisconsin Cooling Savings kWh/year	70.00
Cooling Savings All Systems	25.00
Wisconsin Cooling EFLH	542.50
Wisconsin Heating SavingskWh/year	400.00
Wisconsin Heating EFLH	2,545.25
Wisconsin Circulation Savings kWh/year	2,960.00
% of Circulation Used	10%
Standby losses	30
Missouri Average Heating EFLH	2,218
Missouri Average Cooling EFLH	684
% with New Central Cooling	0.79
% with New ASHP	0.16

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh* CF

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0004660805

NATURAL GAS SAVINGS

Δtherms[225] = - Heating Savings * 0.03412/ AFUE

Where:

0.03412 = Converts kWh to therms

AFUE = Efficiency of the Furnace

= Actual. If unknown assume 95%[226] if in new furnace or 64.4 AFUE%[227] if in existing furnace

Using defaults:

For new Furnace = - (430 * 0.03412) / 0.95

= - 15.4 therms

For existing Furnace = - (430 * 0.03412) / 0.644

= - 22.8 therms

HF = Household factor, to adjust heating consumption for non-single-family households.

Household Type	HF
Single-Family	100%
Multi-Family	65%[228]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[225] The blower fan is in the heating duct so all, or very nearly all, of its waste heat is delivered to the conditioned space. Negative value since this measure will increase the heating load due to reduced waste heat.
[226] Minimum efficiency rating from ENERGY STAR® Furnace Specification v4.0, effective February 1, 2013.
[227] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren IL PY3-PY4.
[228] Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% reduction factor is applied to MF homes with electric resistance, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes

3.3.7 Furnace Tune-Up

DESCRIPTION

This measure is for a natural gas Residential furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure an approved technician must complete the tune-up requirements[229] listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer's recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer's recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer's recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer's
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer's recommendations(if adjustments made, refer to 'Residential Programmable Thermostat' measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

Verified Quality Maintenance:

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and BTU measurement to ensure that existing equipment is operating according to manufacturers' published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Maintenance identifies sub-optimal performance and prescribes a solution during furnace tune ups.

DEFINITION OF BASELINE EQUIPMENT

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

[229] American Standard Maintenance for Indoor Units (see 'HVAC Maintenance American Standard')

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the clean and check tune up is 2 years.[230]

DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune up.

DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure.

LOADSHAPE

Heating RES

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

ΔTherms = (CAPInputPre * EFLH * (1/ Effbefore – 1/ (Effbefore + Ei)))

Where:

Effbefore = Efficiency of the furnace before the tune-up

= Actual

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

EI = Efficiency Improvement of the furnace tune-up measure

= Actual

EFLH = Equivalent Full Load Hours for heating

Climate Region (City based upon)	EFLH(Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

230 Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

3.4 Shell End Use

3.4.1 Air Sealing

DESCRIPTION

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. An estimate of savings is provided in two ways. It is highly recommended that leaks be detected and pre- and post-sealing leakage rates measured with the assistance of a blower-door by qualified/certified inspectors.[231] Where this occurs, an algorithm is provided to estimate the site specific savings. Where test in/test out has not occurred, a conservative deemed assumption is provided.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be assessed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

DEFINITION OF BASELINE EQUIPMENT

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly affects the opportunity for cost-effective energy savings through air sealing.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[232]

DEEMED MEASURE COST

The actual capital cost for this measure should be used.

LOADSHAPE

Building Shell RES

Heating RES (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Test In / Test Out Approach

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

[231] Refer to the Energy Conservatory Blower Door Manual for more information on testing methodologies.
[232] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.

$$= \frac{\left(\frac{CFM50_{Pre} - CFM50_{Post}}{N_{cool}}\right) * 60 * 24 * CDD * DUA * 0.018 * LM}{(1000 * \eta Cool)}$$

$CFM50_{Pre}$ = Infiltration at 50 Pascals as measured by blower door before air sealing

= Actual[233]

$CFM50_{Post}$ = Infiltration at 50 Pascals as measured by blower door after air sealing

= Actual

N_{cool} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on location and number of stories:[234]

Climate Zone (City based upon)	N_cool (by # of stories)			
	1	1.5	2	3
North East (Fort Madison, IA)	43.0	38.1	35.0	31.0
North West (Lincoln, NE)	30.3	26.9	24.6	21.8
South East (Cape Girardeau, MO)	40.9	36.2	33.2	29.4
South West (Kaiser, MO)	41.2	36.5	33.4	29.6
St Louis, MO	34.9	30.9	28.3	25.1
Kansas City, MO	31.3	27.7	25.4	22.5
Average/Unknown (Knob Noster)	35.5	31.4	28.8	25.5

60 * 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location[235]:

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174
South East (Cape Girardeau, MO)	1453
South West (Kaiser, MO)	1344

233 Because the pre- and post-sealing blower door test will occur on different days, there is a potential for the wind and temperature conditions on the two days to affect the readings. There are methodologies to account for these effects. For wind - first if possible, avoid testing in high wind, place blower door on downwind side, take a pre-test baseline house pressure reading and adjust your house pressure readings by subtracting the baseline reading, and use the time averaging feature on the digital gauge, etc. Corrections for air density due to temperature swings can be accounted for with Air Density Correction Factors. Refer to the Energy Conservatory Blower Door Manual for more information.

234 N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets.

235 Based on Climate Normals data with a base temperature of 65°F.

Climate Zone (City based upon)	CDD 65
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [236]

0.018 = Specific Heat Capacity of Air (Btu/ft^3*°F)

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate) - If unknown, assume the following[237]:

Age of Equipment	SEER Estimate
Before 2006	10
2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14

LM = Latent multiplier to account for latent cooling demand

= dependent on location: [238]

Climate Zone (City based upon)	LM
North East (Fort Madison, IA)	5.1
North West (Lincoln, NE)	3.5
South East (Cape Girardeau, MO)	4.5
South West (Kaiser, MO)	3.7
St Louis, MO	3.0
Kansas City, MO	4.0
Average/Unknown (Knob Noster)	3.2

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due

[236] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[237] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[238] The Latent Multiplier is used to convert the sensible cooling savings calculated to a value representing sensible and latent cooling loads. The values are derived from the methodology outlined in Infiltration Factor Calculation Methodology by Bruce Harley, Senior Manager, Applied Building Science, CLEAResult 11/18/2015 and is based upon an 8760 analysis of sensible and total heat loads using hourly climate data.

to air sealing

$$= \frac{\frac{(CFM50_{Pre} - CFM50_{Post})}{N\_heat} * 60 * 24 * HDD * 0.018}{(\eta Heat * 3{,}412)}$$

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on location and building height:[239]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
North East (Fort Madison, IA)	24.9	22.1	20.2	17.9
North West (Lincoln, NE)	23.0	20.4	18.7	16.6
South East (Cape Girardeau, MO)	25.7	22.8	20.9	18.5
South West (Kaiser, MO)	26.6	23.6	21.6	19.2
St Louis, MO	24.0	21.3	19.5	17.3
Kansas City, MO	22.6	20.0	18.4	16.3
Average/Unknown (Knob Noster)	23.8	21.1	19.3	17.1

HDD = Heating Degree Days

= Dependent on location:[240]

Climate Zone (City based upon)	HDD[241]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

239 N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets.

240 The calculations made in this measure have been based on using Climate Normals data with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

241 St Louis and Ameren Missouri Natural Gas are based on HDD65, all others are based on HDD60.

ηHeat = Efficiency of heating system

= Actual - If not available refer to default table below:[242]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 and after	8.2	2.04
Resistance	N/A	N/A	1

3412 = Converts Btu to kWh

Conservative Deemed Approach

$$\Delta kWh = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[243]

Building Type	HVAC System	SavingsPerUnit (kWh/ft)
Manufactured	Central Air Conditioner	0.062
Multifamily	Central Air Conditioner	0.043
Single Family	Central Air Conditioner	0.050
Manufactured	Electric Furnace/Resistance Space Heat	0.413
Multifamily	Electric Furnace/Resistance Space Heat	0.285
Single Family	Electric Furnace/Resistance Space Heat	0.308
Manufactured	Air Source Heat Pump	0.391
Multifamily	Air Source Heat Pump	0.251
Single Family	Air Source Heat Pump	0.308
Manufactured	Air Source Heat Pump - Cooling	0.062
Multifamily	Air Source Heat Pump - Cooling	0.043
Single Family	Air Source Heat Pump - Cooling	0.050
Manufactured	Air Source Heat Pump - Heating	0.329
Multifamily	Air Source Heat Pump - Heating	0.208
Single Family	Air Source Heat Pump - Heating	0.257

242 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

243 The values in the table represent estimates of savings from a 15% improvement in air leakage. The values are half those provided by Cadmus for the Iowa Joint Assessment, based on building simulations performed. While 30% savings are certainly achievable, this represents a thorough job in both the attic and basements and could not be verified without testing. The conservative 15% estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

SqFt = Building conditioned square footage

= Actual

Additional Fan savings

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[244]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

ΔkWh_cooling = As calculated above.

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[245]

NATURAL GAS SAVINGS

Test In / Test Out Approach

If Natural Gas heating:

$$\Delta Therms = \frac{\frac{(CFM50_{Pre} - CFM50_{Post})}{N\_heat} * 60 * 24 * HDD * 0.018}{(\eta Heat * 100{,}000)}$$

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on location and building height:[246]

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
North East (Fort Madison, IA)	24.9	22.1	20.2	17.9
North West (Lincoln, NE)	23.0	20.4	18.7	16.6

244 F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See "Furnace Fan Analysis.xlsx" for reference.

245 Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

246 N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc" and calculation worksheets.

Climate Zone (City based upon)	N_heat (by # of stories)			
	1	1.5	2	3
South East (Cape Girardeau, MO)	25.7	22.8	20.9	18.5
South West (Kaiser, MO)	26.6	23.6	21.6	19.2
St Louis, MO	24.0	21.3	19.5	17.3
Kansas City, MO	22.6	20.0	18.4	16.3
Average/Unknown (Knob Noster)	23.8	21.1	19.3	17.1

HDD = Heating Degree Days

= Dependent on location:[247]

Climate Zone (City based upon)	HDD[248]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[249] - If not available, use 71%[250]

[247] The calculations made in this measure have been based on using Climate Normals data with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.
[248] St. Louis and Ameren Missouri Natural Gas are based on HDD65. All others are based on HDD60.
[249] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf or by performing duct blaster testing.
[250] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

Other factors as defined above

Conservative Deemed Approach

$$\Delta Therms = SavingsPerUnit * SqFt$$

Where:

SavingsPerUnit = Annual savings per square foot, dependent on heating / cooling equipment[251]

Building Type	HVAC System	SavingsPerUnit (Therms/ft)
Manufactured	Gas Boiler	0.022
Multifamily	Gas Boiler	0.018
Single Family	Gas Boiler	0.016
Manufactured	Gas Furnace	0.017
Multifamily	Gas Furnace	0.012
Single Family	Gas Furnace	0.013

SqFt = Building square footage

= Actual

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[251] The values in the table represent estimates of savings from a 15% improvement in air leakage. The values are half those provided by Cadmus for the Iowa Joint Assessment, based on building simulations performed. While 30% savings are certainly achievable, this represents a thorough job in both the attic and basements and could not be verified without testing. The conservative 15% estimate is more appropriate for a deemed estimate. These values should be re-evaluated if EM&V values provide support for a higher deemed estimate.

3.4.2 Ceiling Insulation

DESCRIPTION

This measure describes savings from adding insulation to the attic/ceiling. This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[252]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Cooling RES

Heating RES (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{attic} * (1 - FramingFactor_{Attic}) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Attic} = R-value of new attic assembly including all layers between inside air and outside air (ft^2.°F.h/Btu)

R_{Old} = R-value value of existing assembly and any existing insulation

[252] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

(Minimum of R-5 for uninsulated assemblies[253])

A_{Attic} = Total area of insulated ceiling/attic (ft^2)

$FramingFactor_{Attic}$ = Adjustment to account for area of framing

= 7%[254]

CDD = Cooling Degree Days

= Dependent on location[255]:

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174
South East (Cape Girardeau, MO)	1453
South West (Kaiser, MO)	1344
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [256]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate) - If unknown, assume the following:[257]

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC after 1/1/2015	13
Heat Pump after 1/1/2015	14

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due

[253] An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

[254] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

[255] Based on Climate Normals data with a base temp of 65°F.

[256] This factor's source: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[257] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24 * ADJAttic}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[258]

Climate Zone (City based upon)	HDD [259]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

ηHeat = Efficiency of heating system

= Actual - If not available, refer to default table below:[260]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0
Resistance	N/A	N/A	1.0

3412 = Converts Btu to kWh

ADJ_{Attic} = Adjustment for attic insulation to account for prescriptive engineering algorithms consistently overclaiming savings.

258 The calculations made in this measure have been based on using Climate Normals data with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions

259 St. Louis and Ameren Missouri Natural Gas are based on HDD65. All others are based on HDD60.

260 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

= 74%[261]

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

Where:

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[262]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[263]

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{attic}}\right) * A_{Attic} * (1 - FramingFactor_{Attic}) * HDD * 24 * ADJAttic}{(\eta Heat * 100{,}000)}$$

Where:

HDD = Heating Degree Days

= Dependent on location:[264]

Climate Zone (City based upon)	HDD [265]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau,	3368

[261] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

[262] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See "Furnace Fan Analysis.xlsx" for reference.

[263] Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

[264] The calculations made in this measure have been based on using Climate Normals data with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[265] St. Louis and Ameren Missouri Natural Gas are based on HDD65. All others are based on HDD60.

Climate Zone (City based upon)	HDD [265]
MO)	
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual.[266] If unknown assume 71%[267].

100,000 = Converts Btu to Therms

Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[266] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

[267] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

3.4.3 Duct Insulation

DESCRIPTION

This measure describes evaluating the savings associated with performing duct insulation on the distribution system of homes with central cooling and/or a ducted heating system. While insulating ducts in conditioned space can help with control and comfort, energy savings are largely limited to insulating ducts in unconditioned space where the heat loss is to outside the thermal envelope. Therefore, for this measure to be applicable, at least 30% of ducts should be within unconditioned space (e.g., attic with floor insulation, vented crawlspace, unheated garages. Basements should be considered conditioned space).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is insulated duct work throughout the unconditioned space in the home.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is existing duct work with at least 30% of the ducts within the unconditioned space in the home.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[268]

DEEMED MEASURE COST

The actual duct insulation measure cost should be used.

LOADSHAPE

HVAC RES

Heating RES (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the home and energy saved when heating the home.

$$\Delta kWh = \Delta kWhCooling + \Delta kWhHeating$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWhCooling = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLHcool * \Delta T_{AVG,cooling}}{(1{,}000 * SEER)}$$

[268] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

Where:

$R_{existing}$ = Duct heat loss coefficient with existing insulation ((hr-^{0}F-ft^2)/Btu)

= Actual

R_{new} = Duct heat loss coefficient with new insulation (hr-^{0}F-ft^2)/Btu)

= Actual

Area (ft^2) = Area of the duct surface exposed to the unconditioned space that has been insulated

EFLHcool = Equivalent Full Load Cooling Hours

= Dependent on location[269]:

Climate Region (City based upon)	EFLHcool (Hours)
North East (Fort Madison, IA)	642
North West (Lincoln, NE)	628
South East (Cape Girardeau, MO)	778
South West (Kaiser, MO)	719
St Louis, MO	869
Kansas City, MO	738
Average/Unknown (Knob Noster)	684

$\Delta T_{AVG,cooling}$ = Average temperature difference (^{0}F) during cooling season between outdoor air temperature and assumed 60^{0}F duct supply air temperature[270]

Climate Zone (City based upon)	$OA_{AVG,cooling}$ [°F][271]	$\Delta T_{AVG,cooling}$ [°F]
North East (Fort Madison, IA)	76.2	16.2
North West (Lincoln, NE)	78.8	18.8
South East (Cape Girardeau, MO)	79.4	19.4
South West (Kaiser, MO)	81.3	21.3
St Louis, MO	80.8	20.8
Kansas City, MO	79.0	19.0
Average/Unknown (Knob Noster)	80.7	20.7

269 Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) and reduced by 28.5% based on the evaluation results in Ameren territory suggesting an appropriate EFLH of 869.The other climate region values are calculated using the relative Climate Normals Cooling Degree Day ratios (at 65F set point).

270 Leaving coil air temperatures are typically about 55^{0}F. 60^{0}F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

271 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

1,000 = Converts Btu to kBtu

SEER = Efficiency in SEER of air conditioning equipment

= Actual - If not available, use:[272]

Equipment Type	Age of Equipment	SEER Estimate
Central AC	Before 2006	10
	After 2006	13
Heat Pump	Before 2006	10
	2006-2014	13
	2015 on	14

If the home is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

$$\Delta kWhHeating_{Electric} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLHheat * \Delta T_{AVG,heating}}{(3{,}412 * COP)}$$

Where:

EFLHheat = Equivalent Full Load Heating Hours

= Dependent on location[273]:

Climate Region (City based upon)	EFLHheat (Hours)
North East (Fort Madison, IA)	2459
North West (Lincoln, NE)	2695
South East (Cape Girardeau, MO)	1851
South West (Kaiser, MO)	1957
St Louis, MO	2009
Kansas City, MO	2149
Average/Unknown (Knob Noster)	2218

$\Delta T_{AVG,heating}$ = Average temperature difference (^{0}F) during heating season between outdoor air temperature and assumed 115^{0}F duct supply temperature[274]

[272] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[273] Based on Full Load Hour assumptions (for St Louis and Kansas City) taken from the ENERGY STAR® calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). The other climate region values are calculated using the Climate Normals Heating Degree Day ratios (at 60F set point). NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[274] Forced air supply temperatures are typically 130^{0}F. 115^{0}F is used as an average temperature, recognizing that some heat transfer occurs between the ductwork and the environment it passes through.

Climate Zone (City based upon)	$OA_{AVG,heating}$ [°F][275]	$\Delta T_{AVG,heating}$ [°F]
North East (Fort Madison, IA)	42.1	72.9
North West (Lincoln, NE)	39.0	76.0
South East (Cape Girardeau, MO)	45.7	69.3
South West (Kaiser, MO)	45.0	70.0
St Louis, MO	43.2	71.8
Kansas City, MO	40.3	74.7
Average/Unknown (Knob Noster)	43.4	71.6

3,412 = Converts Btu to kWh

COP = Efficiency in COP of heating equipment

= Actual - If not available, use:[276]

System Type	Age of Equipment	HSPF Estimate	COP (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWhHeating_{Gas} = (\Delta Therms * Fe * 29.3)$$

Where:

ΔTherms = Therm savings as calculated in Natural Gas Savings

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[277]

29.3 = Converts therms to kWh

275 National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3 http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html . Heating Season defined as September 17th through April 13th, cooling season defined as May 20 through August 15th. For cooling season, temperatures from 8AM to 8PM were used to establish average temperatures as this is when cooling systems are expected to be loaded.

276 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

277 F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWhCooling * CF$$

Where:

ΔkWhCooling = Electric energy savings for cooling, calculated above

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[278]

NATURAL GAS SAVINGS

If home uses a gas heating system, the savings resulting from the insulation is calculated with the following formula.

$$\Delta \text{Therms} = \frac{\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) * Area * EFLHheat * \Delta T_{AVG,heating}}{(100{,}000 * \eta\text{Heat})}$$

Where:

All factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[278] 2016 Ameren Missouri Coincident Peak Demand Factor for Residential Cooling. See reference "Ameren Missouri 2016 Appendix E - End Use Shapes and Coincident Factors.pdf"

3.4.4 Floor Insulation

DESCRIPTION

Insulation is added to the floor above a vented crawl space that does not contain pipes or HVAC equipment. If there are pipes, HVAC, or a basement, it is desirable to keep them within the conditioned space by insulating the crawl space walls and ground. Insulating the floor separates the conditioned space above from the space below the floor, and is only acceptable when there is nothing underneath that could freeze or would operate less efficiently in an environment resembling the outdoors. Even in the case of an empty, unvented crawl space, it is still considered best practice to seal and insulate the crawl space perimeter rather than the floor. Not only is there generally less area to insulate this way, but there are also moisture control benefits. There is a “Foundation Sidewall Insulation” measure for perimeter sealing and insulation. This measure assumes the insulation is installed above an unvented crawl space and should not be used in other situations.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no insulation on any surface surrounding a crawl space.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[279]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Building Shell RES

Heating RES (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

[279] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * \ Area * \ (1 - Framing\ Factor) * \ CDD * 24 * \ DUA}{(1000 \ * \ \eta Cool)}$$

R_{Old} = R-value value of floor before insulation, assuming 3/4” plywood subfloor and carpet with pad

= Actual. If unknown assume 3.96 [280]

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

Area = Total floor area to be insulated

Framing Factor = Adjustment to account for area of framing

= 12% [281]

24 = Converts hours to days

CDD = Cooling Degree Days

Climate Zone (City based upon)	Unconditioned Space
	CDD 75 [282]
North East (Fort Madison, IA)	96
North West (Lincoln, NE)	585
South East (Cape Girardeau, MO)	593
South West (Kaiser, MO)	563
St Louis, MO	762
Kansas City, MO	762
Average/Unknown (Knob Noster)	509

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [283]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate). If unknown

[280] Based on 2005 ASHRAE Handbook – Fundamentals: assuming 2x8 joists, 16” OC, ¾” subfloor, ½” carpet with rubber pad, and accounting for a still air film above and below: 1/ [(0.85 cavity share of area / (0.68 + 0.94 + 1.23 + 0.68)) + (0.15 framing share / (0.68 + 7.5” * 1.25 R/in + 0.94 + 1.23 + 0.68))] = 3.96

[281] ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1

[282] The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. Five year average cooling degree days with 75F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72F.

[283] Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Researc,h” p31.

assume the following:[284]

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * HDD * 24 * ADJ_{Floor}}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days:

Climate Zone (City based upon)	Unconditioned Space
	HDD 50 [285]
North East (Fort Madison, IA)	2635
North West (Lincoln, NE)	2973
South East (Cape Girardeau, MO)	1747
South West (Kaiser, MO)	1886
St Louis, MO	1911
Kansas City, MO	2008
Average/Unknown (Knob Noster)	2259

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[286]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0

284 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

285 The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

286 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Resistance	N/A	N/A	1.0

ADJ_{Floor} = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings.

= 88%[287]

Other factors as defined above

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[288]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[289]

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{(R_{Added} + R_{Old})}\right) * Area * (1 - Framing\ Factor) * HDD * 24 * ADJ_{Floor}}{(\eta Heat * 100{,}000)}$$

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

[287] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation. Note that basement wall is used as a proxy for crawlspace ceiling.

[288] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[289] Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

= Actual[290] - If not available, use 71%[291]

100,000 = Converts Btu to Therms

Other factors as defined above.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[290] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf or by performing duct blaster testing.

[291] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

3.4.5 Foundation Sidewall Insulation

DESCRIPTION

Insulation is added to a basement or crawl space. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no basement wall or ceiling insulation.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[292]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Building Shell RES

Heating RES (only use this loadshape for gas savings)

Algorithm

[292] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

Calculation of Savings

Electric Energy Savings

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to Insulation

$$= \frac{\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Added} = R-value of additional spray foam, rigid foam, or cavity insulation.

R_{OldAG} = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0[293]

L_{BWT} = Length (Basement Wall Total) of basement wall around the entire insulated perimeter (ft)

H_{BWAG} = Height (Basement Wall Above Grade) of insulated basement wall above grade (ft)

FF = Framing Factor, an adjustment to account for area of framing when cavity insulation is used

= 0% if Spray Foam or External Rigid Foam

= 25% if studs and cavity insulation[294]

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space

[293] ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991, http://www.ornl.gov/sci/roofs+walls/foundation/ORNL_CON-295.pdf

[294] ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1

	CDD 65 [295]	CDD 75 [296]
North East (Fort Madison, IA)	1200	585
North West (Lincoln, NE)	1174	593
South East (Cape Girardeau, MO)	1453	563
South West (Kaiser, MO)	1344	814
St Louis, MO	1646	762
Kansas City, MO	1360	509
Average/Unknown (Knob Noster)	1278	585

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [297]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following:[298]

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14

295 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

296 The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. Five year average cooling degree days with 75F base temp are provided from DegreeDays.net because the 30 year climate normals from NCDC are not available at base temps above 72F.

297 This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

298 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF)\right) + \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})}\right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF)\right)\right) * HDD * 24 * DUA * ADJ_{Basement}}{(3412 * \eta Heat)}$$

Where

R_{OldBG} = R-value value of foundation wall below grade (including thermal resistance of the earth) [299]

= dependent on depth of foundation (H_basement_wall_total – H_basement_wall_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

For example, for an area that extends 5 feet below grade, an R-value of 7.46 would be selected and added to the existing insulation R-value.

Below Grade R-value									
Depth below grade (ft)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Earth R-value (°F-ft^2-h/Btu)	2.44	4.50	6.30	8.40	10.44	12.66	14.49	17.00	20.00
Average Earth R-value (°F-ft2-h/Btu)	2.44	3.47	4.41	5.41	6.42	7.46	8.46	9.53	10.69
Total BG R-value (earth + R-1.0 foundation) default	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

299 Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

H_{BWT} = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:

Climate Zone (City based upon)	Conditioned Space	Unconditioned Space
	HDD[300]	HDD 50 [301]
North East (Fort Madison, IA)	4475	2,635
North West (Lincoln, NE)	4905	2,973
South East (Cape Girardeau, MO)	3368	1,747
South West (Kaiser, MO)	3561	1,886
St Louis, MO	4486	1,911
Kansas City, MO	4059	2,008
Average/Unknown (Knob Noster)	4037	2,259
Ameren Missouri Natural Gas	4918	

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:[302]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0
Resistance	N/A	N/A	1.0

$ADJ_{Basement}$= Adjustment for basement wall insulation to account for prescriptiveengineering algorithms overclaiming savings.

= 88%[303]

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

F_e = Furnace Fan energy consumption as a percentage of annual fuel

300 St. Louis and Ameren Missouri Natural Gas are based on HDD65. All others are based on HDD60.

301 The base temperature should be the outdoor temperature at which the desired indoor temperature stays constant, in balance with heat loss or gain to the outside and internal gains. Since unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool, they have a bigger delta between the two (heating and cooling) base temperatures. 75F for cooling and 50F for heating are used based on professional judgment. National Climatic Data Center, calculated from 1981-2010 climate normals.

302 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

303 Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

consumption

= 3.14%[304]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[305]

[304] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[305] Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms =

$$= \frac{\left(\left(\left(\frac{1}{R_{OldAG}} - \frac{1}{(R_{Added} + R_{OldAG})}\right) * L_{BWT} * H_{BWAG} * (1 - FF)\right) + \left(\left(\frac{1}{R_{OldBG}} - \frac{1}{(R_{Added} + R_{OldBG})}\right) * L_{BWT} * (H_{BWT} - H_{BWAG}) * (1 - FF)\right)\right) * HDD * 24 * ADJ_{Basement}}{(100{,}000 * \eta Heat)}$$

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[306] - If not available, use 71%[307]

100,000 = Converts Btu to Therms

Other factors as defined above

[306] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf or by performing duct blaster testing.

[307] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

Water Impact Descriptions and Calculation

N/A

Deemed O&M Cost Adjustment Calculation

N/A

3.4.6 Storm Windows

DESCRIPTION

Storm windows installed on either the interior or exterior of existing window assemblies can reduce both heating and cooling loads by reducing infiltration and solar heat gain, and improving insulation properties. Glass options for storm windows can include traditional clear glazing as well as low-emissivity (Low-E) glazing. Low-E glass is formed by adding an ultra-thin layer of metal to clear glass. The metallic-oxide (pyrolytic) coating is applied when the glass is in its molten state, and the coating becomes a permanent and extremely durable part of the glass. This coating is also known as "hard-coat" Low-E. Low-E glass is designed to redirect heat back towards the source, effectively providing higher insulating properties and lower solar heat gain as compared to traditional clear glass. This characterization captures the savings associated with installing storm windows to an existing window assembly (retrofit).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

An interior or exterior storm window installed according to manufacturer specifications.

DEFINITION OF BASELINE EQUIPMENT

The existing window assembly.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

20 years[308]

DEEMED MEASURE COST

The actual capital cost for this measure should be used when available and include both material and labor costs. If unavailable, the cost for a low-e storm window can be assumed as $7.85/ft^2$ of window area (material cost) plus $30 per window for installation expenses[309]. For clear glazing, cost can be assumed as $6.72/ft^2$ of window area (material cost) plus $30 per window for installation expenses[310]

LOADSHAPE

Building Shell RES

Heating RES (only use this loadshape for gas savings)

[308] Task ET-WIN-PNNL-FY13-01_5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones. KA Cort and TD Culp, September 2013. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-22864.

[309] Task ET-WIN-PNNL-FY13-01_5.3: Database of Low-e Storm Window Energy Performance across U.S. Climate Zones. KA Cort and TD Culp, September 2013. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-22864.

[310] A comparison of low-e to clear glazed storm windows available at large national retail outlets showed the average incremental cost for low-e glazing to be $1.13/ft^2$. Installation costs are identical.

Algorithm

CALCULATION OF SAVINGS

The following reference tables show savings factors (kBtu/ft^2) for both heating and cooling loads for each of the seven weather zones defined by the TRM[311]. They are used with savings equations listed in the electric energy and gas savings sections to produce savings estimates. If storm windows are left installed year-round, both heating and cooling savings may be claimed. If they are installed seasonally, only heating savings should be claimed. Savings are dependent on location, storm window location (interior or exterior), glazing type (clear or Low-E) and existing window assembly type.

North East (Fort Madison, IA)

Heating:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	50.1	14.5	50.9	13.3
	CLEAR INTERIOR	52.2	19.2	51.4	15.1
	LOW-E EXTERIOR	54.8	15.0	56.6	20.7
	LOW-E INTERIOR	61.1	22.0	59.3	19.0

Cooling:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	18.0	8.8	17.5	8.0
	CLEAR INTERIOR	18.7	8.7	19.2	8.0
	LOW-E EXTERIOR	23.8	13.3	23.5	7.3
	LOW-E INTERIOR	22.7	11.7	23.1	11.2

North West (Lincoln, NE)

Heating:

311 Savings factors are based on simulation results, documented in “Storm Windows Savings.xlsx”

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	59.4	17.8	60.2	16.3
	CLEAR INTERIOR	61.9	23.0	61.1	18.4
	LOW-E EXTERIOR	65.6	19.1	67.6	24.4
	LOW-E INTERIOR	72.4	26.7	70.5	23.3

Cooling:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	21.9	10.0	21.4	9.1
	CLEAR INTERIOR	22.8	10.1	23.3	9.4
	LOW-E EXTERIOR	28.0	14.6	27.7	8.6
	LOW-E INTERIOR	27.2	13.3	27.5	12.7

South East (Cape Girardeau, MO)

Heating:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	40.4	10.8	41.2	9.9
	CLEAR INTERIOR	42.1	14.9	41.4	11.7
	LOW-E EXTERIOR	43.0	10.1	44.6	16.3
	LOW-E INTERIOR	48.7	16.6	47.1	14.2

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	18.8	9.1	18.3	8.3
	CLEAR INTERIOR	19.6	9.1	20.1	8.3
	LOW-E EXTERIOR	24.8	13.7	24.5	7.7
	LOW-E INTERIOR	23.8	12.2	24.1	11.6

South West (Kaiser, MO)

Heating:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	39.2	10.9	40.0	9.9
	CLEAR INTERIOR	40.8	14.9	40.0	11.4
	LOW-E EXTERIOR	42.6	10.6	44.2	16.7
	LOW-E INTERIOR	48.1	17.0	46.4	14.3

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	20.6	9.9	20.1	8.9
	CLEAR INTERIOR	21.4	9.9	21.9	9.0
	LOW-E EXTERIOR	27.1	14.7	26.8	8.6
	LOW-E INTERIOR	26.1	13.3	26.4	12.6

St Louis, MO

Heating:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	47.7	13.3	48.5	12.3
	CLEAR INTERIOR	49.8	17.9	49.0	14.2
	LOW-E EXTERIOR	51.5	13.3	53.2	19.3
	LOW-E INTERIOR	57.7	20.3	55.9	17.5

Cooling:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	23.0	10.5	22.5	9.6
	CLEAR INTERIOR	23.9	10.7	24.4	9.8
	LOW-E EXTERIOR	29.5	15.4	29.3	9.3
	LOW-E INTERIOR	28.8	14.2	29.0	13.4

Kansas City, MO

Heating:

Savings in kBtu/ft^2		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	57.7	16.8	58.5	15.5
	CLEAR INTERIOR	60.3	22.0	59.5	17.8
	LOW-E EXTERIOR	63.0	17.6	64.8	23.1
	LOW-E INTERIOR	69.8	25.1	67.9	22.0

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	25.4	11.0	24.9	10.1
	CLEAR INTERIOR	26.6	11.4	27.1	10.6
	LOW-E EXTERIOR	31.7	15.7	31.4	9.6
	LOW-E INTERIOR	31.1	14.6	31.4	14.0

Average/Unknown (Knob Noster)

Heating:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	49.2	13.7	50.0	12.7
	CLEAR INTERIOR	51.4	18.4	50.6	14.7
	LOW-E EXTERIOR	53.0	13.7	54.7	19.6
	LOW-E INTERIOR	59.2	20.7	57.5	18.0

Cooling:

Savings in kBtu/ft²		Base Window Assembly			
		SINGLE PANE, DOUBLE HUNG	DOUBLE PANE, DOUBLE HUNG	SINGLE PANE, FIXED	DOUBLE PANE, FIXED
Storm Window Type	CLEAR EXTERIOR	19.7	9.5	19.2	8.6
	CLEAR INTERIOR	20.5	9.5	20.9	8.6
	LOW-E EXTERIOR	25.9	14.2	25.6	8.1
	LOW-E INTERIOR	24.9	12.7	25.2	12.1

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

Where:

ΔkWh_cooling = If storm windows are left installed during the cooling season and the home has central cooling, the reduction in annual cooling requirement due to air sealing

$$= \frac{\Sigma_{cool} * A}{\eta Cool}$$

Σ_{cool} = Savings factor for cooling, as tabulated above.

A = Area (square footage) of storm windows installed.

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate) - If unknown, assume the following[312]:

Age of Equipment	SEER Estimate
Before 2006	10
2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

$$= \frac{\Sigma_{heat} * A}{\eta Heat * 3.412}$$

Σ_{heat} = Savings factor for heating, as tabulated above.

ηHeat = Efficiency of heating system

= Actual - If not available refer to default table below[313]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 and after	8.2	2.04
Resistance	N/A	N/A	1

3.412 = Converts kBtu to kWh

[312] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[313] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

ΔkWh_cooling = As calculated above.

CF = Summer System Peak Coincidence Factor for Cooling

= 0.0009474181[314]

NATURAL GAS SAVINGS

If Natural Gas heating:

$$\Delta Therms = \frac{\Sigma_{heat} * A}{\eta Heat * 100}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[315] - If not available, use 71%[316]

100 = Converts kBtu to Therms

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[314] Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

[315] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf or by performing duct blaster testing.

[316] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

3.4.7 Kneewall and Sillbox Insulation

DESCRIPTION

This measure describes savings from adding insulation (for example, blown cellulose, spray foam) to wall cavities (this includes kneewall and sillbox areas). This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.[317]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Building Shell RES

Heating RES (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$$

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Wall}}\right) * A_{Wall} * (1 - FramingFactor_{Wall}) * CDD * 24 * DUA}{(1000 * \eta Cool)}$$

R_{Wall} = R-value of new wall assembly including all layers between inside air and outside air ($ft^2.°F.h/Btu$)

R_{Old} = R-value value of existing assembly and any existing insulation

[317] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

(ft^2.°F.h/Btu)

(Minimum of R-5 for uninsulated assemblies[318])

A_{Wall} = Net area of insulated wall (ft^2)

$FramingFactor_{Wall}$ = Adjustment to account for area of framing

= 25%[319]

CDD = Cooling Degree Days

= Dependent on location[320]:

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174
South East (Cape Girardeau, MO)	1453
South West (Kaiser, MO)	1344
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

24 = Converts days to hours

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it)

= 0.75 [321]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate) - If unknown, assume the following:[322]

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC after 1/1/2015	13
Heat Pump after 1/1/2015	14

318 An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

319 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1.

320 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temperature of 65°F.

321 This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

322 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Wall}}\right) * A_{wall} * (1 - FramingFactor_{Wall}) * HDD * 24 * ADJWall}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[323]

Climate Zone (City based upon)	HDD[324]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

ηHeat = Efficiency of heating system

= Actual - If not available, refer to default table below:[325]

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.412)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.9
	2015 and after	8.2	2.0
Resistance	N/A	N/A	1.0

3412 = Converts Btu to kWh

ADJ_{Wall} = Adjustment for wall insulation to account for prescriptive engineering

[323] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[324] St. Louis and Ameren Missouri Natural Gas are based on HDD65. All others are based on HDD60.

[325] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

algorithms consistently overclaiming savings

= 63%[326]

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

Where:

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[327]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh_{cooling} * CF$$

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[328]

NATURAL GAS SAVINGS

ΔTherms (if Natural Gas heating)

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{wall}}\right) * A_{wall} * (1 - FramingFactor_{Wall}) * HDD * 24 * ADJWall}{(\eta Heat * 100{,}000)}$$

Where:

HDD = Heating Degree Days

= Dependent on location:[329]

Climate Zone (City based upon)	HDD[330]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905

[326] Based upon comparing algorithm derived savings estimate and evaluated bill analysis estimate in the following 2012 Massachusetts report: "Home Energy Services Impact Evaluation", August 2012. See "Insulation ADJ calculations.xls" for details or calculation.

[327] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See "Furnace Fan Analysis.xlsx" for reference.

[328] Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

[329] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. NOTE: The HDD base temperature for residential measures in the MO-TRM v.1.0 is a non-consensus item. Please refer to Appendix A in Vol 1 of the MO-TRM v1.0 for full documentation of this non-consensus issue and stakeholder positions regarding the appropriate use of HDD60 vs. HDD65. As a non-consensus item, this value should be revisited in future TRM versions.

[330] St. Louis and Ameren Missouri Natural Gas based on HDD65. All others based on HDD60.

Climate Zone (City based upon)	HDD[330]
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[331] - If not available, use 71%[332]

100,000 = Converts Btu to Therms

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[331] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf or by performing duct blaster testing.

[332] This has been estimated assuming that natural gas central furnace heating is typical for Missouri residences (the predominant heating is gas furnace with 48% of Missouri homes (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 29% of furnaces purchased in Missouri were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 16 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows: ((0.29*0.92) + (0.71*0.8)) * (1-0.15) = 0.71.

3.4.8 Door

This measure was not characterized for Version 1 of the Natural Gas TRM.

3.4.9 Wall Insulation

DESCRIPTION

Insulation is added to wall cavities. This measure requires a member of the implementation staff evaluating the pre and post R-values and measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[333]

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

LOADSHAPE

Cooling RES

Heating RES (only use this loadshape for gas savings)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to wall insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{WallCool}$

R_wall = R-value of new wall assembly (including all layers between inside air and outside air).

[333] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

R_old = R-value value of existing assembly and any existing insulation.

(Minimum of R-5 for uninsulated assemblies[334])

A_wall = Net area of insulated wall (ft^2)

Framing_factor_wall = Adjustment to account for area of framing

= 25%[335]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[336]

Climate Zone (City based upon)	CDD 65
North East (Fort Madison, IA)	1200
North West (Lincoln, NE)	1174
South East (Cape Girardeau, MO)	1453
South West (Kaiser, MO)	1344
St Louis, MO	1646
Kansas City, MO	1360
Average/Unknown (Knob Noster)	1278

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [337]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following:[338]

[334] An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

[335] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

[336] National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[337] This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research,"p31.

[338] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

Age of Equipment	ηCool Estimate
Before 2006	10
2006 - 2014	13
Central AC After 1/1/2015	13
Heat Pump After 1/1/2015	14

$ADJ_{WallCool}$ = Adjustment for cooling savings from wall insulation to account for inaccuracies in prescriptive engineering algorithms[339]

= 80%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to wall insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * HDD) / (ηHeat * 3412)) * $ADJ_{WallHeat}$

HDD = Heating Degree Days

= Dependent on location:[340]

Climate Zone	HDD[341]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below:[342]

339 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.

340 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

341 St. Louis and Ameren Missouri Natural Gas are based on HDD65. All others are based on HDD60.

342 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

System Type	Age of Equipment	HSPF Estimate	ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85
Heat Pump	Before 2006	6.8	1.7
	2006 - 2014	7.7	1.92
	2015 on	8.2	2.04
Resistance	N/A	N/A	1

3412 = Converts Btu to kWh

$ADJ_{WallHeat}$ = Adjustment for heating savings to account for inaccuracies in prescriptive engineering algorithms.[343]

= 60%

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * F_e * 29.3

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[344]

29.3 = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh_cooling * CF

Where:

CF = Summer peak coincidence demand (kW) to annual energy (kWh) factor

= 0.0009474181[345]

NATURAL GAS SAVINGS

If Natural Gas heating:

ΔTherms = ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * HDD) / (ηHeat * 100,000 Btu/therm) * $ADJ_{WallHeat}$

Where:

[343] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

[344] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR® version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[345] Based on Ameren Missouri 2016 Loadshape for Residential Cooling End-Use.

HDD = Heating Degree Days

= Dependent on location:[346]

Climate Zone	HDD[347]
North East (Fort Madison, IA)	4475
North West (Lincoln, NE)	4905
South East (Cape Girardeau, MO)	3368
South West (Kaiser, MO)	3561
St Louis, MO	4486
Kansas City, MO	4059
Average/Unknown (Knob Noster)	4037
Ameren Missouri Natural Gas	4918

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[348] If unknown assume 72% for existing system efficiency.[349]

Other factors as defined above

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[346] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in “Statistical Analysis of Historical State-Level Residential Energy Consumption Trends,” 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[347] St. Louis and Ameren Missouri Natural Gas are based on HDD65. All others are based on HDD60.

[348] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (see ‘BPI Distribution Efficiency Table’) or by performing duct blaster testing.

[349] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

Natural Gas Deemed Savings Table

Residential Natural Gas Measures

Air Sealing

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas	Air Sealing (1.0 - story home) Known Heating Efficiency	7.5	Heating RES	15.0	Actual	per square ft.
	Natural Gas	Air Sealing (1.5 - story home) Known Heating Efficiency	8.5	Heating RES	15.0	Actual	per square ft.
	Natural Gas	Air Sealing (2.0 - story home) Known Heating Efficiency	9.3	Heating RES	15.0	Actual	per square ft.
	Natural Gas	Air Sealing (3.0 - story home) Known Heating Efficiency	10.5	Heating RES	15.0	Actual	per square ft.
	Natural Gas	Air Sealing (Unknown Home type) Unknown Heating Efficiency	8.8	Heating RES	15.0	Actual	per square ft.

Ceiling Insulation

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas	Ceiling Insulation	99.7	Heating RES	25.0	Actual	per sq. ft
	Natural Gas	Ceiling Insulation with Audit	65.0	Heating RES	25.0	Actual	per sq. ft

Wall Insulation

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas	Wall Insulation	98.7	Heating RES	25.0	Actual	per sq. ft

Water heater

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas SF	Tank storage Water Heater (20-50 gallon) ER1 Full Cost	45.3	Water Heating Res	4.0	$404.75	per unit
	Natural Gas SF	Tank storage Water Heater (20-50 gallon) ER2 Remaining Life	20.7	Water Heating Res ER2	9.0		
	Natural Gas SF	Tank storage Water Heater (20-50 gallon) ROF	20.7	Water Heating Res	13.0	$256.00	per unit
	Natural Gas SF	Tankless Water Heater ER1 Full Cost	83.0	Water Heating Res	7.0	$607.52	per unit
	Natural Gas SF	Tankless Water Heater ER2 Remaining Life	15.5	Water Heating Res ER2	13.0		
	Natural Gas SF	Tankless Water Heater ROF	15.5	Water Heating Res	20.0	$510.00	per unit

Learning Thermostat / Advanced Thermostat

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas SF	Learning Thermostat - Gas Heated / central AC **	57.6	Heating RES	10.0	$175.00	per measure
	Natural Gas SF	Learning Thermostat - Unknown **	37.42	Heating RES	10.0	$175.00	per measure
	Natural Gas SF	Programmable Thermostat - Gas Heated / central AC **	52.9	Heating RES	0.0	$0.00	per measure
	Natural Gas SF	Programmable Thermostat - Unknown **	34.39	Heating RES	0.0	$0.00	per measure

Kit Faucet Aerators (Kitchen)

Measure Reference No.	Program/Channel	Measure	Therm Annual Savings	End Use	EUL	Inc. Cost	Units	EPG_Gas
	Natural Gas SF	Kit Faucet Aerator (Kitchen)	4.2	Water Heating RES	10.0	$11.33	per measure	0.003
	Natural Gas MF	Kit Faucet Aerator (Kitchen)	5.8	Water Heating RES	10.0	$11.33	per measure	0.004

Residential Natural Gas Measures

Kit Faucet Aerators (Bathroom)

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units	EPG_Gas
	Natural Gas SF	Kit Faucet Aerator (Kitchen)	0.7	Water Heating RES	10.0	$11.33	per measure	0.003
	Natural Gas MF	Kit Faucet Aerator (Kitchen)	1.6	Water Heating RES	10.0	$11.33	per measure	0.003

Low Flow Showerheads

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units	EPG_Gas
	Natural Gas SF	Low Flow Showerheads	5.2	Water Heating RES	10.0	$7.00	per measure	0.004

Pipe Insulation

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
1272	Natural Gas SF	Pipe Insulation	0.5	Water Heating RES	12.0	$7.10	per foot
868	Natural Gas MF	Pipe Insulation	0.7	Water Heating RES	12.0	$7.10	per foot

Duct Repair (Duct Sealing and Repair - Methodology 3)

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost*	Units - DuctLength (ft.)
	Natural Gas SFLI	Duct Repair (Sealing) -Gas Heating	7.8	Heating RES	20.0	$299.34	37
	Natural Gas SFLI	Duct Repair (Sealing) - Electric Heating - MH Adjusted	5.7	Heating RES	20.0	$299.34	37

Boiler

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas SF	Boiler ER1 Full Cost	1080.6	Heating RES	9.0	$53.05	per unit
	Natural Gas SF	Boiler ER2 Remaining Life	104.1	Heating RES ER2	18.0		
	Natural Gas SF	Boiler 85 - 89 ROF	104.1	Heating RES	27.0	$278.00	per unit
	Natural Gas SF	Boiler 90 and above ROF	433.6	Heating RES	27.0	$884.00	per unit

Furnace

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas SF	Furnace ER1 Full Cost		Heating RES	6.0	$1,254.37	per unit
	Natural Gas SF	Furnace ER2 Remaining Life		Heating RES ER2	14.0		
	Natural Gas SF	Tier 1 Furnace ROF	329.3	Heating RES	19.0	$628.22	per unit
	Natural Gas SF	Tier 2 Furnace ROF	369.1	Heating RES	19.0	$820.53	

Residential Natural Gas Measures

Furnace Tune-up

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas SF	Furnace Tune-UP	62.1	Heating RES	2.0	$100.00	per unit

Programmable Thermostat

Measure	Program/Channel	Measure	Therms Annual		End Use	EUL	Inc. Cost	Units
	Natural Gas SF	Programmable Thermostat	26.5		Heating RES	10.0	$70.00	per unit

ECM/ Blower Motor

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas	ECM Auto Fan EUL Replacement -SF	10.52	Heating RES	20.0	$97.00	per measure
	Natural Gas	ECM Auto Fan EUL Replacement -MF	10.52	Heating RES	20.0	$97.00	per measure
	Natural Gas	ECM Auto Fan Early Replacement ER 1 (Full Cost) - SF	10.52	Heating RES	6.0	$475.00	per measure
	Natural Gas	ECM Auto Fan Early Replacement ER2 (Remaining Life) - SF	10.52	Heating RES ER2	12.0		per measure
	Natural Gas	ECM Auto Fan Early Replacement ER 1 (Full Cost) - MF	10.52	Heating RES	6.0	$475.00	per measure
	Natural Gas	ECM Auto Fan Early Replacement ER2 (Remaining Life) - MF	10.52	Heating RES ER2	12.0	$0.00	per measure
	Natural Gas	ECM Continous Fan EUL Replacement - SF	10.52	Heating RES	20.0	$97.00	per measure
	Natural Gas	ECM Continous Fan EUL Replacement - MF	10.52	Heating RES	20.0	$97.00	per measure
	Natural Gas	ECM Continous Fan Early Replacement ER 1 (Full Cost) - SF	10.52	Heating RES	6.0	$475.00	per measure
	Natural Gas	ECM Continous Fan Early Replacement ER2 (Remaining Life) - SF	10.52	Heating RES ER2	12.0		per measure
	Natural Gas	ECM Continous Fan Early Replacement ER 1 (Full Cost) - MF	10.52	Heating RES	6.0	$475.00	per measure
	Natural Gas	ECM Continous Fan Early Replacement ER2 (Remaining Life) - MF	10.52	Heating RES ER2	12.0		per measure

Business Natural Gas Measures

Boiler

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	EUL	Inc. Cost	Units	Efficiency	Capacity
	Natural Gas BUS	Boiler	32.3	Heating BUS	27.0	27.0	$16	per unit	83% AFUE	<300,000 BTU/hr
	Natural Gas BUS		64.6	Heating BUS	27.0	27.0	$31	per unit	84% AFUE	
	Natural Gas BUS		97.0	Heating BUS	27.0	27.0	$187	per unit	85% AFUE	
	Natural Gas BUS		258.5	Heating BUS	27.0	27.0	$776	per unit	90% AFUE	
	Natural Gas BUS		323.2	Heating BUS	27.0	27.0	$1,126	per unit	92% AFUE	
	Natural Gas BUS		452.4	Heating BUS	27.0	27.0	$3,899	per unit	96% AFUE	

Water heater

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Tank storage Water Heater (20-50 gallon)	27.2	Water Heating BUS	13.0	$256.00	per unit

Furnace

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Furnace 92 - 95	179.7	Heating BUS	19.0	$493.96	per unit
	Natural Gas BUS	Furnace 95 and above	187.9	Heating BUS	19.0	$628.22	per unit

Programmable Thermostat

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Small Commercial Programmable Thermostat	62.1	Heating BUS	8.0	$181.00	per measure

Wall Insulation

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Wall Insulation	10.2	Heating BUS	20.0	$1,300.00	per 1000 sq. ft

Ceiling Insulation

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Ceiling Insulation	5.4	Heating BUS	20.0	$600.00	per 1000 sq. ft

Tankless Water heater

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Tankless water heater	29.9	Water Heating BUS	20.0	$510.00	per unit

Steam Trap

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Steam trap	271.3	Miscellaneous BUS	6.0	$177.00	per unit

Business Natural Gas Measures

Pre-Rinse Spray Valve

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Pre-Rinse Sprayers	41.4	Water Heating BUS	5.0	$92.90	per unit

Rack Oven

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units	Pre-Heat	Idle	Cooking
	Natural Gas BUS	Single Rack Oven	1,096	Miscellaneous BUS	12.0	$4,933.00	per unit	6,000	124,681	169,500
	Natural Gas BUS	Double Rack Oven	2,316	Miscellaneous BUS	12.0	$5,187.00	per unit	15,000	236,571	382,462

Fryer

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units		Idle	Cooking
	Natural Gas BUS	Standard Open Deep-Fat Fryer	508	Miscellaneous BUS	12.0	$0.00	per unit		65,769	73,286
	Natural Gas BUS	Large Vat Open Deep-Fat Fryer	415	Miscellaneous BUS	12.0	$1,120.00	per unit		40,364	73,286

Steam Cooker

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units		Idle	Cooking
	Natural Gas BUS	3 Pan	634	Miscellaneous BUS	12.0	$ 4,150.00	per unit		137,606	36,005
	Natural Gas BUS	4 Pan	690	Miscellaneous BUS	12.0	$ 4,150.00	per unit		152,934	36,005
	Natural Gas BUS	5 Pan	741	Miscellaneous BUS	12.0	$ 4,150.00	per unit		166,955	36,005
	Natural Gas BUS	6 Pan	789	Miscellaneous BUS	12.0	$ 4,150.00	per unit		180,048	36,005
	Natural Gas BUS	10 Pan	1,182	Miscellaneous BUS	12.0	$ 4,150.00	per unit		287,527	36,005

Air Sealing

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Air Sealing for small - Commercial office space	55.3	Heating BUS	15.0	Actual	per square ft.

Learning Thermostat / Advanced Thermostat

Measure Reference No.	Program/Channel	Measure	Therms Annual Savings	End Use	EUL	Inc. Cost	Units
	Natural Gas BUS	Learning Thermostat - Gas Heated / central AC **	124.3	Heating BUS	10	$224.00	per measure

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

RED TAG REPAIR PROGRAM

APPLICATION

The Red Tag Repair Program is an experimental program for customers receiving service on Companys Residential Service Rate to receive funding towards minor repairs or replacements of their gas appliances and piping in order to obtain or retain gas service. The Program has two components: (i) Heating Only for Lower Income, and (ii) Avoid Red Tags.

AVAILABILITY

1. Heating Only for Lower Income provides payment assistance to eligible residential customers of the Company, with a household income equal to or less than 80% of Area Median Income, who require repairs or replacement of natural-gas appliances and/or piping that have been red- tagged. If the customer is renting the premises, approval of the landlord will be required. Customers receiving natural gas service to operable permanent space heating equipment ("PSHE"), i.e. furnaces and boilers, do not qualify; this program is designed to assist only those lower income customers who would otherwise be eligible to commence or maintain service, but whose facilities are "red-tagged," that is, whose service will be or is disconnected at the meter or to the PSHE, and are without space heating, due to unsafe PSHE, unsafe piping or unsafe non-space heating appliance where there is no shut off valve to the non-space heating appliance.

2. Avoid Red Tags permits Company's field service representatives ("FSR") who are already on-site to spend a nominal amount of time to perform minor repairs of the customer's gas appliances and piping when doing so would result in the customer gaining or keeping use of service rather than having the piping or appliance "red-tagged" as unsafe.

MEASURES AND INCENTIVES

1. Heating Only for Lower Income - The program provides up to $25,000 annually to credit customers or reimburse qualified social service agencies within its service territory that can provide or arrange to provide and pay for such emergency service work consistent with the terms set forth herein and at an administrative cost not to exceed 10% of the funds provided. No customer shall receive assistance greater than $1,000.00 under this Program, with no more than $700 going towards a PSHE and no more than $450 going toward each other gas appliance or piping. To the extent repairs are not cost effective, such customers should be referred to the Company's low-income energy efficiency program. In the event customer incentives from the Company's low-income energy efficiency program do not cover the full cost of PSHE replacement, eligible funds from this program can be put towards the energy efficient replacement PSHE equipment.

DATE OF ISSUE December 3, 2018 DATE EFFECTIVE January 2, 2019

ISSUED BY Michael Moehn (Name of Officer) President (Title) St. Louis, Missouri (Address)

UNION ELECTRIC COMPANY
GAS SERVICE

Applying to MISSOURI SERVICE AREA

RED TAG REPAIR PROGRAM (cont'd)

MEASURES AND INCENTIVES (cont'd)

2. Avoid Red Tags - If an FSR determines that any gas appliance should be "red-tagged" as unsafe or out of compliance with applicable codes, but the FSR believes that the problem can be repaired in no more than 15 minutes using parts that cost $20 or less, the FSR may, with the customer's consent, attempt to affect such repairs in conjunction with utility service at no cost to the customer. At any time that the FSR determines that the repair will fall outside of these parameters, the FSR shall cease the repair effort and proceed in accordance with the Company's safety practices and the Utility Promotional Practices.