

The Missing Piece: How Test Procedures Enable Market Transformation

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ABSTRACT

Product efficiency ratings provide invaluable information used by various stakeholders to purchase, incentivize, or regulate products. However, many existing efficiency metrics do not fully capture all factors that affect energy consumption. Representative test procedures and metrics play an important role in transforming markets by providing voluntary programs and regulatory agencies accurate information on actual energy consumption to enable product differentiation, recognize manufacturers for efficiency innovations, and empower consumers to make informed choices. Natural gas rooftop units (RTU) are ubiquitous in existing commercial buildings and customers currently base their decisions on an efficiency rating that only tells part of the story. Historically, two metrics define an efficient RTU: its thermal efficiency (TE) and its cooling efficiency. TE excludes several key components that impact gas energy consumption: the benefits of a heat or energy recovery ventilator, damper leakage rates, and insulation levels in the RTU cabinet. As the U.S. increasingly focuses on reducing natural gas consumption, it is critical that test procedures and metrics include all of the factors that contribute to gas RTU performance.

A recent update to the Canadian RTU test procedure, CSA¹ P.8 Edition 3.0² (CSA P.8), creates a new gas RTU metric, a heating season total coefficient of performance (TCOP_{HS}), that better represents gas RTU efficiency. This paper will compare the new metric with existing RTU performance metrics including TE and IEER and will describe how a TCOP_{HS} will support long-term market transformation goals.

Introduction

This paper describes why representative test procedures and metrics are important for achieving real world energy efficiency, and how a representative test procedure can enable market transformation. The Northwest Energy Efficiency Alliance's (NEEA's) gas commercial packaged rooftop HVAC initiative offers a clear example of test procedure development in support of market transformation. This paper is focused on gas heating efficiency and ratings for gas rooftop units (RTU), since NEEA has particular experience with this product, however, we note that the general concepts around the importance of representative test procedures and metrics also apply to cooling efficiency and electric heating (e.g., heat pump) efficiency. The

¹ CSA Group (formerly Canadian Standards Association) is an international standards and test procedure organization

² CSA P.8 Edition 3: Thermal efficiencies of industrial and commercial gas-fired package furnaces

following pages will describe what NEEA has learned about representative test procedures, including:

- How non-representative test procedures can be a barrier.
- Lessons learned from supporting test procedure development.
- How NEEA plans to use an improved metric for gas RTU to further their market transformation goals.

Value of Representative Test Procedures

The purpose of a test procedure (in the context of this paper) is to rate the energy efficiency of a piece of equipment – to produce a rated metric. Equipment that uses less energy (is more efficient) gets a higher rating. Equipment that uses more energy (is less efficient) gets a lower rating. The rated metric is then used to identify and differentiate more efficient equipment from less efficient options. While simple in concept, the design of a useful and representative test procedure is complex, and the details of the scope, methods, and results of the prescribed laboratory test method will directly impact how valuable the test procedure and rating will be for consumers, manufacturers, utilities, and regulators.

A “representative” test procedure is one that closely matches the operating conditions an installed unit will experience and accounts for all the energy consuming and energy saving features of the unit. If the test procedure is representative, the metric it produces can be used to help consumers identify which products will use less energy. Since testing is conducted in a laboratory setting for convenience and cost reasons, the test procedure will not be a perfect representation of real-world conditions. Additionally, each equipment installation is unique whereas test procedures need to be consistent and repeatable, so it is inevitable that a test rating will not predict the energy consumption of every unit in every application. The goal is a test procedure that is representative of *average* unit conditions and a rating metric that will clearly identify products that save energy. There is no perfect test procedure and achieving the right balance of representativeness and burden is tricky. Additionally, products and applications change over time, so it is important to periodically review and revise test procedures to ensure they are representative.

Test procedures and rating metrics are used by regulatory bodies, efficiency organizations, utilities, and by manufacturers. In the U.S., the Department of Energy (DOE) sets the test procedure, metrics, and minimum efficiency standards for federally regulated consumer (residential), commercial, and industrial products. DOE may develop their own unique test procedure, or adopt an industry accepted TP that already exists, such as one developed by a trade organization (e.g. AHRI) or ENERGY STAR. DOE’s final adopted test procedure and metric are usually used by all other organizations to reduce testing burden and confusion. DOE’s regulations can result in significant energy savings for the nation but can also be burdensome for manufacturers to test and ensure compliance with the standards. More stringent standards will often require manufactures to redesign and retest their products to ensure they meet the baseline rating. DOE’s test procedure and standard development process strives for test procedures that are as representative as possible without being unduly expensive and time consuming for manufacturers to conduct.

Barriers to Market Transformation from Non-representative Test Procedures

A non-representative test procedure and metric, in contrast, may not account for all energy saving features or the rating only represents a specific operating condition instead of the entire period of use. The issue with non-representative metrics is that they can be misleading when they are missing these key pieces. Equipment that gets a high rating with a non-representative metric may not use less energy overall, and equipment with some energy saving features don't get credit for this in the rating. Consumers that want to save energy select a product with a high rating and may overlook another product with more impactful but underrepresented energy saving features.

Examples of non-representative metrics are those currently used in the U.S. to rate electric motors and gas RTU. In both cases, the current regulated metric is a full-load efficiency, when the average piece of equipment operates at a consistent part-load or the load varies over an average period of use. Additionally, the technology with the largest energy saving potential for this equipment, energy recovery for RTU and variable speed drives for electric motors, does not impact the regulated metric at all.

There are multiple barriers to market transformation if the regulated metric (or industry accepted metric if the product isn't regulated) is not representative.

- Consumers and installers are unable to differentiate products that will have lower energy costs
- Manufacturers may not prioritize or include features that save energy in their designs if they are not represented in the regulated metric
- Voluntary programs (e.g., utility programs or EnergyStar) have fewer options to incentivize features that save energy
- The perception of “efficient” units is limited to that metric

These barriers can also severely hamper efforts to transform the market for energy efficiency. The last section of this paper describes how many of these barriers can be overcome by the adoption of a more representative test procedure, paving the way for market transformation.

Efficient RTU as an Example Equipment Type for Market Transformation through Test Procedures

As the goal of market transformation programs is to remove barriers to adoption, test procedures and metrics are typically a core component successful market transformation programs. The Northwest Energy Efficiency Alliance (NEEA) is a non-profit organization working to effect market transformation through the acceleration and adoption of energy-efficient products, services and practices. NEEA is an alliance of more than 140 Northwest utilities and energy efficiency organizations working on behalf of more than 13 million energy consumers. One technology identified as an opportunity for natural gas savings is RTUs. NEEA estimates that there are over 240,000 gas RTUs in the Northwest heating approximately 680 million square feet – or about a quarter of all commercial floorspace in the Northwest (NEEA, 2020a). Nationwide, the use of gas RTUs in commercial buildings is even more widespread, where they heat one-third of the total floor area and over one-fifth of all commercial buildings (EIA, 2021). NEEA developed their Efficient RTU initiative (NEEA, 2022a) to realize gas

savings in the Northwest through market transformation, with the core strategy being a revised TP that effectively differentiates efficient equipment.

NEEA completed a comprehensive review of technology options for RTUs that save gas including: condensing furnaces, increased cabinet insulation, low leakage dampers, and heat or energy recovery ventilators (HRV/ERV). NEEA found, however, that the TE metric only accounts for the impact of condensing furnaces even though the other measures can save as much or more gas energy (**Error! Reference source not found.**). In a recent CWF standards proposed determination (EERE, 2022c), DOE noted that moving to a condensing level standard (92% TE) in the U.S. would result in 2.1 quads of primary energy savings over 30 years. NEEA's energy modeling showed that condensing equipment results in approximately 10% energy savings over baseline, increased insulation and dampers saved about 5% when combined, and an HRV/ERV would save 24% on average (NEEA, 2022b). Using these percentages with DOE's energy analysis gives a ballpark idea of the energy savings potential of these features – 1.1 quads for insulation and dampers, and over 5 quads for HRV/ERV. These numbers are certainly significant by DOE's standards, and yet these components are not even being considered as energy saving features. The limitations to the TE metric and the impact of these issues is discussed further in the next section, "Background on RTU".

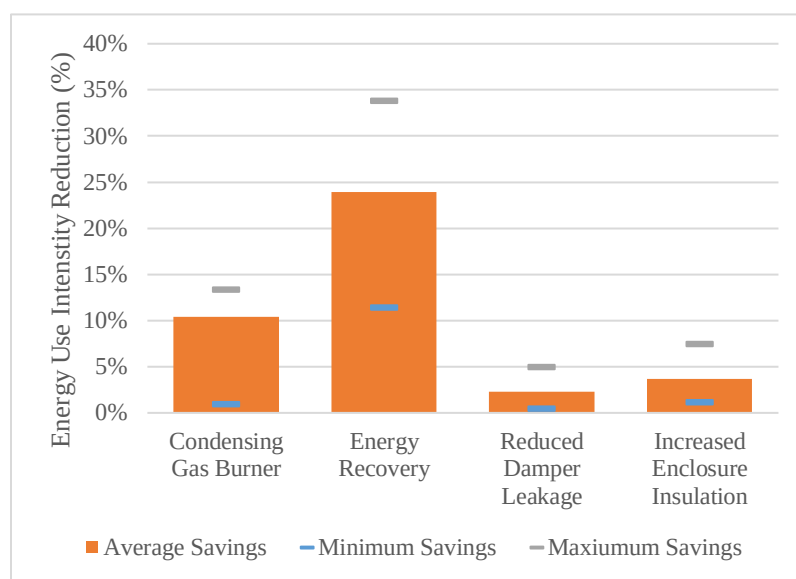


Figure 1 - Savings from RTU Energy Efficiency Measures (NEEA, 2022b)

Improving and expanding the representativeness of gas RTU efficiency metrics has been a key focus of NEEA's recent Efficient RTU initiative. NEEA worked with manufacturers, other utilities, and regulatory agencies on the CSA Group P.8 Standard committee to recently publish an improved test procedure and is working to increase adoption of the test procedure in the industry. NEEA views this updated test procedure as a critical tool to support long-term adoption of more efficient gas RTU equipment.

Background On RTU

This background section provides additional detail on the product we're describing, gas RTUs, why they are a good opportunity for gas energy savings, how they are currently tested, rated, and regulated, and outlines the features of an RTU that are known to save energy.

Industry Used Terminology and Equipment Characteristics

RTU is an imprecise term that can apply to several different types of HVAC equipment and applications. While industry terms are not used uniformly, in this paper RTU will refer to any piece of weatherized packaged HVAC equipment that can provide heating, cooling and ventilation air (or some combination thereof) through a combination of warm air furnace and/or direct expansion cooling.

There are multiple sub-types of RTUs to which the findings of this paper apply. Generally, RTUs can be categorized by their ability to provide space conditioning and the amount and function of the outside air introduced. An RTU generally provides space conditioning and brings in only enough air to meet ventilation requirements (typically around 30%). Application specific sub-types of RTUs include dedicated outdoor air systems (DOAS) and make up air (MUA) units, both of which bring in 100% outdoor air, DOAS for ventilation purposes and MUAs to replace air exhausted elsewhere in the building such as a commercial kitchen hood. DOAS and MAUs typically do not provide space conditioning³; heating and cooling consumption only serves to temper the incoming outside air. Figure 2 below is a simple schematic of the main functional components of an RTU.

As stated previously, this paper focuses on the heating season performance of gas RTUs, which includes a warm air furnace as the primary heating system. Since all three types of packaged rooftop equipment (RTU, MAU, and DOAS) can have a gas furnace, they are subject to the test procedures and ratings discussed in this paper. Gas RTUs will commonly include a direct expansion (DX) cooling system along with a gas furnace. Other (non-gas) configurations of RTUs can include *only* DX cooling, a heat pump (DX heating and cooling) or electric resistance heating, but these are not the focus of this paper.

³ CWAFF applies to the furnace section of gas-fired RTU, including DOAS and MAUs equipped with gas furnaces. If gas-fired RTU include cooling, they may also be subject to DOE's Commercial Unitary Air-Conditioner and Heat Pump test procedures and standards, although those regulations have different scope restrictions.

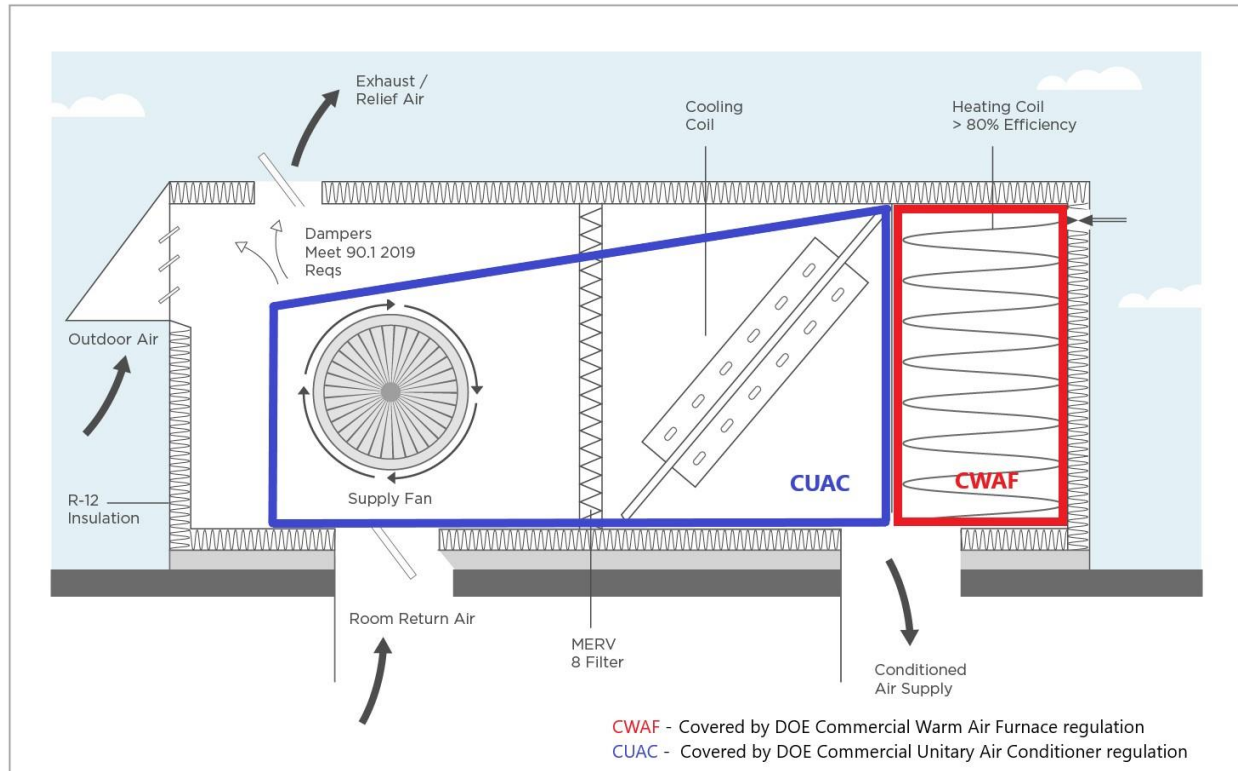


Figure 2: RTU Schematic with applicable DOE regulation

Efficiency Ratings of Gas RTUs

The DOE regulated product for gas RTU equipment is Commercial Warm Air Furnace (CWF) (EERE, 2022a). The current CWF heating efficiency test procedure references ANSI Z21.47⁴ (CFR, 2015a) and the regulated metric is TE. Gas RTU test procedures and efficiency requirements have barely changed in over two decades, even though gas RTUs have a large market share and are a huge opportunity for energy savings. Gas RTUs are also subject to DOE's Commercial Unitary Air Conditioning (CUAC) product regulation if they include DX cooling. Figure 2 notes what basic components of an RTU are covered by the CWF and CUAC regulations.

The CWF test procedure and TE metric only account for a single source of RTU inefficiency: heat lost through the flue (combustion inefficiency). Furthermore, the current test procedure is only applied to equipment operating at full fire, which represents a small minority of the time that RTUs operate under typical service conditions.⁵

The limitations of DOE test procedures on the heating side (CWF) contrast with those on the cooling side (CUAC) where the DOE employs a more comprehensive metric, the Integrated Energy Efficiency Ratio (IEER) (CFR, 2015b). IEER is not a completely

⁴ CSA/ANSI Z21.47-21/CSA 2.3 | Gas-Fired Central Furnaces

⁵ For example, energy modeling done in support of the development of CSA P.8 estimates that less than 5% of the heating season operating hours are spent in full fire in a typical Canadian climate. <https://neea.org/resources/energy-modeling-of-commercial-gas-rooftop-units-in-support-of-csa-p-8-standard>

representative metric either, but does include a weighted average efficiency of multiple load points and accounts for all sources of electric energy use (e.g. fan energy) – not just the cooling system. While not the focus of this paper, NEEA has also supported development of the CSA EXP 07 load-based test procedure (CSA, 2019), which is another example of efforts to increase the representativeness of residential HVAC test procedures (NEEA, 2020b).

When considering an RTU as a system, heating efficiency should be a ratio of the energy delivered to a building (via heated air) compared to the energy consumed (gas and electricity) by the RTU. A detailed consideration of the energy balance around an RTU shows that any energy not delivered to an occupied space as useful heat is lost through four main ways. These four heat loss mechanisms are:

1. Conduction through the RTU enclosure (external walls)
2. Air leakage through the RTU enclosure and dampers
3. Required exhausting of preconditioned air to meet ventilation requirements
4. Heat loss through the flue (exhausting of the heating products of combustion)

Energy modeling performed by NEEA (NEEA, 2022b) has shown that mitigating any of these energy transfer pathways can save significant gas energy but only the last mechanism (heat loss through the flue) will have any impact on the TE rating. The first three loss pathways (conduction, air leakage, and exhaust air) will also impact the electric consumption of an RTU for the cooling system (through heat *gains*) or for the heating system if the RTU has a heat pump or hybrid system.⁶ Thinking about efficiency more broadly as the amount of space conditioning that occurs for a given amount of energy input (a system approach), it becomes clear that the current metrics do not tell the whole story.

RTU Features That Save Energy

There are several different component improvements that can be employed to address the different energy loss pathways of RTUs described above. All involve robust and established technologies, which relevant energy codes and standards already require in many cases. These energy saving components are listed below, along with total HVAC energy savings from a recent NEEA model-based analysis (NEEA, 2022b):

- Low leak dampers
 - Average energy savings across the Northwest were 3% from reducing damper leakage and savings of up to 5% for buildings with multiple smaller RTUs.
 - Low leakage dampers⁷ are already required in many cases by code⁸, so ratings of damper leakage rates are readily available.
- Enclosure insulation
 - Increasing enclosure insulation to R-12 from a baseline of R-2.3 will save an average of 4% across the Northwest and up to 7%, with the higher energy savings values, again, in buildings with multiple smaller RTUs such as retail strip malls.

⁶ Hybrid in this case refers to a heating system that uses both a heat pump and a gas furnace. The furnace is commonly used as backup or supplementary heat for the colder days.

⁷ Defined according to AMCA 500-D ANSI/AMCA Standard 500-D-18 | Laboratory Methods of Testing Dampers for Rating

⁸ ASHRAE 90.1 Section 6.4.3.4.3 Damper Leakage

- ASHRAE 90.1 includes a requirement that furnace jacket loss be less than 0.75% of the input rating (ASHRAE, 2019). This requirement, however, is limited to losses occurring at the furnace section under full fire, and only gives limited picture of conduction losses across the entirety of an RTU.
- In addition to energy benefits, added enclosure insulation may contribute to increased equipment longevity through improved structural integrity, and may also increase the overall air tightness of the enclosure with similar benefits to those of the low leak dampers.⁹
- Exhaust air energy recovery
 - Adding energy recovery (either sensible or total) to an RTU is the single most impactful efficiency upgrade available for RTUs. With models predicting HVAC energy use reductions of 25% in the Northwest region (and considerably higher for buildings with high ventilation requirements) the impacts of ERVs exceed those of even condensing gas burners.
 - Beyond reducing energy use under typical ventilation conditions, RTUs that have ERVs greatly decrease the impact of increasing ventilation air, which could allow a facility to improve indoor air quality without suffering a significant energy penalty.
- Condensing gas furnace – secondary heat exchanger
 - Condensing gas furnaces will improve TE by 10% or more and can be cost effective in strongly heated dominated climates or applications with high outside air percentages (DOAS and MAU). This is the only RTU efficiency intervention on this list that impacts the current efficiency metric of TE and is therefore the only option available to increase TE above the current federal minimum of 81%.

One final RTU technology option that is touted as a potential energy saving feature is modulating burners. Modulating gas burners allow burner firing rates to turn-down to better meet the heat load of a building and enable the gas RTU to run more evenly. While modulating burners are known to increase occupant comfort, NEEA is not aware of any robust data that suggests modulating burners save energy in the field. In fact, modulating and multi-stage equipment can use *more* energy than their single-stage counterparts if the part-load efficiency of the equipment (which is currently not regulated by the full-fire TE metric) is a lower efficiency than full-fire efficiency. NEEA is not currently recommending modulating burners as an energy saving feature as part of the Efficient RTU market transformation initiative but is interested in continuing to explore the potential for efficiency benefits from this technology.

CSA P.8 – A Representative RTU Test Procedure

As we’ve established, there is a need for the gas RTU industry to move beyond the limitations of the TE metric and use a metric that better represents gas RTU energy consumption

⁹ Enclosure air leakage reduction (convective loss other than dampers) is not currently well documented for RTU and there are not established test procedures for measuring air leakage for RTU (AHRI, 2016). Initial laboratory testing by NRCAN has shown enclosure leakage rates are similar to damper leakage rates depending on the dimensions of the unit, so enclosure leakage improvements may still be an incremental efficiency opportunity to consider long-term.

and accounts for features¹⁰ that save gas energy. To address this need, NEEA collaborated with manufacturers, utilities, regulatory entities, and other stakeholders as part of the CSA P.8 Standard Project Committee to develop a new test procedure and metric, the Heating Season Total Coefficient of Performance (TCOP_{HS}), that better represents gas RTU efficiency. The new CSA P.8 (Edition 3.0) (CSA, 2022) is unique from other commercial gas RTU test procedures because the TCOP_{HS} metric is a seasonally weighted, whole box metric that accounts for multiple modes of operation.

The TCOP_{HS} metric is based on an energy balance of the RTU: energy delivered to the space divided by energy consumed by the RTU. This energy balance is considered for six different operating modes: full fire, full fire with ventilation, low fire, low fire with ventilation, ventilation only (e.g., economizing), and standby. These six operating modes are weighted based on the time spent in each over the heating season (October-April). Operating mode weights vary depending on the amount of outside air (0% 30% or 100%) the unit introduces, and the turndown of the furnace (single stage, two stage, or modulating). Energy modeling in support of CSA P.8 (NEEA, 2021a) showed that units spend the majority of their time in standby mode, where enclosure losses can be the most significant, so adding this operating mode was an important piece – one that is not considered in the TE or IEER metrics.

In order to calculate the energy delivered to the space, the TCOP_{HS} metric accounts for several different heat loss mechanisms including damper leakage, enclosure conduction loss, and heat lost through the flue. These heat loss rates are considered for a population weighted average heating season temperature. The metric also accounts for both gas and electric energy inputs, and heat gains if there is an HRV/ERV present. CSA P.8 also considers an outside air correction factor for the high fire and low fire efficiency of the unit, since the test procedure takes place at lab conditions, but these units will operate at a much colder average heating season temperature.

The inclusion of multiple modes of operation, multiple heat loss pathways, average seasonal conditions, and different unit configurations and applications was necessary to make the TCOP_{HS} metric truly representative.

The CSA P.8 technical committee developed a calculation methodology to generate the TCOP_{HS} metric, knowing that lab testing each RTU component in each operating mode would increase testing burden. Manufacturers already complete testing on several of the new components individually (dampers, HRV/ERV, and furnace efficiency), and the remaining component (enclosure insulation) was able to be incorporated using physical data. Since the metric is based on an energy balance, all components were able to be incorporated using thermodynamic calculations. For example, heat loss rate through the enclosure is incorporated using the outside dimensions of the unit, the thickness and type of insulation specified by the manufacturer, and average heating season internal¹¹ and outside air temperatures. This calculation method provides the benefits of a whole box representative metric, without increasing testing burden for the manufacturers.

A frequently asked question about CSA P.8 is its applicability to U.S. climates, since CSA P.8 was developed for an average Canadian climate. There are two pieces of the calculation that are informed by Canadian climate:

¹⁰ Modulating burners are not included due the lack of robust data representing their energy impacts. Casing air leakage is not included due to the need for additional testing to include this component (lack of existing data to support inclusion) and suspected limited impact, compared to other features that were prioritized in the update.

¹¹ The internal temperature of the RTU – this is either the return air temperature from the building or a mixed air temperature, depending on the specified ventilation air percentage and the operating mode.

1. Canadian national average outdoor air temperature during the heating season (October to April), $T_{OA} = 28.4^{\circ}\text{F}$
2. Operating mode weights – percent of time spent in each operating mode during the heating season.

These two items were based on Canadian weather data (for T_{OA}) and energy modeling of Canadian cities (operating mode weights) (NEEA, 2021a). These could be modified to represent U.S. specific data and could also be adapted to anticipate climate zone shifts expected over the life of the equipment. However, these changes would only shift the *absolute value* of intermediate calculations or the final TCOP_{HS} , but not the *directional* or *relative* ranking of equipment using TCOP_{HS} . Equipment that uses less energy will get a high ranking using the Canadian heating season data, the same as it would with U.S. specific heating season data. Therefore, CSA P.8 can be used as written to rate equipment in the U.S., and updates for U.S. climates are optional.

Development Process for CSA P.8

NEEA was highly involved with the technical development process for the third edition of CSA P.8, from 2018 through 2021. CSA Group and the CSA P.8 technical subcommittee identified that the previous version, CSA P.8-2009, was not sufficiently accounting for the impacts of cold temperatures on performance, such as reduced combustion efficiency and heat loss. NEEA got involved with the CSA P.8 update because of their interest in gas savings opportunities for RTUs after learning that the intent of the update was to better reflect real-world operation of units and help differentiate products that use less energy in cold climates. NEEA joined the CSA P.8 technical subcommittee which was a consensus-based committee of multiple stakeholders from industry, regulatory bodies, and efficiency organizations.

In order to support development of the TCOP_{HS} metric, NEEA invested significantly in energy modeling of gas RTUs. This energy modeling was instrumental in defining a typical period of use for gas RTU equipment in heating climates, establishing weights for different operating modes of the equipment, and determining typical savings rates for different efficiency features. NEEA and the CSA P.8 committee leveraged these energy modeling results to guide development of the TCOP_{HS} calculation methodology.

In collaboration with NRCAN, NEEA also sponsored equipment testing to validate the new test procedure and calculation. Validation of the laboratory test method was important, as it identified areas of the procedure that needed revision or clarification that would not have been flagged without physically performing the test procedure. This testing also provided a comparison point of laboratory heat loss rates compared to the calculated heat loss rates in the standard to ensure they were representative of the equipment.

The third edition of CSA P.8 passed the technical development stage and was released for public review at the end of 2021. It has since completed the review process and is currently in the final editorial and balloting stages before publication, which is expected in 2022.

Future Use of TCOP_{HS} In Support of Market Transformation Goals

TCOP_{HS} provides a method of differentiation for the market – consumers, contractors, and manufacturers. This metric will allow manufactures that are already producing units with efficient features to better differentiate their products from competitors. While many RTU consumers prioritize purchase price, many consumers are also aware of the long-term cost

savings from more efficient equipment. These customers look to efficiency ratings to identify what products will be more or less efficient, and which products will use less energy in their application.

The industry hasn't traditionally thought of an Efficient RTU outside of cooling efficiency and condensing RTUs. Manufacturers advertise "efficient" RTU equipment almost exclusively as those with a high IEER rating, which provides no information on the heating season performance of a gas RTU. Additionally, because TE does not account for energy saving features (i.e., insulation, low-leak dampers, and HRV/ERV), manufacturers lack a key incentive to develop products with these features. The limitations of the regulated metric and any increases in the associated standard efficiency level are a barrier to manufacturers producing units with features that will save energy, since developing products to address code and regulatory changes will often take all their available R&D resources. Features like increased insulation and HRV/ERV are a lower priority product development because a manufacturer will not "get credit" for them in the regulated metrics. On the flip side, manufacturers that already produce units with these features are receiving no credit for the energy efficiency they provide to consumers. For example, the U.S. manufacturer Aeon produces units with R12 insulation standard having switched over their manufacturing process to double wall construction several years ago. NEEA reviewed products on the market that meet NEEA's draft specification, which requires the energy saving features discussed in this paper and identified many manufacturers already selling products with these features (NEEA, 2021b).

A comprehensive metric like TCOP_{HS}, which gives credit for any features that save significant amounts of gas energy, also gives greater flexibility to manufacturers to pursue multiple paths of product development. Additionally, the CSA P.8 approach could be a starting point for similar rating metrics for cooling season efficiency, or electric heating efficiency (e.g., heat pumps). For electric heating, the CSA P.8 approach is more directly transferrable, as it would be straightforward to switch out the gas energy input and combustion efficiency for an electric energy input and efficiency. The rest of the heat loss and heating season inputs could be unchanged. For cooling season efficiency, the CSA P.8 approach could also be leveraged, though operating mode weights and seasonal outside air temperatures would need to be developed specifically for the cooling season. The benefit to using a seasonal cooling metric (e.g., Cooling Season TCOP, or TCOP_{CS}) with the same approach as a seasonal heating metric (TCOP_{HS}) is that these metrics could also be combined to create a metric that describes annual RTU energy consumption and efficiency.

With new carbon reduction goals and an increase in demand for efficient products, there's an opportunity to redefine efficient gas RTU by using the TCOP_{HS} metric. The CSA P.8 metric gives consumers more information to make informed decisions when purchasing and is more representative of actual gas energy consumption. Consumers can be confident that when comparing two potential units for their application the unit with a higher TCOP_{HS} rating will use less energy. TCOP_{HS} differentiates products that will save more energy – products that will produce savings on an energy bill, not just an increased "efficiency" rating. This differentiation is a crucial component of MT and can be utilized in a variety of ways to get MT rolling. The long-term goal of market transformation is broad and sustained adoption of the more efficient product. While federal regulation can cement the transformation by making it illegal to sell non-qualifying products, there are several ways to accelerate the path to a more representative test procedure and more stringent federal standard. Often, regulation is the final step, with voluntary programs and energy codes commonly used as intermediate or alternative steps.

Voluntary Specifications and Programs

Utility programs and other voluntary programs like ENERGY STAR can be a market transformation option if regulation is not there yet. These programs can be a “North Star” to better define what efficient products look like (EnergyStar) and give incentives to early adopters who are producing or purchasing efficient equipment (utility programs).

Non-representative test procedures can again be a barrier to programs at both levels because it will limit the options or flexibility for program design. In the case of commercial gas RTUs, we’ve established that the regulated metric is not accounting for key features that save energy, so the program design cannot use TE as the single efficiency metric. In this case, programs may be designed with a number of prescriptive requirements that get around the non-representative metric. NEEA has developed a specification for commercial RTUs (NEEA, 2021b) that has prescriptive requirements in this way, but is aware of the drawbacks to this method as it limits flexibility and innovation in how manufacturers achieve energy efficiency in their products and makes it more confusing for the market to easily identify and adopt “efficient” technologies.

Once a metric accounts for the features a program is looking to encourage, it is then possible to use a more straightforward method of setting the program-required rating at an appropriate level higher than the market baseline. This gives manufacturers greater flexibility to meet the voluntary program than implementing prescriptive measures. In the case of TCOP_{HS} manufacturers are also not required to do additional laboratory testing in order to determine ratings for their units, as it is possible to calculate a TCOP_{HS} rating using pre-existing test data and physical characteristics of the RTU.

The best-case scenario is when the voluntary program and federal regulation use the same representative metric, as manufacturers are already required to test their equipment to the standard, so there is no additional testing or administrative burden for them to qualify for the voluntary program. This also simplifies program implementation, as the ratings they need are readily accessible and the incentive structure can be simple, significantly reducing the burden of tracking equipment technical specifications and maintaining Qualified Product Lists.

Building and Energy Codes

Energy codes (both local and national) can have additional requirements beyond the federal standard and will often lead to efficiency improvements if the federal standard is not doing so. Even if it is not adopted at the federal level, a representative metric like CSA P.8 can be a starting place for state energy codes looking to decrease energy consumption in their jurisdiction. If federal regulations are lagging, market transformation can begin through codes. Energy codes in turn can influence federal regulation if multiple jurisdictions have successfully implemented the representative metric. Furthermore, codes serve to build additional demand for high efficiency products which encourages manufactures to develop such products. However, any code requirements miss out on a significant portion of the market that is focused on replacement units because codes do not always apply to the replacement market.

Federal Regulation (Standards)

The long-term goal of market transformation is sustained adoption of the more efficient product. If a federal regulation requires the energy savings features a market transformation

program encourages, this guarantees a completely transformed market. Because the existing regulated metric for commercial gas RTUs, TE, does not account for all the features that save energy in RTUs, it is impossible to achieve market transformation through current regulation. DOE's goal with the CWAFF regulation is to reduce gas energy consumption, but their current regulation is causing manufacturers to spend their limited time and product development resources on an 1% reduction in gas energy use, which consequently prevents manufacturers from developing product features that save 5-30% of gas energy.

Therefore, a crucial market transformation goal in respect to regulation is to first improve the metric. A representative test procedure like CSA P.8 can be a starting place for improvements to U.S. regulation for CWAFF. CSA P.8 can serve as the directly adopted test procedure and metric or serve as a concrete example of the whole box method and a calculation-based approach. DOE could choose to create their own test procedure that modifies the CSA P.8 approach to suit their purposes, and possibly improve upon it. CSA P.8's comprehensive, calculation-based approach could be further adapted and applied to other HVAC equipment, such as CUAC, to improve the comprehensiveness and representativeness of those test procedures.

While not as comprehensive as CSA P.8, DOE's proposed new efficiency metric (TE2), described in the recently issued CWAFF TP notice of proposed rule (NOPR) (EERE, 2022b), attempts to address some of the deficiencies of the TE metric. TE2 includes the impacts of furnace jacket losses and efficiency at reduced fire but still ignores the impact of any system components outside of the furnace section. TE2 is an improved *component* efficiency metric, but it is still not a representative whole box metric for gas RTUs. However, DOE's proposal to move to the TE2 metric shows that the DOE is interested in improving the representativeness of their regulation and is considering aspects other than full fire TE.

Conclusion

Equipment test procedures and ratings have a large impact on how consumers select equipment, how products are regulated in the U.S., and where manufacturers will focus product development. When a metric is not representative it presents multiple barriers to market transformation and can even create market distortion. This is the case for the current regulated gas RTU metric, TE, which is not representative for gas RTUs over an average period of use.

Development of a representative metric can simplify program design, offer greater flexibility to manufacturers to meet regulation or voluntary standards, and provide clearer information on efficiency and energy consumption to consumers. NEEA, along with CSA Group and the many contributors on the CSA P.8 technical subcommittee, has recently completed this process for the CSA P.8 test procedure and TCOP_{HS} metric. NEEA plans to leverage this metric across voluntary programs, code, and federal standards as a concrete example of both what it takes to develop a representative metric and how it can better serve all stakeholders in the market.

References

AHRI (Air-Conditioning Heating, and Refrigeration Institute). 2015. *ANSI/AHRI 1350 (I-P/2014): Mechanical Performance Rating of Central Station Air-handling Unit Casings*. Arlington, VA: AHRI.

www.ahrinet.org/App_Content/ahri/files/STANDARDS/ANSI/ANSI_AHRI_Standard_1350_I-P_2014_with_Addendum_1.pdf

ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers). 2019. *Standard 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings*. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers.

CFR (Code of Federal Regulations). 2015a. 431.76: Uniform test method for the measurement of energy efficiency of commercial warm air furnaces. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-D/subject-group-ECFR31345513b5c2666/section-431.76>

CFR (Code of Federal Regulations). 2015b. 431.96 *Uniform test method for the measurement of energy efficiency of commercial air conditioners and heat pumps*. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR3d6ef8108d161bf/section-431.96>

CSA Group. Anticipated 2022. *Edition 3 of CSA P.8: Thermal efficiencies of industrial and commercial gas-fired package furnaces*

CSA Group. 2019. *CSA EXP07:19 Load-based and climate-specific testing and rating procedures for heat pumps and air conditioners*. <https://www.csagroup.org/store/product/CSA%20EXP07:19/>

EERE (Energy Efficiency and Renewable Energy Office). 2016. "Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards for Small, Large, and Very Large Air-Cooled Commercial Package Air Conditioning and Heating Equipment and Commercial Warm Air Furnaces; Direct final rule". <https://www.regulations.gov/document/EERE-2013-BT-STD-0007-0113>.

EERE (Energy Efficiency and Renewable Energy Office). 2022a. *Appliance and Equipment Standards Rulemakings and Notices*. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=49&action=viewlive.

EERE (Energy Efficiency and Renewable Energy Office). 2022b. "Energy Conservation Program: Test Procedure for Commercial Warm Air Furnaces; Notice of proposed rulemaking and announcement of public meeting". <https://www.regulations.gov/document/EERE-2019-BT-TP-0041-0011>.

EERE (Energy Efficiency and Renewable Energy Office). 2022c. "Energy Conservation Program: Energy Conservation Standards for Commercial Warm Air Furnaces; Notification of

proposed determination and request for comment”.
<https://www.regulations.gov/document/EERE-2019-BT-STD-0042-0026>.

EIA (Energy Information Administration). 2021. *Commercial Buildings Energy Consumption Survey (CBECS)*. Washington, DC: EIA.
<https://www.eia.gov/consumption/commercial/data/2018/index.php?view=microdata>.

NEEA (Northwest Energy Efficiency Alliance). 2020a. *Commercial Building Stock Assessment (CBSA) 4 (2019)*. Portland, OR: NEEA. <https://neea.org/data/commercial-building-stock-assessments>

[NEEA \(Northwest Energy Efficiency Alliance\). 2020b. *EXP07:19 Plain Language Guide*.
<https://neea.org/img/documents/CSA-EXP07-Plain-Language-Guide.pdf>](https://neea.org/data/commercial-building-stock-assessments)

NEEA (Northwest Energy Efficiency Alliance). 2021a. *Energy Modeling of Commercial Gas RTU in Support of CSA P.8 Standard*. Portland, OR: NEEA. neea.org/resources/energy-modeling-of-commercial-gas-rooftop-units-in-support-of-csa-p-8-standard.

NEEA (Northwest Energy Efficiency Alliance). 2021b. *Efficient Gas RTU: System Requirements & Compliant Equip*. Portland, OR: NEEA. https://betterbricks.com/uploads/resources/Efficient-RTU_SystemRequirements.pdf.

NEEA (Northwest Energy Efficiency Alliance). 2022a. *BetterBricks: Efficient Gas Rooftop Units*. Portland, OR: NEEA. <https://betterbricks.com/solutions/efficient-rooftop-units>.

NEEA (Northwest Energy Efficiency Alliance) and Nicor Gas. 2022b. *Energy Savings from Efficient Rooftop Units in Heating Dominated Climates*. Portland, OR: NEEA.